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Patterns and Longitudinal Changes in the Practice of Breast Cancer Radiotherapy in Korea: Korean Radiation Oncology Group 22-01

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ABSTRACT

Purpose: We aimed to analyze contemporary practice patterns in breast cancer radiotherapy (RT) and assess longitudinal changes over five years in Korea.
Methods: In 2022, a nationwide survey was conducted among board-certified radiation oncologists. The survey consisted of 44 questions related to six domains: hypofractionated (HypoFx) whole breast RT, accelerated partial breast RT (APBI), regional nodal irradiation (RNI), RT for ductal carcinoma *in situ* (DCIS), postmastectomy RT (PMRT), and tumor bed boost.
Results: Seventy radiation oncologists from 61 (out of 101; 60%) institutions participated in the survey. HypoFx RT was used by 62 respondents (89%), a significant increase from 36% in 2017. HypoFx RT is commonly administered at 40–42.5 Gy in 15–16 fractions. APBI was used by 12 respondents (17%), an increase from 5% in 2017. The use of RNI did not change significantly: ≥ pN2 (6%), ≥ pN1 (33%), and ≥ pN1 with pathological risk factors (61%). However, indications for internal mammary lymph node (IMN) irradiation have expanded. In particular, the rates of routine treatment of IMN (11% from 6% in 2017) and treatment in cases of ≥ pN2 (27% from 14% in 2017) have doubled; however, the rate of treatment for only IMN involvement, identified on imaging, has decreased from 47% in 2017 to 31%. For DCIS, the use of HypoFx RT increased from 25% in 2017 to 75%, and the rate of RT omissions after breast-conserving surgery (BCS) decreased from 48% in 2017 to 38%. The use of HypoFx RT for PMRT increased from 8% in 2017 to 36%.
Conclusion: The adoption of HypoFx RT after BCS for invasive breast cancer and DCIS has increased significantly, whereas the use of HypoFx PMRT has increased moderately since 2017. However, further studies are required to determine the optimal use of RNI.

Keywords: Breast Neoplasms; Practice Patterns, Physicians'; Radiotherapy; Republic of Korea; Surveys and Questionnaires

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Conflict of Interest
The authors declare that they have no competing interests.

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INTRODUCTION

Breast cancer is the most common cancer and is one of the leading causes of cancer-related deaths among women worldwide [1]. Breast cancer is the most common cancer in Korean women, and its incidence is progressively increasing. In 2019, 24,820 newly diagnosed breast cancer cases were reported in Korea. Moreover, 2,622 breast cancer-specific deaths occurred in 2019, making breast cancer the sixth leading cause of cancer-related deaths. However, the mortality rate associated with breast cancer has not improved significantly [2].

Postoperative radiotherapy (RT) is an essential component of breast cancer treatment after breast-conserving surgery (BCS) and mastectomy as it reduces the risk of locoregional and distant recurrences and improves overall survival rates [3,4]. Several clinical trials have evaluated the optimal RT indications, dose fractionation, treatment volume, and techniques to improve clinical outcomes. Despite revisions to the guidelines based on new high-quality evidence, there is a variable time lag for implementing guidelines in clinical practice. Several studies based on surveys or population-based databases have reported wide variations in practice patterns among practitioners in different countries [5-8] and within the same [9] countries.

In 2017, the Korean Radiation Oncology Group (KROG) conducted the first nationwide survey of RT practices in six domains: (1) hypofractionated (HypoFx) whole breast RT, (2) accelerated partial breast RT (APBI), (3) postmastectomy RT (PMRT), (4) regional nodal irradiation (RNI), (5) RT for ductal carcinoma *in situ* (DCIS), and (6) RT toxicity [10]. Consistent with previous studies, Korean radiation oncologists showed considerable variations in practice patterns related to breast cancer RT.

We investigated contemporary RT practice patterns for breast cancer in 2022 and the trends over the previous five years. Furthermore, we aimed to elucidate the issues involved in reaching a consensus among Korean radiation oncologists.

METHODS

The Division for Breast Cancer of KROG conducted a nationwide survey based on a modified version of the 2017 survey. The survey questionnaire was piloted among division members at the beginning of 2022. The questionnaire consisted of 44 questions related to six domains, namely HypoFx whole breast RT (7 questions), APBI (5 questions), RNI (11 questions), RT for DCIS (3 questions), PMRT (13 questions), and tumor bed boost (4 questions). Furthermore, an additional question was asked regarding cardiac-sparing RT.

In March 2022, the survey was circulated twice via e-mail to all board-certified radiation oncologists in Korea. The responses were analyzed to determine contemporary patterns and longitudinal changes in the practice of breast cancer RT in Korea over the past five years. The KROG authorized the survey process and encouraged Korean radiation oncologists to participate in the study.

