Effects of Different Arm Immobilization Methods on Set-Up Accuracy in Photon and Proton Radiotherapy Techniques for Breast Cancer: A Systematic Review

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SUMMARY

Purpose: *This study aimed to review the effects of different arm immobilization methods on set-up accuracy in photon and proton radiotherapy techniques for breast cancer with supraclavicular lymph node (LN) involvement. Methods: A systematic review was conducted using a comprehensive literature search of English-language sources from PubMed, Google Scholar, ScienceDirect, and Medline databases, with no restrictions on publication date. Two independent reviewers assessed and screened titles and abstracts for inclusion.*

Results: *Following screening and eligibility determination, 14 articles were included. Of these, 11 studies focused on photon radiotherapy (8 in the supine position and 3 in the prone position), while 3 studies examined proton radiotherapy.*

Conclusion: *For the supine position, the "both hands above the head" method demonstrated superior set-up accuracy. In the prone position, the crawl position combined with the deep inspiration breath-hold (DIBH) method outperformed other approaches. In proton radiotherapy for breast cancer, both "hands-up" and "hands-down" methods yielded equivalent results.*

Keywords: *breast cancer, accuracy, arm immobilization, photon and proton radiotherapy*

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INTRODUCTION

External beam radiotherapy is commonly used for breast cancer treatment, either following breast-conserving surgery or as post-mastectomy radiation therapy, to reduce the risk of local recurrence (1–3). In radiotherapy, two opposing tangential photon beams and two opposing oblique anterior-posterior fields (supra fields) are typically employed to irradiate the whole breast, chest wall, and ipsilateral internal mammary nodes (4–6). To enhance the treatment outcomes and improve the patient survival rates, the irradiation of the supraclavicular fossa (SCF) and axillary lymph node (LN) regions is advantageous for the patients with positive nodes, in addition to radiotherapy targeting the breast tissue (5,7–9).

An accurate and reproducible patient set-up, along with proper immobilization methods during the radiation treatment sessions, are critical components of effective radiotherapy (10). This is particularly important in breast cancer treatment due to the inherent mobility of breast tissue and the significant positional changes in regional LN sites caused by even slight movements of the patient's arm (8,9,11). Set-up errors and positional variations in the regional LN are more critical than those in the breast tissue when it comes to target volume dose coverage, necessitating precise positioning and effective immobilization (12). Any carelessness in these aspects can result in locoregional recurrence due to mismatching at the junction between the supraclavicular and tangential fields in the regional LN sites (7,11,13). Additionally, set-up errors and patient positioning inconsistencies may lead to side effects such as radiation-induced skin injury and persistent humeral head pain following breast radiotherapy. These effects are often linked to field overlaps between the tangential and supraclavicular fields (14–16).

Probst et al. (17) reviewed various methods for breast tissue immobilization during tangential field treatment. Their systematic review evaluated the benefits of novel arm immobilization approaches compared to the standard supine position, specifically the single–arm abducted technique, during adjuvant breast irradiation. However, based on our search, no comprehensive study has been published on the effects of different arm immobilization methods on the set-up accuracy of breast cancer patients with supraclavicular LN involvement in photon and proton radiotherapy techniques. Therefore, the aim of this systematic review was to gather and compare data from previous studies on set-up approaches for breast cancer patients, with a focus on arm immobilization. Specifically, this review seeks to address the following questions: How important is arm position in achieving set-up accuracy (considering both random and systematic errors)? Which arm position–one hand or both hands raised over the head–provides greater accuracy?

METHODS

To conduct this review, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist was followed. A comprehensive literature search was performed using English-language sources from PubMed, Google Scholar, ScienceDirect, and Medline databases, with no restrictions on the publication date. The search strategy employed a combination of keywords, alternatives, and their variations, including: ((breast cancer [Title/Abstract]) AND ((set-up error [Title/Abstract]) OR (radiotherapy set-up error [MeSH Terms])) AND ((radiation therapy [Title/Abstract]) OR (radiation therapy [MeSH Terms]))), paired with terms

related to “arm” for specificity.
The inclusion and exclusion criteria used in the review are detailed in Table 1.

by Winfield et al. (19), two groups of patients (one arm vs. both arms positioned over the head) were assessed. The study concluded that breast positioning

Table 1. Eligibility and non-eligibility criteria for document selection.

