RESEARCH ARTICLE

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Optimizing Staging Imaging in Early-Stage Breast Cancer: Predictive Factors and Guideline Alignment in Oman

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Abstract

Objectives: To evaluate the diagnostic yield of staging imaging in detecting distant metastases among women with early-stage breast cancer in Oman, assess alignment with international guidelines, and identify key patient factors that could guide selective imaging use. **Methods:** A retrospective cohort study was conducted at Sultan Qaboos University Hospital, Muscat, Oman, including women diagnosed with stage 0–II breast cancer between January 2014 and December 2019. Patient demographics, tumor characteristics, imaging modalities, and outcomes were reviewed. Staging imaging included computed tomography (CT) with bone scintigraphy and/or positron emission tomography (PET-CT). The primary outcome was the prevalence of confirmed metastatic disease (M1). Fisher's exact test was used to assess associations between clinicopathological factors and metastatic yield. The Number Needed to Image (NNI) was calculated to estimate the efficiency of imaging. **Results:** Among 207 patients, 187 (90.3%) underwent staging imaging. Suspicious findings were detected in 10 patients (5.3% of those imaged), but only six cases (3.2% of those imaged; 2.9% of the total cohort) were confirmed as true metastases. All confirmed metastases were identified using CT with bone scans, while PET-CT did not detect any additional cases. Lymph node status was the strongest predictor of metastases ($p = 0.011$). Node-positive patients had a 19.0% metastasis rate compared with 1.1% among node-negative patients. The NNI was 5 for node-positive versus 93 for node- negative patients, demonstrating the limited value of routine imaging in low-risk groups. **Conclusion:** The overall yield of routine staging imaging in early-stage breast cancer is low, with the greatest benefit observed in node-positive patients. Adopting risk-based, guideline- aligned imaging strategies could reduce unnecessary investigations, patient anxiety, and healthcare costs while ensuring optimal use of resources.

Keywords: Breast cancer- staging imaging- lymph node status- PET-CT- guideline adherence

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Introduction

Breast cancer is the most common malignancy among women globally, and Oman is no exception, representing a major public health burden among the female population. Omani women are often diagnosed at a younger age, with a mean age of about 47.5 years, compared to women in Western countries [1, 2]. Unfortunately, only around 20% of breast cancers in Oman are detected at an early stage (stage I or II). This is much lower than the early detection rates seen in countries with well-established screening programs, where finding cancer early is closely linked to better survival outcomes [1, 2]. Limited access to organized screening, sociocultural barriers, and healthcare resource variation continue to contribute to delayed diagnosis and highlight the need for optimized, evidence-based management strategies [1-4].

International guidelines, including those from the European Society for Medical Oncology (ESMO), the American Society of Clinical Oncology (ASCO), and the National Comprehensive Cancer Network (NCCN), recommend against routine baseline staging imaging in asymptomatic women with early-stage breast cancer (stages 0–II), given the very low prevalence of distant metastases in this population [5-9]. Unnecessary use of computed tomography (CT), bone scintigraphy, or positron emission tomography (PET-CT) may result in false-positive findings, additional investigations, treatment delays, increased radiation exposure, patient anxiety, and avoidable healthcare costs [10,11].

Despite these recommendations, staging imaging remains commonly performed in clinical practice in Oman, potentially reflecting clinician caution, medico-legal concerns, and broad imaging accessibility. However,

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local data assessing the true diagnostic yield and guideline alignment of staging investigations in early-stage breast cancer are limited. Therefore, this study aimed to evaluate the prevalence of distant metastases detected through staging imaging among women with stage 0–II breast cancer in Oman, assess concordance with international guideline recommendations, and identify clinicopathological factors, such as nodal involvement, that may support a selective risk-based imaging approach.

Materials and Methods

Study Design and Setting

This retrospective cohort study was conducted at Sultan Qaboos University Hospital (SQUH), a tertiary academic referral center in Muscat, Oman, between January 2014 and December 2019. Ethical approval was obtained from the SQUH Institutional Review Board. The study aimed to evaluate the diagnostic yield and clinical utility of staging imaging among women with early-stage breast cancer.