RESULTS

Seventy radiation oncologists from 61 (out of 101; 60.4%) Korean institutions with RT facilities responded to the survey. The 70 respondents were from Seoul (n = 24), Incheon and Gyeonggi-do (n = 20), Busan-Ulsan-Gyeongsangnam-do (n = 9), Daegu-Gyeongsangbuk-do (n = 5), Gangwon-do (n = 5), Daejeon-Chungcheong-do (n = 3), Gwangju-Jeolla-do (n = 3), and Jeju-do (n = 1). Furthermore, 61 (87.1%) respondents were affiliated with academic institutions, and 39 (55.7%) were affiliated with institutions qualifying as radiation oncology training centers that employed three or more radiation oncologists. Thirty-nine (55.7%) respondents worked in institutions that employed two or more breast specialists. When divided based on the number of breast cancer patients treated per month, 21 (30.0%), 31 (44.3%), 15 (21.4%), and 3 (4.3%) institutions treated > 20, 11–20, 5–10, and < 5 breast cancer patients per month, respectively.

HypoFx whole breast RT

HypoFx whole breast RT was performed for invasive breast cancer by 62 respondents (88.6%) in 2022, a substantial increase from 35.9% in 2017 (**Table 1**). Additionally, shared decision-making with patients regarding the use of HypoFx RT decreased over time, and decision-making was more likely based on physician discretion in 2022 than in 2017 (79.0% vs. 52.2%, respectively). This study defined HypoFx as a fraction size of 2.5 Gy or more.

With regard to HypoFx RT volume, 17 respondents (73.9%) applied HypoFx to the whole breast only, whereas 6 (26.1%) applied it to the whole breast and regional lymph nodes (LNs) in 2017. However, the practice patterns changed slightly in 2022; 37 respondents (59.7%) applied it to the whole breast only, and 25 (40.3%) applied it to the whole breast and regional LNs in 2022. Notably, 17 (27.4%) respondents used HypoFx for all patients who required

Table 1. Hypofractionated whole breast radiotherapy

Responses	No. of respondents (%)	
	2017	2022
Use of hypofractionation*		
Yes	23 (35.9)	62 (88.6)
No	41 (64.1)	8 (11.4)
Selection of hypofractionation		
Shared decision	11 (47.8)	13 (21.0)
Physician's discretion	12 (52.2)	49 (79.0)
WBRT fraction size (Gy)		
5.2	0	3‡ (4.8)
3	4† (17.4)	0
2.6–2.7	18 (78.3)	58§ (93.5)
2.5	2 (8.7)	6‖ (9.7)
Boost fraction size (Gy)		
3.5	1 (4.3)	0
3.15 or 3.2 (SIB)	2 (8.7)	2 (3.2)
3	10† (43.5)	11 (17.7)
2.6–2.7	4 (17.4)	4 (6.5)
2.5	3 (13.0)	22 (35.5)
2–2.4	2 (8.7)	22 (35.5)

WBRT = whole breast radiotherapy; SIB = simultaneous integrated boost.
*Hypofractionation was defined as fraction size ≥ 2.5 Gy.
†A respondent used different fractionation schedules in 2017: 40 Gy in 16 fractions without boost RT or 39 Gy in 13 fractions with boost RT.
‡,§,‖Five respondents used different fractionation schedules in 2022: three used 26 Gy in 5 fractions‡ more frequently, but also used 40.05 Gy in 15 fractions§ one used 43.2 Gy in 16 fractions§ more frequently, but also used 43.35 Gy in 17 fractions‖; one used 40 Gy in 16 fractions‖ more frequently, but also used 42.56 Gy in 16 fractions.§

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whole breast RT and RNI, irrespective of poor prognostic features, such as patient age, stage, molecular subtype, and tumor grade.

The general dose-fractionation scheme did not change over the past five years: most respondents administered 40–43.2 Gy in 15–16 fractions (2.6–2.7 Gy/fraction), except for 3 (4.8%) respondents who used 5.2 Gy/fraction in 2022 compared to no respondents in 2017. The specific dose fractionation details for whole breast and boost RT are presented in **Table 1**.

In terms of the HypoFx RT technique, intensity-modulated RT (80.6%), including volumetric modulated arc therapy and TomoTherapy®, was the most preferred technique. In contrast, the field-in-field technique (35.5%) was also frequently used in 2022. The use of three-dimensional conformal RT decreased from 39.1% in 2017 to 7.9% in 2022. Duplicate answers were allowed for questions on the RT technique.