Inclusion criteria	Exclusion criteria
• Studies primarily focused on the positioning and immobilization of breast cancer patients.	• Abstracts or poster presentations.
• Studies reporting set-up error and dosimetry data for different arm positions in supine or prone setups.	• Studies focusing on brachytherapy.
• Publications available in English only.	• Studies exclusively analyzing dosimetry parameters for organs at risk (OAR).
	• Studies utilizing the isocentric lateral decubitus position.

might be more accurate when both arms are raised. In another qualitative study (18), all patients were positioned supine, with the ipsilateral arm either lifted over the head or placed akimbo. The authors found that the designed shield intended to protect the humeral head could be misaligned when the arm position was altered (e.g., changes in the degree of abduction), potentially resulting in the underdosage of certain lymph node (LN) regions.
The quantitative findings of the remaining six studies are summarized in Table 2.
Only 3 of the 14 studies investigated the impact of the immobilization methods on the patient set-up accuracy in the prone position (Table 3), compared to the supine position. Although some other studies compared the supine and prone positions, they did not specifically evaluate the effect of arm positioning or immobilization on set-up accuracy, either qualitatively or quantitatively. Additionally, 3 studies focused on the proton radiation therapy technique, and their findings are summarized in Table 4.

After removing duplicates, the screening process began with an independent review of all abstracts by two authors to exclude irrelevant or low-quality studies. Next, the authors assessed the remaining articles based on the inclusion and exclusion criteria to identify eligible studies. Any disagreements regarding the selected studies were resolved through consultation with a third author. Once a final agreement was reached, relevant information was extracted and summarized from the selected studies.
The study selection process is illustrated in a flow chart (Figure 1).

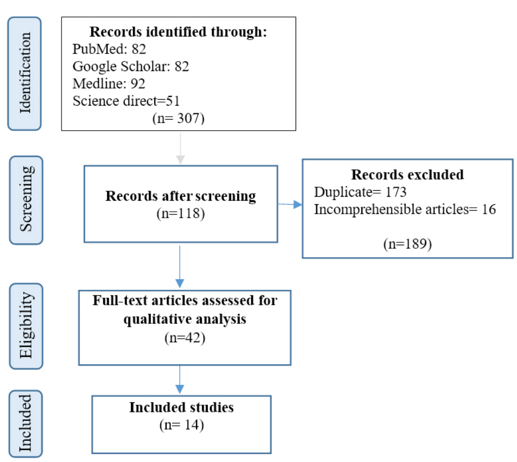

Figure 1. Flow chart illustrating the identification, screening, and inclusion of studies.

RESULTS

After the screening and eligibility determination steps, 14 studies were included in this systematic review. Most of these investigations analyzed factors such as random and systematic set-up errors, LN displacement, and OAR doses associated with various arm immobilization methods.
Of the 14 studies included, 8 utilized the supine position. Among these, two studies evaluated the effects of arm positions on breast radiotherapy qualitatively (18,19), while the others presented the quantitative findings (Table 2). In one qualitative study conducted

Table 2. Overview of literature on patient arm immobilization management during breast photon radiotherapy (supine position).

Study, year	Description	Average set-up error (mm)			Dosimetry parameters		Preferred set-up
		Random	Systematic	LN displacement	LN region	OAR	
Saito et al., 2009 (8) N=16	Differences in axillary LN irradiation based on various arm positions: one arm (H-P) or both arms (CT-P) elevated over the head.	-	-	The depth of level LN I decreased by 14.8 mm. The depth of level LN III increased. An average medial shift of 6-7 mm was observed for all LNs.	From H-P to CT-P position: • Higher V90 for level LN I. • Higher V110 and Dmax for level LNs II and III.	Significantly more homogeneous dose distribution for the CT-P group.	Both methods are applicable; however, accurate contouring of the lymph nodes for each arm position should be carefully considered.
Goldsworthy et al., 2011 (6) N=50	Stability measurement in bilateral (BL) arm abduction versus unilateral (UL) arm abduction in the x (CLD) and y (CCD) directions.	UL/BL group: X direction: 2.1/1.6. Y direction: 2.4/2.6.	UL/BL group: X direction: 4/2.3 Y direction: 3.6/2.2.	A lower translational displacement of 3.1 mm was observed in the BL group compared to 5.3 mm in the UL group.	-	-	The two-arms-up method demonstrates superiority over the one-arm-up method.
Janus et al., 2014 (9) N=60	The effect of individualized stabilization on the consistency of SCF in breast radiotherapy using a vacuum-lock bag with both arms raised versus a breast board with one arm abducted.	One arm/two arms: Y direction: 2.93/2.1. X direction: 3.8/2.85.	One arm/two arms: Y direction: 3.39/1.67. X direction: 2.30/2.87.	-	-	-	The patient set-up using the breast board technique is more time-consuming and challenging compared to the vacuum-lock bag method with both arms raised.
Kapanen et al., 2015 (16) N=113	The comparison of the standard wrist-hold (WH) and rod-hold (RH) techniques, and the effect of arm position correction with both arms raised above the head.	-	The residual error of WH/RH after electronic portal imaging: •Superior-inferior: 3.4/2.1 mm •Lateral: 1.9/1.7 mm	The set-up margins for the WH/RH are as follows: • LN region: 8.1 mm / 6.7 mm • Humeral head: 4.6 mm / 3.6 mm.	-	The percentage of the humeral head volume receiving a dose of 15 Gy for: WH :32 RH: 56.	The house-made RH was preferred. To minimize the humeral head irradiation volume, greater consideration should be given to the RH compared to the WH.
Xiang et al., 2018 (4) N=94	The comparison of single-pole vs. double-pole immobilization in intensity-modulated radiation therapy (IMRT) with both arms raised above the head.	-	X, Y, Z directions, and total vector: • Single-pole: 0.7, 0.4, -0.7, and 3 mm. • Double-pole: 0.5, 0.2, -0.7, and 2.6 mm.	-	-	Single-pole vs. double-pol: Heart: • V30 :3.17/6.15 (%) Dmean: 657/834 (Gy) Ipsilateral lung: • V20: 31.8/30.1 (%).	Both methods were similar in terms of reproducibility, set-up accuracy, and dosimetric parameters.
Song et al., 2021 (20) N=100	The comparison of inter-fractional set-up reproducibility between a vacuum-lock bag with one hand raised and a thermoplastic mask with both hands raised.	-	X, Y, Z directions, and their summation for vacuum-lock bag/ thermoplastic mask groups: • X direction: 3.66 / 1.56 mm • Y direction: 4.34 / 1.48 mm • Z direction: 3.68 / 0.84 mm • Total: 7.64 / 2.95 mm	-	Conformity index (CI): 0.60 ± 0.05	-	The patients in the vacuum-lock bag group reported feeling more comfortable than those in the thermoplastic group. The set-up errors were fewer for the two hands-up positions and thermoplastic mask.