Early-stage breast cancer was defined according to the AJCC 8th edition staging system, including clinical stage 0 (TisN0), stage I (T1N0), and stage IIA (T1N1 or T2N0).11 These categories represent ductal carcinoma in situ or invasive tumors up to 5 cm (Tis–T2), with absent or limited regional lymph node involvement (N0–N1), and no evidence of distant metastasis (M0) at diagnosis. All patients received their diagnostic work-up and initial oncological management at SQUH, ensuring consistent institutional protocols and follow-up.

Patient Selection

Patients were identified through electronic medical records. Women aged ≥18 years with biopsy-confirmed ductal carcinoma in situ or invasive breast carcinoma meeting AJCC stage 0–IIA criteria were included.

Eligible patients were those who underwent staging investigations at diagnosis, including computed tomography (CT) of the chest, abdomen, and pelvis, technetium-99m bone scintigraphy, and/or positron emission tomography/computed tomography (PET-CT). Patients who did not undergo staging imaging were also included if they had at least 4–5 years of follow-up without evidence of distant metastasis, reflecting real-world practice and reducing selection bias.

Patients with stage IIB or higher disease, metastatic presentation, prior or synchronous malignancy, or incomplete clinical documentation were excluded.

Data Collection

Data were extracted from electronic medical records using a standardized abstraction form. Demographic variables included age at diagnosis and menopausal status. Tumor-related variables recorded were tumor size (T stage), lymph node status, histologic grade, and receptor profile (ER, PR, HER2), along with the Ki-67 proliferation index.

Molecular subtypes were classified according to the St. Gallen 2013 criteria [12-14]. Luminal A-like tumors were ER-positive, PR-positive, HER2-negative with low Ki-67, whereas Luminal B-like tumors were ER-positive with low/negative PR or high Ki-67 and HER2-negative. HER2-positive tumors were defined by HER2 overexpression/amplification, and triple-negative tumors lacked ER, PR, and HER2 expression. A Ki-67 threshold of ≥20% was considered high and used to distinguish Luminal B-like from Luminal A-like disease.

Staging imaging modality was documented as CT with technetium-99m bone scintigraphy, PET-CT, or no staging imaging. Imaging reports were reviewed for suspicious findings suggestive of distant metastasis (e.g., lung, liver, or bone lesions). Positive findings were defined as lesions interpreted as potentially metastatic. Follow-up investigations, including interval imaging and/or biopsy, were used to confirm true distant metastasis (M1) or classify findings as benign/unconfirmed. Any changes in staging or management resulting from imaging outcomes were also recorded. Discrepancies in data extraction were resolved by investigator consensus.

Statistical Analysis

Descriptive statistics were used to summarize patient characteristics and staging imaging practices. Categorical variables were reported as frequencies and percentages, while continuous variables were summarized using medians. Associations between clinicopathological factors, imaging modality (CT with bone scintigraphy, PET-CT, or no staging imaging), and confirmed metastatic yield were assessed using Fisher's exact test due to small subgroup sizes.

Imaging efficiency was evaluated using the Number Needed to Image (NNI), calculated as the inverse of the metastatic detection rate. A two-sided p-value <0.05 was considered statistically significant. All analyses were performed using R software (version 4.4.0; R Foundation for Statistical Computing).

Results

This study included a total of 207 women diagnosed with early-stage breast cancer between 2014 and 2019. The median age at diagnosis was 46 years. Among patients, 31.9% were younger than 40 years and 13.0% were under 35 years of age. Patients aged 41–50 years accounted for 36.7%, while 31.4% were over 50 years of age.

Regarding menopausal status, most patients were pre-menopausal (69.6%), while 27.1% were post-menopausal (Table 1).

Tumor Characteristics

The majority of patients (85%) were diagnosed with invasive breast carcinoma (classified as T1 or T2), whereas 15% presented with ductal carcinoma in situ (DCIS), staged as Tis. Among the invasive cases for which histologic grading was available (n = 176), the predominant classification was Grade II (55.1%), followed by Grade III (22.7%) and Grade I (22.2%).

Lymph node assessment revealed that the vast majority of patients (89.9%) exhibited no nodal involvement (N0), while 10.1% had positive nodes (N1), which is consistent with an early-stage classification. Clinical staging further

indicated that 15.0% were Stage 0, 33.3% were Stage I, and 51.7% were Stage IIA.