APBI

Twelve respondents (17%) administered APBI in 2022, an increase from 5% in 2017. In 2022, seven respondents followed the American Society for Radiation Oncology (ASTRO) guidelines, whereas six followed their institutional policies (one answered "both"). Regarding the dose-fractionation scheme, 30 Gy in 5 fractions (41.7%) and 38–40 Gy in 10 fractions (58.3%) were administered. Intensity-modulated RT (66.7%), magnetic resonance-guided RT (33.3%), and CyberKnife® (25.0%) were commonly used RT techniques.

RNI

The indications for RNI accepted by Korean radiation oncologists have not changed over the past five years (**Table 2**). Most respondents (n = 43, 61.4%) administered RNI for patients with involvement of one or more axillary LNs (≥ pN1) and adverse pathological features, such as tumor size (n = 29), molecular subtype (n = 31), lymphovascular space invasion (n = 33), LN-related parameters (n = 41), and others. The number of respondents who administered RNI only for patients with the involvement of four or more axillary LNs (≥ pN2) decreased from 10.9% in 2017 to 5.7% in 2022. In contrast, those administering it for all patients with the involvement of one or more axillary LNs (≥ pN1) increased from 26.6% in 2017 to 32.9% in 2022.

The 2022 survey provided the same clinical scenario as the 2017 survey, based on the American College of Surgeons Oncology Group (ACOSOG) Z0011 trial. The scenario involved a patient

Table 2. Regional nodal irradiation

Responses	No. of respondents (%)	
	2017	2022
RNI indication		
≥ pN2	7 (10.9)	4 (5.7)
≥ pN1 + adverse features	40 (62.5)	43 (61.4)
≥ pN1	17 (26.6)	23 (32.9)
IMN irradiation		
Always, on RNI	4 (6.3)	8 (11.4)
Involved IMN on imaging	30 (46.9)	22 (31.4)
≥ pN2	9 (14.1)	19 (27.1)
≥ pN2 with inner location	19 (29.7)	21 (30.0)
≥ pN2 with central location	6 (9.4)	6 (8.6)
≥ pN1 with inner location	13 (20.3)	13 (18.6)
≥ pN1 with central location	7 (10.9)	7 (10.0)
Others	2 (3.1)	2 (2.6)

RNI = regional nodal irradiation; IMN = internal mammary lymph node.

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with early-stage breast cancer, clinically negative nodes, and pathological involvement of 1–2 nodes after BCS and sentinel LN biopsy without further axillary dissection (Q. How do you treat the axilla in early-stage breast cancer patients with clinically node-negative but 1–2 pathologic nodal involvement after BCS and sentinel LN biopsy without further axillary dissection [based on ACOSOG Z0011 trial]?). The use of standard tangents decreased from 12.5% (n = 8) in 2017 to 7.1% (n = 5) in 2022, and the use of high tangents, with or without supraclavicular LN (SCN) irradiation, decreased from 50.0% (n = 32) in 2017 to 32.9% (n = 23) in 2022. However, the routine use of SCN irradiation increased from 31.3% (n = 12) in 2017 to 45.7% (n = 32) in 2022.

The indications for internal mammary LN (IMN) irradiation have expanded over the past five years (**Table 2**). The proportion of respondents who administered IMN irradiation only if IMN involvement was identified on imaging decreased from 46.9% (n = 20) in 2017 to 31.4% (n = 22) in 2022. Conversely, the proportion of respondents who always treated IMN doubled from 6.3% (n = 4) in 2017 to 11.4% (n = 8) in 2022, and the proportion of those who treated IMN in cases with ≥ pN2 doubled from 14.1% (n = 9) in 2017 to 27.1% (n = 19) in 2022. A similar proportion of respondents treated IMN in cases of ≥ pN2 with inner/central location and ≥ pN1 with the same location of the tumor in 2017 (39.1% and 31.2%, respectively) and 2022 (38.6% and 28.6%, respectively).

Most radiation oncologists included up to the third (n = 30, 42.9%) and fourth (n = 30, 42.9%) intercostal spaces for IMN irradiation in 2022, similar to the number of respondents in 2017. Intensity-modulated RT for IMN irradiation increased in BCS (n = 59, 84.3%) and mastectomy patients (n = 58, 82.9%) in 2022 from 67.2% and 54.7% in 2017, respectively. The partial wide tangent technique was used in 15.7% (n = 11) of patients who underwent BCS and mastectomy, whereas the mixed photon-electron technique was seldom used in 2022.

The 2022 survey included new clinical scenarios for treating regional LNs involving axillary LN dissection and neoadjuvant chemotherapy (neoCTx).