LN: lymph node; Vx(90): represents the percentage volume corresponding to x (90) Gy dose.

Table 3. Overview of literature on patient arm immobilization management during breast photon radiotherapy (prone position).

Study, year	Description	Average set-up error (mm)			Dosimetry parameters		Preferred set-up
		Random	Systematic	LN displacement	LN region	OAR	
Deseyne et al., 2017 (21) N=5	A modified prone study called the crawl position compared to the supine position in left-sided breast cancer.	-	-	LN I was generated much closer to the skin in a prone position compared to the supine position.	Underdosage occurred slightly in the prone position compared to the supine position (D98 of 33.12 Gy vs. 36.11 Gy for axillary LN I).	A significant dose reduction to adjacent OARs was observed in the prone crawling position compared to the supine position.	The prone crawl position demonstrates better sparing of adjacent OARs and more effective planning target volume (PTV) dose coverage compared to other positions.
Boute et al., 2017 (22) N=9	The comparison between the newly designed special couch for the crawl position and the prone position with bilateral arm elevation on AIO™ (a prone breast-board).	For the crawl breast couch vs. AIO: -In the left-right direction, it was almost less than 3-4/3-8 mm. - In the ant-post directions, it was equal for both techniques.	-	-	-	Promoted dose homogeneity in the breast and lymph node (LN) targets. Achieved dose reductions to all organs at risk (OARs) for the crawling position.	The crawl prototype provided superior comfort and set-up precision compared to AIO.
Schoepen et al., 2022 (23) N=51	A comprehensive dosimetric study of supine, prone crawl, and prone dive patient positions for different irradiation techniques.	One arm/two arms: Y direction: 2.93/2.1. X direction: 3.8/2.85.	-	-	-	Both the prone dive and crawl positions confirmed lung sparing. The deep inspiration breath hold (DIBH) method was superior to the prone techniques in terms of reducing the heart dose. The prone crawl position offered a deeper location for the ipsilateral breast and a larger distance between the target volume and organs at risk (OARs).	The prone crawl position combined with the deep inspiration breath hold (DIBH) method.

Table 4. Overview of literature on patient arm immobilization management during breast proton radiotherapy.