Out of a total of 207 patients, 183 cases (88.4%) had complete molecular profiles, including Ki-67%. Among these, the most common subtype was HER2-positive (34.9%, n = 64), followed by Luminal A (32.2%, n = 59), Luminal B (21.3%, n = 39), and triple-negative breast cancer (TNBC) (11.4%, n = 21) (Table 1).

Utilization of Staging Imaging

Within this cohort of 207 women with early-stage breast cancer, the utilization of staging imaging modalities varied according to clinical and pathological characteristics. The imaging modalities included no imaging, CT with bone scintigraphy, and PET-CT. Overall, 10.1% of patients did not undergo staging imaging, while 74.9% underwent CT/bone imaging and 15.0% underwent PET-CT (Table 2).

Tumor size was significantly associated with imaging modality selection ($p < 0.0001$). Among patients with ductal carcinoma in situ (DCIS/Tis), 32.3% received no staging imaging, 58.1% underwent CT/bone imaging, and 9.7% underwent PET-CT. For patients with T1 tumors, 10.2% were not staged, while 77.3% underwent CT/bone imaging and 12.5% underwent PET-CT. In T2 tumors, only 1.1% were not staged, with 77.3% receiving CT/bone imaging and 21.6% receiving PET-CT. Clinical stage also influenced imaging utilization ($p = 0.0001$). In Stage IIA disease, 3.7% were not staged, whereas 74.8% underwent CT/bone imaging and 21.5% underwent PET-CT (Table 2).

Lymph node status was not significantly associated with imaging modality ($p = 0.47$). Among node-negative patients (N0), 75.8% underwent CT/bone imaging, 15.1% underwent PET-CT, and 9.1% received no staging imaging. Among node-positive patients (N1), PET-CT was performed in 23.8%, while 61.9% underwent CT/bone imaging (Table 2).

Molecular subtype showed a non-significant trend in imaging selection ($p = 0.51$). PET-CT was performed in 21.9% of HER2-positive tumors (14/64) and 19.0% of triple-negative tumors (4/21), compared with 11.8% of Luminal A tumors (7/59). Most Luminal A and Luminal B tumors underwent CT/bone imaging (78.0% and 82.1%, respectively) (Table 2).

CT/bone imaging was the most frequently used modality across all age groups. Among women who underwent CT/bone staging, 70.1% were aged ≥40 years

Table 1. Patient Demographics and Tumor Characteristics (N=207)

Characteristic	Category	N (%)
Age at Diagnosis	<40 years	66 (31.9%)
	41–50 years	76 (36.7%)
	>50 years	65 (31.4%)
Menopausal Status	Pre-menopausal	144 (69.6%)
	Post-menopausal	56 (27.1%)
	Peri-menopausal	7 (3.4%)
Tumor Type	Invasive Breast Carcinoma (T1 or T2)	176 (85.0%)
	Ductal Carcinoma In Situ (Tis)	31 (15.0%)
Histologic Grade (n=176)	Grade I	39 (22.2%)
	Grade II	97 (55.1%)
	Grade III	40 (22.7%)
Lymph Node Status	N0 (No nodal involvement)	186 (89.9%)
	N1	21 (10.1%)
Clinical Stage	Stage 0	31 (15.0%)
	Stage I	69 (33.3%)
	Stage IIA	107 (51.7%)
IHC Subtype (n=202)	Luminal A: HR+/HER2−	59 (32.2%)
	Luminal B: (KI 67% >20)	39 (21.3%)
	HER2+	64 (31.7%)
	Triple-Negative Breast Cancer	21 (11.4%)

Table 2. Utilization of Staging Imaging Modalities

Variable	No Imaging n (%)	CT/Bone n (%)	PET-CT n (%)
Overall (n=207)	21 (10.1%)	155 (74.9%)	31 (15.0%)
By Tumor Size (T Stage)			
Tis (DCIS)	10 (32.3%)	18 (58.1%)	3 (9.7%)
T1	9 (10.2%)	68 (77.3%)	11 (12.5%)
T2	1 (1.1%)	68 (77.3%)	19 (21.6%)
By Clinical Stage			
Stage I	8 (11.6%)	54 (78.3%)	7 (10.1%)
Stage IIA	4 (3.7%)	80 (74.8%)	23 (21.5%)
By Nodal Status			
Node Negative (N0)	17 (9.1%)	141 (75.8%)	28 (15.1%)
Node Positive (N1)	2 (9.5%)	13 (61.9%)	5 (23.8%)
By Molecular Subtype (n=183)			
Luminal A	6 (10.2%)	46 (78.0%)	7 (11.8%)
Luminal B	2 (5.1%)	32 (82.1%)	5 (12.8%)
HER2-positive	3 (4.7%)	47 (73.4%)	14 (21.9%)
TNBC	2 (9.6%)	15 (71.4%)	4 (19.0%)