The first scenario was related to the treatment of the axilla along with the SCN in a patient with axillary LN involvement on sentinel LN biopsy who underwent additional axillary dissection (Q. How do you treat the axilla along with SCN for a patient with axillary LN involvement by sentinel LN biopsy who underwent additional axillary dissection?). Most respondents (n = 45, 64.3%) recommended treatment for levels I–III. Thirteen (18.6%), 3 (4.3%), and 9 (12.9%) respondents recommended treatment for levels II–III, only level III, and all levels except for the dissected ones, respectively (**Figure 1**).

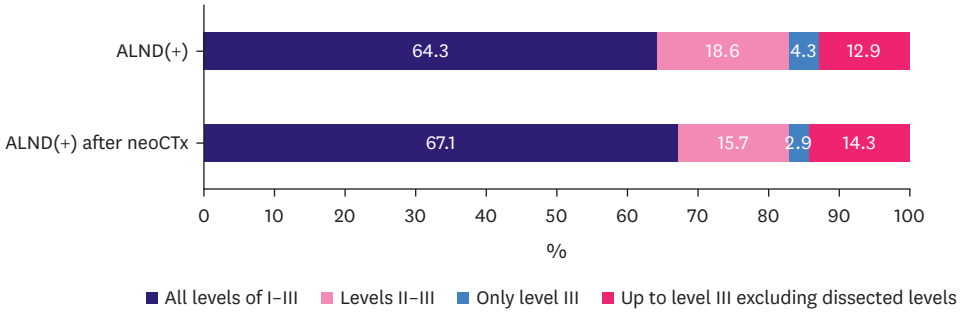

Figure 1. Respondents' answers to "How do you treat the axilla along with the supraclavicular fossa for a patient with axillary lymph node involvement on sentinel lymph node biopsy who underwent additional axillary dissection?"
ALND = axillary lymph node dissection; neoCTx = neoadjuvant chemotherapy.

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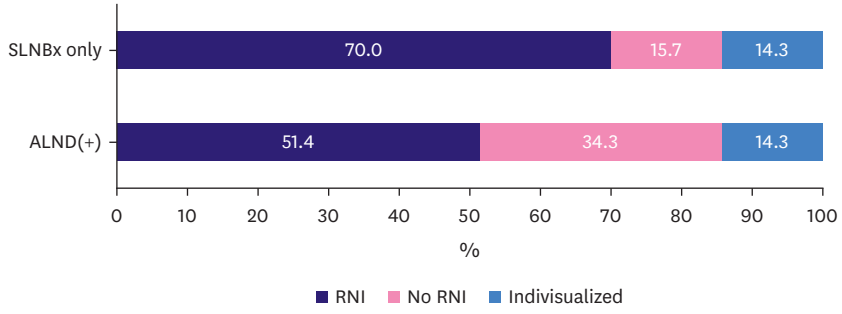

Figure 2. Respondents' answers to "Would you administer regional nodal irradiation for a cT1-3N1 patient who achieved ypN0 after neoadjuvant chemotherapy?"
SLNBx = sentinel lymph node biopsy; ALND = axillary lymph node dissection; RNI = regional nodal irradiation.

The second scenario was related to treating the axilla and SCN in a patient with axillary LN involvement by sentinel LN biopsy who underwent additional axillary dissection after neoCTx (Q. How do you treat the axilla along with SCN for a patient with axillary LN involvement by sentinel LN biopsy who underwent additional axillary dissection after neoCTx?). The responses were similar to those in the first scenario: most respondents (n = 47, 67.1%) recommended treatment including levels I–III. Eleven (15.7%), two (2.9%), and 10 (14.3%) respondents recommended treatment for levels II–III, only level III, and all levels except for the dissected ones, respectively (**Figure 1**).

The third scenario was related to the use of RNI in a cT1-3N1 patient who achieved ypN0 after neoCTx and sentinel LN biopsy without further axillary dissection (Q. Do you apply RNI for a cT1-3N1 patient achieving ypN0 after neoCTx and sentinel LN biopsy with further axillary dissection?). Most respondents (n = 49, 70.0%) recommended that RNI should be administered, whereas 11 (15.7%) did not recommend (others, n = 10; **Figure 2**).

The fourth scenario was related to the administration of RNI to a cT1-3N1 patient who achieved ypN0 after neoCTx and axillary dissection (Q. Do you apply RNI for a cT1-3N1 patient achieving ypN0 after neoCTx and sentinel LN biopsy without further axillary dissection?). More than half the respondents (n = 36, 51.4%) recommended RNI administration, whereas 24 (34.3%) did not (others, n = 10; **Figure 2**).

RT for DCIS

RT for patients with DCIS treated with BCS has three issues: HypoFx, tumor bed boost, and RT omission for low-risk patients (**Table 3**).