Study, year	Description	Average set-up error (mm)			Dosimetry parameters		Preferred set-up
		Random	Systematic	LN displacement	LN region	OAR	
Depauw et al., 2020 (24) N=10	Arm positions in post-mastectomy proton radiation.	The arms-down/up mode for the vertical, longitudinal, and lateral directions: 1.2 mm / 1.3 mm, 1.1 mm / 1.2 mm, and 1.5 mm / 1.4 mm, respectively.	The arms-down/up mode for the vertical, longitudinal, and lateral directions: 1.0/1.3 mm, 0.6/0.8 mm, and 1.4/1.5 mm, respectively.	-	Similar coverage was achieved for LN II and III. Axillary level I received a modestly lower dose in the arms-down position compared to the arms-up position.	Both the esophagus and thyroid received slightly lower doses in the arms-down position. V20 and mean lung doses were similar in both positions. The heart mean doses were significantly lower in both positions.	Arms-down positioning appears equivalent to arms-up positioning in terms of set-up error and dosimetry parameters.
Garda et al., 2022 (25) N=22	Proton radiotherapy for the breasts and comprehensive nodal irradiation for breast cancer in two different arm positions.	Crawl breast couch / AIO:	-	-	-	Arms-up positioning requires longer treatment times due to the break between the fields. In cases requiring a supraclavicular or high axillary boost, the arms-down position allows for the use of additional posterior beam angles to limit the brachial plexus. 4o mini	Some patient factors and anatomical structures determine the most appropriate set-up approach.
Hong et al., 2023 (26) N=84	A comparison of adverse reactions in conventional-dose versus hypofractionated-dose regimens with respect to patient arm positioning.	-	An error in the positioning of the arm could result in:	-	-	For both the prone dive and crawl positions, lung sparing was demonstrated, with a greater effect observed in the prone crawl position. The DIBH method was superior to the prone techniques in terms of the heart dose. The ipsilateral breast was positioned deeper, and there was a larger distance between the target volume and OARs in the prone crawl position.	Both arms-up positions, combined with a vacuum pad to immobilize the patient's affected arm, help reduce set-up errors and increase the repeatability of positioning.

DISCUSSION

Photon radiotherapy

Supine position

The appropriate method for arm immobilization in breast radiotherapy is a critical consideration, particularly for patients with supraclavicular LN involvement (6,9). Although surface matching between the tangential and supraclavicular fields is achieved, the stability of the LN region remains unreliable due to arm movement and must be carefully addressed.

In 2005, Mansur et al. (18), emphasized the importance of arm positioning, immobilization, and set-up reproducibility in breast radiotherapy, particularly for patients with axillary node involvement. Since the location of the axillary nodes is related to the humeral head, they measured the distance between axillary lymph node levels I-III and the humeral head, as well as the angle of the humeral head using computed tomography (CT). The findings indicated that when the patients' arms were abducted at angles greater than 90 degrees over their heads, the lymph nodes were closer to the humeral head. As a result, in treatment planning, only the most cranial aspect of the humeral head could be safely blocked or removed. In contrast, when the arm was positioned at less than 90 degrees in the hands-on-hips (akimbo) position, no overlap with the axillary nodal region was observed in any of the patients, allowing the entire humeral head to be safely blocked. For patients with restricted shoulder movement following axillary surgery, the reproducibility of the set-up was reduced with each session, resulting in varying humeral angles and a potential lymph node miss. In such cases, the akimbo position was preferred, but a wide-bore CT scanner was required for simulation. However, no set-up error data related to these positions was reported in their study.

In two studies by Saito et al. (8) and Goldsworthy et al. (6), the effects of the arm position on set-up accuracy were assessed by comparing two different set-up approaches on an inclined breast board without additional immobilization devices: one arm elevated versus both arms elevated over the head. Saito et al. (8) demonstrated that the location of the LNs depends on the arm position. From unilateral hand elevation to bilateral hand elevation, the distance from LN level I to the anterior skin surface decreased by 14.8 mm, while the distance to the posterior skin surface increased. No changes in depth were observed for LN level II. For LN level III, the distance from the anterior skin surface increased, while no significant changes were seen with the posterior skin surface. An average medial shift of 6-7 mm was observed across all LN levels. The dose distribution in the two-hands-up group was significantly more homogeneous, with a higher volume of tissue receiving at least 90% of the prescribed dose (V90) for LN level I, and a smaller volume receiving more than 110% of the prescribed dose (V110) for LN levels II and III. Goldsworthy et al. (6), in a randomized study, found that bilateral arm abduction during breast radiotherapy is considered a standard technique due to its more stable and reproducible position, which reduces systematic errors compared to unilateral arm abduction.

Several studies have investigated the simultaneous effects of arm positions and immobilization devices (e.g., individualized molded vacuum-lock bag, standard wrist-hold and rod-hold arm fixation devices, single-pole and double-pole positions, and thermoplastic masks) on set-up accuracy in breast cancer patients (4,9,16,20). Janus et al. (9) compared the average random and systematic set-up errors between two patient groups using the relationship between the clavicle and vertebrae. In the first group, the ipsilateral hand was lifted on the breast board, while in the second group, both arms were abducted and stabilized in an individualized molded vacuum-lock bag. The results showed that the systematic errors for the first and second groups in the longitudinal and lateral directions were 3.39/1.67 mm and 2.30/2.87 mm, respectively. Vacuum-lock bag stabilization reduced the systematic errors by about 40% in the longitudinal direction; however, no meaningful differences were observed in the lateral direction. The random errors in the second group (vacuum-lock bag) were lower than in the one-hand-up group for both directions. Notably, the longitudinal systematic errors for the two-hands-up group were significantly reduced compared to Goldsworthy et al.'s study (6), with errors of 1.67 mm versus 2.2 mm, highlighting the benefit of vacuum-lock bag stabilization in reducing set-up errors. Song et al. (20) studied two groups of patients: one group with vacuum-lock bag immobilization and the ipsilateral hand elevated, and the other with thermoplastic immobilization and both hands elevated over the head. The study found that the systematic errors in all directions for the vacuum-lock bag with one hand up followed an ascending pattern compared to the results from Janus et al. (9), who used the vacuum-lock bag with both hands up. This suggested that using a vacuum-lock bag in the one-hand-up position had a negative effect on accuracy, reducing its effectiveness. An interesting aspect of this study was the consideration of patient comfort during set-up and its relationship with set-up accuracy. The findings showed that patients in the vacuum-lock bag group reported greater comfort, especially in the early weeks of treatment, compared to the thermoplastic group. However, the set-up errors in the vacuum-lock bag group were significantly fewer than those in the thermoplastic group (20).