and 29.9% were younger than 40. PET-CT was more commonly used in younger patients, with 45.5% of PET-staged women being under 40 years of age.

Yield of Imaging in Detecting Metastatic Disease

Of the 207 women included in the study, 187 (90.3%) underwent staging imaging, consisting of computed tomography (CT) with bone scintigraphy and/or positron emission tomography (PET-CT). Suspicious findings suggestive of metastasis were reported in 10 patients, representing 5.3% of those imaged and 4.8% of the total cohort. After follow-up assessment, six patients (3.2% of those imaged and 2.9% of the entire cohort) were confirmed to have true distant metastatic disease (M1), while four cases were classified as false-positive findings (Table 3).

The overall metastatic detection yield of staging imaging was 3.2%. All confirmed metastatic cases were detected using CT with bone scintigraphy. PET-CT did not identify any additional metastatic cases beyond those detected by conventional imaging.

When stratified by lymph node status, a statistically significant association was observed between nodal involvement and confirmed distant metastasis ($p = 0.011$). Among patients with node-positive (N1) disease, 4 cases (19.0%) were confirmed metastatic, compared with 2 cases (1.1%) among node-negative (N0) patients. In the node-negative group, two-thirds of initial suspicious findings were subsequently classified as benign (Table 3; Figure 1).

Imaging efficiency, expressed as the Number Needed to Image (NNI), was 5 for node-positive patients and 93

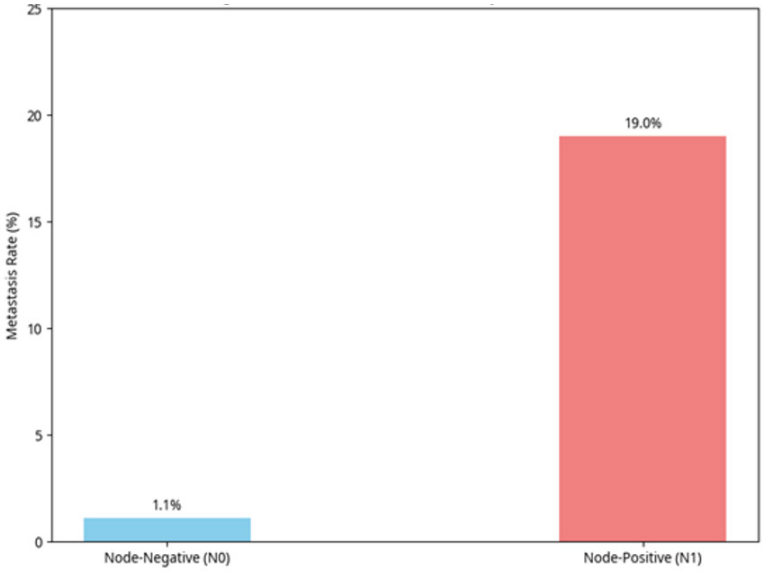

Figure 1. Metastatic Yield by Nodal Status (N0 vs N1). Metastatic disease was detected more frequently in node-positive (N1) compared with node-negative (N0) patients ($p = 0.011$).