The practice patterns related to HypoFx RT for DCIS have dramatically changed over the past five years. Most radiation oncologists (87.5%) did not administer HypoFx RT in 2017, whereas most (71.4%) administered HypoFx RT in 2022. The dose fractionation scheme for HypoFx was similar (40–50 Gy in 15–20 fractions) to that used for invasive cancers. In 2022, three respondents administered 26 Gy in 3 fractions in 2022.

The use of tumor bed boost for DCIS increased slightly over the study period. The number of respondents who selectively used boost RT for patients based on the presence of adverse features, such as patient age, resection margin, and tumor size, remained similar (45.3% in 2017 and 40.6% in 2022), whereas the number of respondents who routinely administered

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Table 3. Radiotherapy for ductal carcinoma *in situ*

Responses	No. of respondents (%)	
	2017	2022
Hypofractionation*		
Yes	8 (12.5)	50 (71.4)
No	56 (87.5)	19 (27.1)
No answer	-	1 (1.4)
Boost		
Always	25 (39.1)	35 (50.7)
No	10 (15.6)	6 (8.7)
Selective	29 (45.3)	28 (40.6)
No answer	-	1 (1.4)
Omission		
Considered	31 (48.4)	26 (37.7)
Not considered	33 (51.6)	43 (62.3)
No answer	-	1 (1.4)

*Hypofractionation was defined as fraction size ≥ 2.5 Gy.

boost RT increased from 2017 to 2022 (39.1% and 50.7%, respectively). The typical boost schedule was 9–10 Gy in 3–5 fractions in 2022.

RT omissions for DCIS have declined over the past five years; almost half (48.4%) of the respondents considered it in 2017, whereas one-third (37.7%) of them considered it in 2022. Similar to 2017, the respondents identified low-risk patients in 2022 based on risk factors such as patient preference (n = 15), age (n = 14), comorbidities (n = 14), tumor size (n = 13), resection margin (n = 12), and nuclear grade (n = 11).

PMRT

The use of HypoFx in PMRT has increased moderately, in concordance with that of whole breast RT for BCS, from 7.8% in 2017 to 35.7% in 2022. The dose-fractionation schemes applied for HypoFx were 40–48 Gy in 15–17 fractions (**Table 4**).

Table 4. Postmastectomy radiotherapy

Responses	No. of respondents (%)	
	2017	2022
Hypofractionation		
Yes	5 (7.8)	25 (35.7)
No	59 (92.1)	45 (64.3)
Hypofractionation schedules (Gy)		
2.7	4 (80.0)	10 (40.0)
2.65–2.67	1 (20.0)	14 (56.0)
2.5	-	1 (4.0)
Boost		
Yes, always	8 (12.5)	5 (7.1)
Yes, selectively	16 (25.0)	27 (38.6)
No	28 (62.5)	38 (54.3)
Use of bolus		
Yes, entire chest wall	24 (37.5)	28 (40.0)
Yes, scar only	16 (25.0)	8 (11.4)
No	12 (18.8)	24 (34.3)
Others	12 (18.8)	10 (14.3)
Use of bolus after reconstruction		
Yes	7 (10.9)	8 (11.4)
No	46 (71.9)	49 (70.0)
Not experienced	9 (14.1)	6 (8.6)
Others	2 (3.1)	7 (10.0)

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The proportion of respondents who never administered tumor bed boost RT decreased from 62.5% in 2017 to 54.3% in 2022. Twenty-five (35.7%) respondents selectively applied boost RT for close resection margins or pT4 tumors in 2022.

Table 4 presents details of the use of bolus. Notably, more than 70% of radiation oncologists did not administer bolus in cases with immediate reconstruction or insertion of tissue expander after mastectomy. Moreover, more than half of the respondents did not administer boost RT (n = 36, 51.4%) or restrictively administered it for close resection margins (n = 26, 37.1%), and 43 out of 47 (91.5%) respondents who used tissue expanders did not deflate them in 2022.

The 2022 survey questionnaire introduced new clinical scenarios related to the use of PMRT based on the pathological response after neoCTx in initially node-positive patients.

The first scenario involved using PMRT for an initial cT1-2N1 patient who achieved a pathological complete response (pCR) (ypT0N0) or ypT1-2N0 after neoCTx, followed by mastectomy and sentinel LN biopsy. Forty respondents (57.1%) recommended PMRT, while 22 (31.4%) did not (others, n = 8; **Figure 3**).

The second scenario was related to the use of PMRT for an initial cT1-2N1 patient who achieved pCR (ypT0N0) or ypT1-2N0 after neoCTx, followed by mastectomy and axillary dissection (Q. Do you apply PMRT for an initially cT1-2N1 patient achieving pCR [ypT0N0] or ypT1-2N0 after neoCTx followed by mastectomy and axillary dissection?). Thirty-four respondents (48.7%) recommended PMRT, while 29 (41.4%) did not (others, n = 7; **Figure 3**).