The remaining two studies, by Kapanen et al. (16) and Xiang et al. (4), investigated patient set-up errors using a special arm holder on the breast boards. In the first study (16), the researchers assessed the effect of arm positioning on set-up accuracy and the required set-up margin in terms of Th1-2, clavicle, and humeral head displacement. They used two arm fixation devices: the standard wrist-hold (WH) and rod-hold (RH). In the standard WH method, the patient's right hand is placed on the left wrist (or vice versa), while in the

RH method, a plastic self-made rod-holding device is used, where both hands grip rods attached to a base plate, maintaining a similar abduction angle. The residual systematic error of the WH/RH devices after the portal imaging set-up in the superior-inferior and lateral directions were 3.4/2.1 mm and 1.9/1.7 mm, respectively, indicating a better result with the homemade RH method. Xiang et al. (4) examined the set-up accuracy in single-pole and double-pole positions on inclined breast boards. In the single-pole method, one pole was positioned on the treatment side over the head, with the ipsilateral arm abducted to 90 degrees while both hands gripped the pole. In the double-pole method, one pole was placed on each side of the head, with each hand gripping one pole. Additionally, the study evaluated the patients' dosimetry parameters, including V55, Dmin, Dmax, homogeneity index, and conformity index for the planning target volume (PTV), as well as the dose tolerances for the heart, spinal cord, and ipsilateral lung. The set-up deviations in the lateral direction for the single-pole and double-pole methods were 0.07 $\pm$ 0.17 cm and 0.05 $\pm$ 0.18 cm, respectively. The results showed that both methods were similar in terms of reproducibility, set-up accuracy, and dosimetric parameters; however, the single-pole method resulted in a lower dose to the heart.

The overall results from these studies indicate that the patient set-up with both arms raised is significantly preferable to having just one arm raised. The number of errors in the group with both arms raised was reduced when immobilization tools were used. The vacuum-lock bag immobilization device led to a greater reduction in errors for the two-arms-up group, whereas, in the one-arm-up group, it had little effect on error reduction and even caused an increase in errors in some directions. However, further investigations are needed to confirm this finding.

Prone position

The radiotherapy of patients with large breast sizes has acute and late skin toxicities, particularly in the inframammary fold (27). In the supine position, breast tissue becomes closer to the chest, and the critical internal organ dose will increase. To resolve these problems, Memorial Sloan-Kettering Cancer Center (MSKCC) offered prone breast radiotherapy as an alternative method (28). This method is administered on a specially-designed couch with a breast board, the ipsilateral arm is placed either at the side or elevated in front of the head. However, there are several disadvantages associated with the prone position, including reduced set-up precision and the patients' discomfort. The support material itself blocks access to the anterior beam of the regional LNs, which is one of the major drawbacks of this position (29). To overcome these problems, Deseyne et al. (21) assessed the modified prone position for breast patients with LN involvement in a crawl position. In this position, the arm on the treated side was placed beside the body, while another arm was lifted above the head. To achieve the accuracy of this proposed set-up, all patients were simulated in both supine with the arms elevated above the head and prone crawl position as explained above. Dosimetric analysis of the patient's plan in the two positions confirmed a good coverage of the LN region with significant dose reduction of ipsilateral lung, contralateral breast, thyroid, contralateral lung, and esophagus for the prone crawling position compared to the supine position (21).