Table 3. Diagnostic Yield of Imaging by Key Factors

	Total Cases (n)	Positive Findings n (%)	Confirmed Metastases n (%)	False Positive Rate (%)
Overall	207	10 (4.8%)	6 (2.9%)	40.00%
By Node Status				
Node Negative (N0)	186	6 (3.2%)	2 (1.1%)	66.70%
Node Positive (N1)	21	4 (19.0%)	4 (19.0%)	0%
By Clinical Stage				
Stage 0 (Tis)	31	0 (0%)	0 (0%)	–
Stage I	69	3 (4.3%)	1 (1.4%)	66.70%
Stage IIA	107	7 (6.5%)	5 (4.7%)	28.60%
By Tumor Size				
T1	88	6 (6.8%)	4 (4.5%)	33.30%
T2	88	4 (4.5%)	2 (2.3%)	50.00%
By Molecular Subtype (n=183)				
Luminal A	59	4 (6.8%)	2 (3.4%)	50.00%
Luminal B	39	1 (2.6%)	1 (2.6%)	0%
HER2-positive	64	3 (4.7%)	2 (3.1%)	33.30%
TNBC	21	2 (9.5%)	1 (4.7%)	50.00%

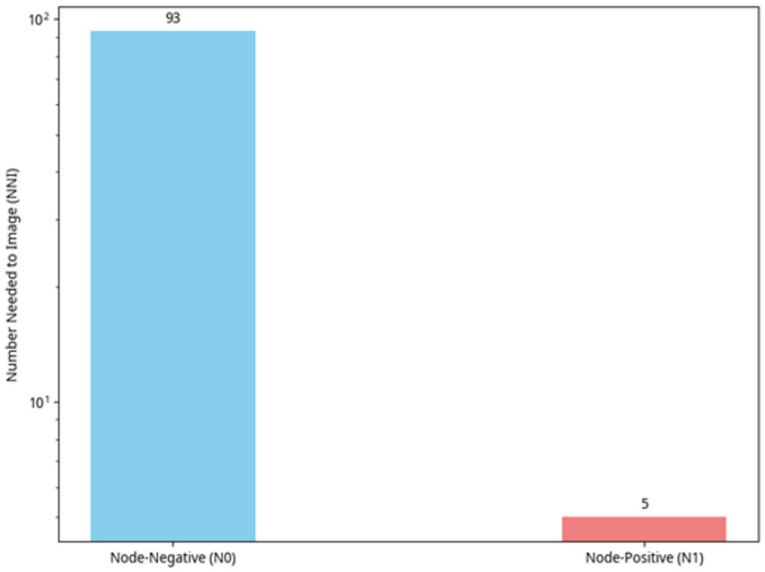

Figure 2. Number Needed to Image (NNI) by Nodal Status. NNI was 5 for node-positive patients and 93 for node-negative patients.

for node-negative patients (Figure 2).

Tumor Size and Clinical Stage

No metastatic disease was detected in patients with Tis tumors. Among patients with T1 tumors, 6 (6.8%) had suspicious findings on initial imaging, with 4 (4.5%) confirmed metastatic after follow-up. In T2 tumors, 4 patients (4.5%) had suspicious findings, with 2 (2.3%) confirmed metastases. Tumor size was not significantly associated with confirmed metastatic yield.

By clinical stage, no metastatic disease was detected in Stage 0 patients. In Stage I disease, 3 patients (4.3%) had suspicious findings, with 1 case (1.4%) confirmed metastatic. In Stage IIA disease, 7 patients (6.5%) had suspicious findings, and 5 (4.7%) were confirmed metastatic. Metastatic yield was significantly higher in Stage IIA compared with Stage 0–I disease ($p \approx 0.02$) (Table 3).

Histological Grade and Molecular Subtype

Most confirmed metastatic cases occurred in Grade II tumors (5 of 6), with no statistically significant association between histologic grade and metastatic yield.

When analyzed by molecular subtype, Luminal A tumors accounted for 4 suspicious scans (6.8%), with 2 cases (3.4%) confirmed metastatic. Luminal B tumors had one suspicious scan (2.6%), confirmed as metastatic. Among HER2-positive patients, 3 had suspicious findings (4.7%), with 2 cases (3.1%) confirmed metastatic. Triple-negative breast cancer showed 2 suspicious scans (9.5%), with 1 case (4.7%) confirmed metastatic. Differences in confirmed metastatic yield across subtypes were not statistically significant ($p \approx 0.80$) (Table 3).