The third scenario was related to the use of PMRT for an initially cT1-2N2 patient who achieved pCR (ypT0N0) after neoCTx, followed by mastectomy and sentinel LN biopsy (Q. Do you apply PMRT for an initially cT1-2N1 patient achieving pCR [ypT0N0] or ypT1-2N0 after neoCTx followed by mastectomy and sentinel LN biopsy?). Almost all the respondents (n = 68, 97.1%) recommended PMRT, whereas two (2.9%) did not (**Figure 4**).

The fourth was related to the use of PMRT for an initially cT1-2N2 patient who achieved pCR (ypT0N0) after neoCTx, followed by mastectomy and axillary dissection (Q. Do you apply PMRT for an initially cT1-2N2 patient achieving pCR [ypT0N0] after neoCTx followed by mastectomy and axillary dissection?). Almost all the respondents (n = 66, 94.3%) recommended PMRT, whereas only four (5.7%) did not (**Figure 4**).

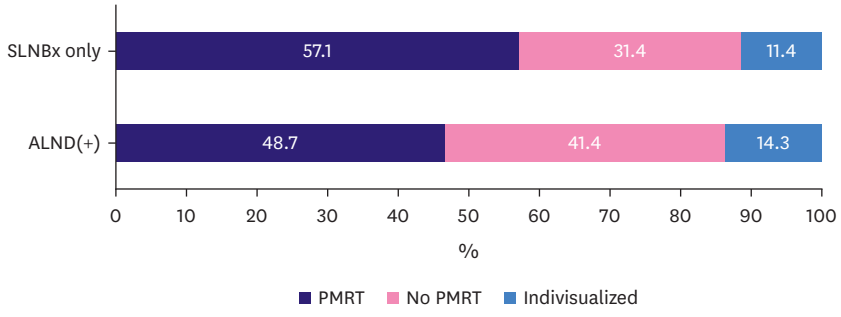

Figure 3. Respondents' answers to "Would you administer postmastectomy radiotherapy for an initially cT1-2N1 patient who achieved pathological complete response (ypT0N0) or ypT1-2N0 after neoadjuvant chemotherapy followed by mastectomy?"
SLNBx = sentinel lymph node biopsy; ALND = axillary lymph node dissection; PMRT, postmastectomy radiotherapy; SIB, simultaneous integrated boost.

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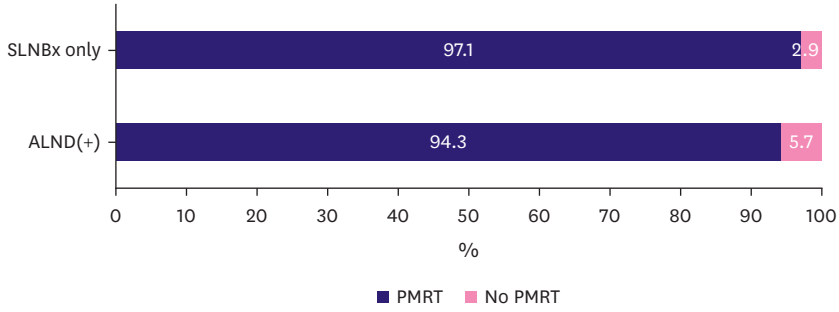

Figure 4. Respondents' answers to "Would you administer postmastectomy radiotherapy for an initially cT1-2N2 patient who achieved pathological complete response (ypT0N0) after neoadjuvant chemotherapy followed by mastectomy?"
SLNBx = sentinel lymph node biopsy; ALND = axillary lymph node dissection; PMRT = postmastectomy radiotherapy.

Tumor bed boost

Fifty-seven respondents (81.4%) preferred the use of tumor bed boost for all patients with invasive breast cancer treated with BCS. Thirteen (18.6%) respondents considered omitting boost RT based on the patient's age (n = 10), resection margin (n = 10), histological grade (n = 9), molecular subtype (n = 7), and other factors such as tumor size, pathological response, and preference.

Radiation oncologists defined the tumor bed volume based on postoperative changes in planning computed tomography (n = 48), surgical clip (n = 44), surgical scar (n = 18), physical examination (n = 4), and other factors (n = 2) (duplicate answers were allowed). The most common boost RT technique was an electron beam (n = 50), whereas a photon beam was used sequentially (n = 31) or as a simultaneous integrated boost (n = 14) (duplicate answers were allowed).