In a similar study by Boute et al. (22), the pain and comfort levels, set-up precision, beam access, and plan dosimetric parameters of the crawl position were investigated and compared to the commonly used prone position with bilateral arm elevation (prone dive) on AIO™ (a prone breast-board, Orfit, Wijnegem, Belgium). They designed and built a special couch for a crawl position in which the regional LNs exposed without any beam restriction (22). It was shown that the crawl position had superior comfort and set-up precision compared to AIO. The promoted dose homogeneity in the breast and LN targets, as well as the reduced OAR received dose for the crawling position, was obtained. In most of the patients, the random set-up error in the left-right direction was almost less than 3-4 mm and more than 3-8 mm for the crawl breast couch and AIO, respectively. However, in the anteroposterior or craniocaudal directions, it was equal for the two positions. In another work by Schoepen et al. (23), a comprehensive dosimetric study of supine, prone dive, and prone crawl patient positions for different whole-breast irradiation techniques was performed. The dosimetric parameters and conformity indexes of different patient datasets, including prone dive–supine (left and right-sided breasts), prone crawl–supine (left-sided breast), prone crawl–prone dive (right-sided breast), and prone crawl-deep inspiration breath hold (DIBH) for left-sided breast were analyzed. They concluded that lung-sparing was better in the prone crawl position compared to the prone dive (the supine position was considered the reference one). For the heart, both methods had the same results; however, the DIBH method was superior to the heart-sparing one. In addition, special arm positioning in the prone crawl leads to a larger distance between the target volume and OARs.

Proton radiotherapy

In recent years, proton radiotherapy has become increasingly common for breast cancer patients. This technique offers several advantages, such as the unique physical properties of the Bragg peak and the absence of the exit dose, which enable better dose coverage in the PTV, particularly for the internal mammary LNs (30). The use of one field per fraction in proton radiotherapy allows for both arms-up and arms-down positioning. However, for some patients who have undergone breast surgery, maintaining the arms-up position can be painful. As a result, the only viable positioning options may be the akimbo position or an arms-down position (30,31).

There are very few studies that examine the effect of arm positioning on set-up accuracy in proton radiotherapy (30,32). Most studies on proton radiotherapy for breast cancer refer to supine simulation with arms positioned above the head, similar to photon radiotherapy. Depauw et al. (24) evaluated the dosimetric impact of the arm position on PTV coverage, OAR sparing, and set-up reproducibility for daily treatments in mastectomy patients, comparing two arm positions: both arms up and both arms down with arms slightly akimbo to the sides, while maintaining a similar head position. To ensure immobilization accuracy, they used additional tools such as a chin strap, head and neck cups, and hand grips. The systematic and random set-up errors, as well as dosimetry parameters in the vertical, longitudinal, and lateral directions, were similar for both positions. Garda et al. (25) demonstrated that longer treatment times might be required due to the break between the fields in the arms-up position. In cases requiring high axillary boosts or supraclavicular treatment, the arms-down position allows for the use of additional posterior beam angles to reduce the dose to the brachial plexus. Hong et al. (26) found that errors in arm positioning could alter breast tissue thickness and the posterior border in proton therapy, potentially leading to insufficient target dose coverage or increased dose to the lung and heart. To address this issue, a vacuum pad was used to immobilize the affected arm, reduce set-up errors, and improve the repeatability of patient positioning.

Recently, surface-guided radiation therapy (SGRT) has become a preferred method for daily patient monitoring and positioning in all radiotherapy techniques due to its effectiveness as a quality assurance tool (33). SGRT uses the reconstructed external surface of the patient and three stereo-camera systems to track thousands of points on the patient's skin. Unlike the traditional image-guided procedures, SGRT relies on light reflected from the patient's skin rather than radiation exposure (33). For example, Dekker et al. (34) assessed the accuracy of arm positioning using clavicle rotation under SGRT for patients positioned on a breast board with their arms lifted above their heads. They reported mean residual set-up errors of -0.015 (± 0.90) mm, -0.58 (± 1.1) mm, and -0.18 (± 0.82) mm in the vertical, longitudinal, and lateral directions, respectively. The accuracy observed in their study was superior to that in previous studies, particularly in the vertical direction, highlighting the efficiency of SGRT in ensuring precise arm positioning. Further investigation into this area is beyond the scope of the present study but is a goal for our future research.

CONCLUSION

In this systematic review, we aimed to evaluate the effects of different arm immobilization methods on set-up accuracy in breast cancer radiotherapy. For the supine position, raising both hands above the head proved to be a more effective method; however, this may not be feasible in cases where the patient's movement is restricted. In such instances, individualized immobilization tools, such as a vacuum-lock bag with one arm elevated, are preferred. Several disadvantages were reported for the prone position, including reduced precision in patient positioning and patient discomfort. However, the crawl position combined with the DIBH method was found to be superior to other methods. In proton beam breast radiotherapy, some studies assessed showed that both the hands-up and hands-down methods had equivalent effects on set-up accuracy.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