Discussion

This retrospective analysis of 207 women with early-stage breast cancer at SQUH demonstrates that routine staging imaging has a low diagnostic yield for detecting distant metastases. With a confirmed metastasis rate of 2.9% across the cohort, these findings are consistent with international guideline recommendations supporting a selective, risk-adapted approach to staging investigations [15-17]. The relatively young median age at diagnosis in our cohort is consistent with prior national reports indicating that breast cancer in Oman is frequently diagnosed at a younger age compared with Western populations [14]. Routine use of advanced imaging may offer limited clinical benefit in low-risk patients while increasing radiation exposure and healthcare costs.

Lymph node involvement was the strongest clinicopathological factor associated with distant metastatic disease. Patients with node-positive (N1) status had a confirmed metastasis rate of 19.0%, compared with 1.1% among node-negative (N0) patients ($p = 0.011$). The Number Needed to Image (NNI) further illustrates this difference, with five node-positive patients requiring imaging to detect one metastasis compared with ninety-three node-negative patients. These results suggest that nodal status may be a useful stratifier when considering baseline staging imaging.

Regarding imaging modality, our findings do not support routine PET-CT use over conventional CT with bone scintigraphy in this early-stage population. All confirmed metastatic cases were detected using CT-based imaging, and PET-CT did not identify additional metastatic disease. PET-CT was performed in a subset of patients with Stage IIA disease and occasionally in lower-stage cases, which is not aligned with NCCN and ASCO guidance that recommends PET-CT primarily in symptomatic patients or those with higher-risk features [6,7,18]. Unnecessary PET-CT use may contribute to increased costs and false-positive findings.

Overuse of staging imaging was also observed among patients with ductal carcinoma in situ (DCIS). In this cohort, 41.9% of Tis cases underwent staging imaging,

despite guideline recommendations against routine systemic staging due to negligible metastatic risk [19]. As expected, no metastases were detected in this group.

The role of molecular subtype in guiding staging decisions remains uncertain. Although there was a non-significant trend toward higher suspicious imaging rates in HER2-positive and triple-negative subtypes, confirmed metastatic yield did not differ significantly across subgroups ($p \approx 0.80$). This suggests that molecular subtype alone may not justify staging imaging in the absence of other high-risk clinical factors, such as nodal positivity or higher stage [7, 8, 20].

From a clinical perspective, a selective imaging approach appeared safe in this cohort. No unexpected metastatic events were observed among patients who did not undergo baseline staging imaging during follow-up, while metastatic cases were detected and managed appropriately. However, the small number of confirmed metastatic events limited the feasibility of multivariable predictive modeling or ROC-based analysis.

Overall, these findings support a more guideline-concordant, risk-based staging strategy in early-stage breast cancer, with imaging reserved for patients with higher-risk features, particularly nodal involvement. Larger multi-center studies are warranted to further refine predictors and optimize imaging pathways in the regional setting.

Study Strengths and Limitations

This study's strengths include its real-world institutional setting, comprehensive clinical and pathological data collection, and the availability of molecular profiling for nearly 90% of patients. However, several limitations should be noted. The retrospective design may introduce selection bias, and the relatively small number of confirmed metastatic events ($n = 6$) limited the feasibility of robust multivariable regression modeling or ROC-based predictive analysis, and reduced the statistical power to detect subtle differences across molecular subtypes. In addition, follow-up duration was not uniform, which may have influenced the classification of some indeterminate or false-positive imaging findings.

In conclusion, our findings highlight that clinical stage and nodal status are the most reliable predictors of metastatic disease in early breast cancer, whereas molecular subtype plays a more limited role in initial staging decisions. Imaging strategies should focus on high-yield populations, avoiding routine imaging for Stage 0–I, node-negative, or low-risk molecular subtypes. Implementing evidence-based, risk-adapted imaging protocols can minimize false positives, reduce patient anxiety, and optimize healthcare resources, ensuring that advanced imaging is used where it provides true clinical value.

Author Contribution Statement

R.A.M. conceived the study and supervised the project. B.A.Q., A.A., I.A., H.A.A., and S.A. contributed to data collection and analysis. All authors reviewed and approved the final manuscript.

Acknowledgements

Ethics Approval

The study was approved by the Ethics Committee, College of Medicine and Health Sciences, Sultan Qaboos University (SQU), Muscat, Oman (Ref. No. SQU-EC/052/16; MREC #1260), with approval granted during the committee meeting of 31 March 2016.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Conflict of Interest

The authors declare no conflict of interest.

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