Cardiac toxicity

In 2022, most respondents used heart-sparing techniques to reduce cardiac toxicity, including intensity-modulated RT (n = 58), heart block (n = 19), deep inspiration breath hold (n = 10), and others (n = 6) (duplicate answers were allowed). The use of intensity-modulated RT increased (n = 33), and that of heart block decreased (n = 31) compared with their respective levels in 2017.

DISCUSSION

The KROG conducted a nationwide survey designed by the Division for Breast Cancer to identify practice patterns related to breast cancer RT in Korea in 2017. The initial results were published in 2018 [10]. The 2022 survey, modified from the 2017 survey based on recent trials, was conducted to evaluate longitudinal changes in practice patterns over the previous five years.

Over five years, the most significant change in practice patterns was the increased use of HypoFx RT in patients with invasive breast cancer and DCIS treated with BCS. HypoFx RT is superior to conventionally fractionated RT in terms of patient convenience and cost; randomized trials have found comparable oncological and cosmetic outcomes with HypoFx RT and conventionally fractionated RT [3,11-14]. Increased implementation of HypoFx RT in radiation oncologists' real-world practice is notable.

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Although only 35.9% of radiation oncologists used HypoFx RT for invasive cancers in 2017, the use of HypoFx RT dramatically increased to 88.6% in 2022. Two population-based cohort studies and a cancer database have reported longitudinal changes in HypoFx RT use over time. The use of HypoFx RT increased from 35% in 2012 to 66% in 2017 in Australia; however, notably, a previous study defined HypoFx as < 25 fractions of RT rather than as dose per fraction [6]. The use of HypoFx RT in the USA in patients who fulfilled the 2011 ASTRO criteria increased from 26.2% in 2012 to 67.0% in 2016 [7]. Compared to that in Australia and the USA, the rate of HypoFx RT use in Korea was relatively low in 2017, but it has currently become the predominant pattern of care in the treatment for early breast cancer. In addition to the high-quality evidence supporting its use, reimbursement by Korean healthcare services for intensity modulated RT of 20 fractions or less for breast cancer has contributed to the increasing use of HypoFx RT since 2018.

The seventh edition of the Korean Clinical Practice Guideline for Breast Cancer, published in 2017, and its later revisions recommended HypoFx and conventionally fractionated whole breast RT for early breast cancer treated with BCS [15]. Notably, HypoFx RT has been recommended as the preferred RT schedule in the ninth edition of the 2021 guidelines. Additionally, the indication for the use of HypoFx RT was limited to whole breast RT and did not include RNI [16]. Similarly, the revised ASTRO guidelines in 2018 recommended expanded indications for HypoFx RT without RNI after BCS regardless of age, stage, or chemotherapy status [17]. Meanwhile, the European Society for Radiotherapy and Oncology (ESTRO) recommends HypoFx for all patients receiving whole breast RT and RNI [18].

The use of HypoFx RT in patients with DCIS has substantially increased over five years, from 12.5% in 2017 to 71.4% in 2022. Few randomized trials have evaluated the use of HypoFx RT in patients with only DCIS; therefore, its use is primarily based on guidelines. The Danish Breast Cancer Cooperative Group (DBCG) HYPO trial investigated the oncological outcomes of HypoFx RT for node-negative breast cancer and DCIS; the subgroup analysis of DCIS (consisting of 13.3% of study patients) showed no difference in locoregional recurrence between HypoFx and conventional fractionation ($p = 0.53$) [19]. The revised 2018 ASTRO guidelines include *in situ* disease as an indication for HypoFx RT [17]. The ninth edition of the 2021 Korean Clinical Practice Guideline for Breast Cancer also includes HypoFx for DCIS as an RT option [16].

A recently published phase 3 study by BIG 3-07/TROG 07.01 investigated HypoFx whole breast RT and tumor bed boost in patients with non-low-risk DCIS [13]. The study defined non-low-risk DCIS as the presence of at least one clinical or pathological adverse factor, such as young age (< 50 years), large tumor size (≥ 15 mm), and close resection margin (< 10 mm). There were no significant differences in disease recurrence between the conventional fractionation (50 Gy in 25 fractions) and HypoFx (42.5 Gy in 16 fractions) whole breast RT groups ($p = 0.36$). However, a tumor bed boost (16 Gy in 8 fractions) significantly reduced the local recurrence rate ($p = 0.0042$). In the present study, 50.7% of respondents routinely administered boost RT, whereas 40.6% selectively administered it in cases with adverse features. This is in line with the BIG 3-07/TROG 07.01 study, which presented the first randomized trial data to support the use of boost radiation for non-low-risk DCIS patients. One-third of the respondents considered RT omission in patients with low-risk DCIS. However, a phase 3 NRG/RTOG 9804 study reported a relatively high ipsilateral breast recurrence rate without whole breast RT, even in low-risk patients with DCIS (15-year rate, 15.1% vs. 7.1%, $p = 0.0007$) [20].