REFERENCES

1. Firouzjah RA, Banaei A, Farhood B, Bakhshandeh M. Dosimetric comparison of four different techniques for supraclavicular irradiation in 3D-conformal radiotherapy of breast cancer. Health Phys. 2019;116(5):631–6.
2. Nadi S, Abedi-Firouzjah R, Banaei A, Bijari S, Elahi M. Dosimetric comparison of level II lymph nodes between mono-isocentric and dual-isocentric approaches in 3D-CRT and IMRT techniques in breast radiotherapy of mastectomy patients. Journal of Radiotherapy in Practice. 2020;19(3):254-258. doi:10.1017/S146039691900061X.
3. Bagheri H, Firouzjah RA, Farhood B. Measurement of the photon and thermal neutron doses of contralateral breast surface in breast cancer radiotherapy. J Radiother Pract. 2020;19(3):226–32.
4. Xiang Q, Jie W, Zhu K, Wang Q ,Cheng J. Which technique of positioning and immobilization is better for breast cancer patients in postmastectomy IMRT, single-pole or double-pole immobilization? J Appl Clin Med Phys. 2019;20(1):168–74.
5. Feng CH, Gerry E, Chmura SJ, Hasan Y, Al-Hallaq HA. An image-guided study of setup reproducibility of postmastectomy breast cancer patients treated with inverse-planned intensity modulated radiation therapy. Int J Radiat Oncol Biol Phys. 2015 Jan 1;91(1):58-64. doi: 10.1016/j.ijrobp.2014.09.007.
6. Goldsworthy SS, Sinclair NN, Tremlett JJ, Chalmers AA, Francis MM, Simcock RR. Abducting both arms improves stability during breast radiotherapy: The Bi Arm study in radiotherapy. Journal of Radiotherapy in Practice. 2011;10(4):250-259. doi:10.1017/S1460396910000452.
7. McCune K, Parsons L, Schoenfeld L, Madderford A. A technique for evaluating cast foam positioning and immobilization devices used in breast cancer radiotherapy. Med Dosim. 1991;16(3):119–25.
8. Saito AI, Vargas C, Morris CG, Lightsey J, Mendenhall NP. Differences between current and historical breast cancer axillary lymph node irradiation based on arm position: implications for radiation oncologists. Am J Clin Oncol. 2009 Aug;32(4):381-6. doi: 10.1097/COC.0b013e318191718d.
9. Janus A, Plank A, Middleton M. Influence of individualized stabilization on the consistency of supraclavicular fossa positioning in breast radiation therapy: A retrospective study. J Med Imaging Radiat Sci. 2014; 45(3):210–7.
10. Creutzberg CL, Althof VG, Huizenga H, Visser AG, Levendag PC. Quality assurance using portal imaging: the accuracy of patient positioning in irradiation of breast cancer. Int J Radiat Oncol Biol Phys. 1993 Feb 15;25(3):529-39. doi: 10.1016/0360-3016(93)90077-9.
11. Gielda BT, Strauss JB, Marsh JC, Turian JV, Griem KL. A dosimetric comparison between the supine and prone positions for three-field intact breast radiotherapy. Am J Clin Oncol. 2011 Jun;34(3):223-30. doi: 10.1097/COC.0b013e3181dbb9c1.
12. Costin IC, Marcu LG. Factors impacting on patient setup analysis and error management during breast cancer radiotherapy. Crit Rev Oncol Hematol. 2022;178:103798.
13. Thilmann C, Adamietz IA, Saran F, Mose S, Kostka A, Böttcher HD. The use of a standardized positioning support cushion during daily routine of breast irradiation. Int J Radiat Oncol Biol Phys. 1998 May 1;41(2):459-63. doi: 10.1016/s0360-3016(98)00022-4.
14. Zhang Y, Ding K, Cowan G, Tryggestad E, Armour E, Wang KK. Alignment of multiradiation isocenters for megavoltage photon beam. J Appl Clin Med Phys. 2015 Nov 8;16(6):314-324. doi: 10.1120/jacmp.v16i6.5733.
15. Batumalai V, Holloway L, Delaney GP. A review of setup error in supine breast radiotherapy using cone-beam computed tomography. Med Dosim. 2016; 41(3):225–9.
16. Kapanen M, Laaksomaa M, Skyttä T, Haltamo M, Pehkonen J, Lehtonen T et al. Residual position errors of lymph node surrogates in breast cancer adjuvant radiotherapy: comparison of two arm fixation devices and the effect of arm position correction. Med Dosim. 2016;41(1):47–52.
17. Probst H, Bragg C, Dodwell D, Green D, Hart J A systematic review of methods to immobilise breast tissue during adjuvant breast irradiation. Radiography. 2014;20(1):70–81.
18. Mansur DB, Kong FM, El Naqa I, Taylor ME, Zoberi I, Bradley JD, et al. CT localization of axillary lymph nodes in relation to the humeral head: significance of arm position for radiation therapy planning. Radiother Oncol. 2005 Nov;77(2):191-3. doi: 10.1016/j.radonc.2005.09.019.
19. Winfield E, Deighton A, Venables K, Hoskin PJ, Aird EGA. Survey of UK breast radiotherapy techniques: background prior to the introduction of the quality assurance programme for the START (standardisation of radiotherapy) trial in breast cancer. Clin Onc. 2002;14(4):267–71.
20. Song Y, Peng J, Chen Q, Luo H. Compare of Interfractional Setup Reproducibility Between Vacuum-Lock Bag and Thermoplastic Mask in Radiotherapy for Breast Cancer. Technol Cancer Res Treat. 2021;20:1-6.
21. Deseyne P, Speleers B, De Neve W, Boute B, Paelinck L, Van Hoof T, et al. Whole breast and regional nodal irradiation in prone versus supine position in left sided breast cancer. Radiat Oncol. 2017 May 26;12(1):89. doi: 10.1186/s13014-017-0828-6.
22. Boute B, De Neve W, Speleers B, Van Greveling A, Monten C, Van Hoof T, et al. Potential benefits of crawl position for prone radiation therapy in breast cancer. J Appl Clin Med Phys. 2017 Jul;18(4):200-205. doi: 10.1002/acm2.12118.
23. Schoepen M, Speleers B, De Neve W, Vakaet V, Deseyne P, Paelinck L, et al. Four irradiation and three positioning techniques for whole-breast radiotherapy: Is sophisticated always better? J Appl Clin Med Phys. 2022 Nov;23(11):e13720. doi: 10.1002/acm2.13720.
24. Depauw N, Batin E, Johnson A, MacDonald SM, Jimenez RB. Arms positioning in post-mastectomy proton radiation: Feasibility and development of a new arms down contouring atlas. Phys Imaging Radiat Oncol. 2020 May 26;14:6-11. doi: 10.1016/j.phro.2020.04.003.
25. Garda AE, Hunzeker AE, Michel AK, Fattahi S, Shiraishi S, Remmes NB, et al. Intensity Modulated Proton Therapy for Bilateral Breast or Chest Wall and Comprehensive Nodal Irradiation for Synchronous Bilateral Breast Cancer: Initial Clinical Experience and Dosimetric Comparison. Adv Radiat Oncol. 2022 Jan 24;7(3):100901. doi: 10.1016/j.adro.2022.100901.
26. Hong Z, Yang Z, Mei X, Li P, Bao C, Wang Z, et al. A retrospective study of adjuvant proton radiotherapy for breast cancer after lumpectomy: a comparison of conventional-dose and hypofractionated dose. Radiat Oncol. 2023 Mar 23;18(1):56. doi: 10.1186/s13014-023-02213-8.
27. Hannan R, Thompson RF, Chen Y, Bernstein K, Kabarriti R, Skinner W, et al. Hypofractionated whole-breast radiation therapy: does breast size matter? Int J Radiat Oncol Biol Phys. 2012 Nov 15;84(4):894-901. doi: 10.1016/j.ijrobp.2012.01.093.
28. Huppert N, Jozsef G, Dewyngaert K, Formenti SC. The role of a prone setup in breast radiation therapy. Front Oncol. 2011 Oct 11;1:31. doi: 10.3389/fonc.2011.00031.
29. Krengli M, Masini L, Caltavuturo T, Pisani C, Apicella G, Negri E, et al. Prone versus supine position for adjuvant breast radiotherapy: a prospective study in patients with pendulous breasts. Radiat Oncol. 2013 Oct 8;8:232. doi: 10.1186/1748-717X-8-232.

30. Liang X, Mailhot Vega RB, Li Z, Zheng D, Mendenhall N, Bradley JA. Dosimetric consequences of image guidance techniques on robust optimized intensity-modulated proton therapy for treatment of breast Cancer. Radiat Oncol. 2020 Feb 27;15(1):47. doi: 10.1186/s13014-020-01495-6.

31. Mutter RW, Choi JI, Jimenez RB, Kirova YM, Fagundes M, Haffty BG, et al. Proton Therapy for Breast Cancer: A Consensus Statement From the Particle Therapy Cooperative Group Breast Cancer Subcommittee. Int J Radiat Oncol Biol Phys. 2021 Oct 1;111(2):337-359. doi: 10.1016/j.ijrobp.2021.05.110.

32. Cuaron JJ, MacDonald SM, Cahlon O. Novel applications of proton therapy in breast carcinoma. Chin Clin Oncol. 2016;5(4):52.

33. Batin E, Depauw N, MacDonald S, Lu HM. Can surface imaging improve the patient setup for proton postmastectomy chest wall irradiation? Pract Radiat Oncol. 2016 Nov-Dec;6(6):e235-e241. doi: 10.1016/j.prro.2016.02.001.

34. Dekker J, Essers M, Verheij M, Kusters M, de Kruijf W. Dose coverage and breath-hold analysis of breast cancer patients treated with surface-guided radiotherapy. Radiat Oncol. 2023 Apr 20;18(1):72. doi: 10.1186/s13014-023-02261-0.