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Two phase 3 randomized trials that compared HypoFx RT with conventionally fractionated RT for node-positive patients after mastectomy showed no difference in the recurrence rates between the treatment arms. A Chinese study reported that the five-year locoregional recurrence rate was 8.3% in the Hypo Fx group (43.5 Gy in 15 fractions) and 8.1% in the conventional fractionation group (50 Gy in 25 fractions; $p < 0.0001$ for non-inferiority) [21]. The investigators found no differences in disease-free survival rates, overall survival rates, or late toxicity. In the DBCG Skagen trial 1, 48% of patients underwent a mastectomy, and there were no differences in the three-year locoregional recurrence rate:1.8% in the HypoFx (40 Gy in 15 fractions) and conventional fractionation (50 Gy in 25 fractions) groups [22]. The current ESTRO guidelines recommend HypoFx for patients receiving chest wall RT after mastectomy (with or without reconstruction) and RNI [18]. Our study showed that the use of HypoFx for PMRT has increased over the past five years. However, only one-third (35.7%) of the respondents administered HypoFx PMRT, suggesting that there is room for more adoption of HypoFx PMRT.

The indications for RNI have not changed substantially over the past five years. Although the use of IMN irradiation has increased, it remains low, with only 11.4% of the respondents always treating IMN when RNI is administered. Additionally, the National Comprehensive Cancer Network guidelines recommend the addition of comprehensive RNI, including SCN and IMN, in cases of ≥ pN2 (category 1) and ≥ pN1 (category 2A) [23] patients, based on the results of the MA.20 and EORTC 22922/10925 studies [24,25].

A plausible reason for the low rate of IMN irradiation is that the two aforementioned studies had insufficient evidence for the positive effect of IMN irradiation in their study design [24,25]. In contrast, recently published trials by the DBCG and KROG that investigated the use of IMN irradiation for node-positive breast cancer after BCS or mastectomy could provide better guidance for IMN irradiation. The DBCG-IMN trial showed that IMN irradiation reduced the risk of distant metastases and death due to breast cancer, thereby improving long-term survival [26]. In contrast, the KROG phase 3 trial showed that IMN irradiation did not significantly improve disease-free survival but might benefit patients with medially or centrally located tumors [27].

Another reason for the low rate of IMN irradiation is associated with cardiotoxicity. Although RT achieves local control and improves survival, incidental radiation exposure to the heart increases the subsequent risk of ischemic heart disease [28]. To prevent this, radiation oncologists have used various RT techniques such as heart blocks, prone positioning, deep inspiration breath hold, and intensity-modulated RT [29]. Most of the respondents preferred intensity-modulated RT (82.9%). The exact indications for IMN irradiation can be further refined by implementing modern heart-sparing techniques.

The questionnaire used in the present study included new scenarios related to the treatment of regional LNs after neoCTx, followed by surgery. The main treatment principle is that the need for RNI should be determined by the maximal clinical (cTN) or pathological (ypTN) stage of breast cancer. However, further evidence is required. In the current study, the respondents agreed on the use of PMRT for cT1-2N2 patients who achieved pCR (ypT0N0) after neoCTx followed by a mastectomy, irrespective of the use of sentinel LN biopsy (97.1%) or axillary dissection (94.3%). However, other cN1 cases that achieved ypN0 showed different responses in terms of RNI or PMRT. The RAPCHEM trial is a prospective registry study that investigated the de-escalation of locoregional RT in cT1-2N1 breast cancer based on

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ypN status after neoCTx, with no RNI for ypN0, RT to axilla levels I–II for ypN1 (including the chest wall in cases of mastectomy), or RNI for ypN2 (IMN irradiation was considered optional) [30]. The five-year locoregional recurrence rate in all patients was 2.2%, and the investigators hypothesized that locoregional RT could be omitted in selected patients in whom axillary dissection was performed. The NSABP B-51/RTOG 1304 phase 3 randomized clinical trial is currently investigating the need for PMRT/RNI in ypN0 patients after neoCTx (NCT01872975). We anticipate that these coming results will provide guidance for future clinical practice.

In conclusion, we evaluated the longitudinal changes in practice patterns related to breast cancer RT among Korean radiation oncologists. Our results show a significant increase in the rate of use of HypoFx RT after BCS for invasive breast cancer and DCIS and a moderate increase in the rate of PMRT compared to 2017. However, there were significant differences among respondents regarding the use of RNI, particularly IMN irradiation. Further clinical studies are required to establish a standardized treatment in clinical practice, particularly regarding RNI, with an emphasis on the neoCTx setting.

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