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Predictors of Residual Nodal Disease After Positive Sentinel Lymph Node Biopsy: A Retrospective Cohort Study of Axillary De-escalation in Breast Cancer

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ABSTRACT

Background: The management of the axilla following a positive sentinel lymph node biopsy (SLNB) in breast cancer remains a nuanced clinical challenge. A significant proportion of these patients will have no additional nodal disease identified on completion axillary lymph node dissection (ALND)—a phenomenon colloquially referred to in some institutions as the "white axilla" (i.e., no residual nodal disease). This phenomenon questions the universal application of ALND, a procedure associated with considerable morbidity. This study aims to quantify the incidence of no residual nodal disease after positive SLNB and to identify the clinicopathological factors predictive of additional nodal metastases to refine surgical decision-making.

Methods: A single-center, retrospective cohort study was conducted on patients with invasive breast cancer and a positive SLNB who had undergone completion ALND at Rotherham Foundation Trust, UK, between 2010 and 2023. Clinicopathological variables including tumor size, grade, receptor status, lymphovascular invasion (LVI), and extracapsular extension (ECE) were analyzed. The predictive performance of the Memorial Sloan Kettering (MSK) nomogram was also evaluated. Multivariable logistic regression was performed, with two separate models for clinicopathological variables and nomogram scores to avoid collinearity. The primary dependent outcome variable for multivariable logistic regression was the presence versus absence of residual nodal metastasis on completion axillary lymph node dissection.

Results: Among 160 eligible patients (after excluding 17 patients due to incomplete histopathology records, prior ipsilateral axillary surgery, or presentation with cN+ disease), 96 (60.0%) exhibited no further nodal involvement. This group was characterized by significantly lower Nottingham Prognostic Index (NPI) scores (mean 4.8 vs. 5.06, $P = .04$), smaller median primary tumor size (33.7 mm vs. 39.1 mm, $P = .04$), and a lower incidence of ECE (31.3% vs. 53.1%, $P = .006$). Multivariable logistic regression identified tumor size >35 mm (adjusted OR 2.11, 95% CI 1.08–4.12, $P = .03$), presence of ECE (adjusted OR 2.63, 95% CI 1.36–5.09, $P = .004$), and HER2-negative status (adjusted OR 3.87, 95% CI 1.23–12.21, $P = .02$) as independent predictors of non-sentinel node metastasis. When the MSK nomogram score was analyzed as a continuous variable, it demonstrated a good discriminatory ability (AUC 0.81, 95% CI 0.74–0.88).

Conclusion: The high proportion of patients without residual nodal disease in this cohort suggests that completion ALND may be unnecessary for many patients with a positive SLNB. The identified predictive factors may help guide a more selective, personalized approach to axillary management. These findings should be interpreted with awareness of the institutional practice pattern during this era, recognizing that evaluating Z0011 adherence was not a goal of this study. Prospective validation is warranted.

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INTRODUCTION

The surgical management of the axilla in breast cancer has undergone a profound and deliberate evolution over recent decades. The transition from routine axillary lymph node dissection (ALND) to sentinel lymph node biopsy (SLNB) for clinically node-negative patients represents a cornerstone achievement in surgical oncology, significantly reducing arm morbidity, lymphedema, and sensory deficits while providing equally accurate staging information.[1,2] However, the optimal management strategy following a positive SLNB result continues to be a subject of intense clinical investigation and debate.[3]

Central to this debate is the well-documented observation that a completion ALND after a positive SLNB fails to identify any additional nodal metastases in a substantial subset of patients. This scenario—often termed the ”white axilla” in some institutional practices (referring to the absence of residual nodal disease found at dissection)—occurs in approximately 40–60% of cases involving one or two positive sentinel nodes.[4,5] This finding challenges the historical imperative for mandatory ALND, suggesting that a significant number of patients are exposed to the risks of a more extensive procedure without any discernible oncologic benefit.

The publication of the landmark ACOSOG Z0011 trial fundamentally altered the treatment landscape. The trial demonstrated that, among women with T1/T2 tumors, one or two positive SLNs, and planned breast-conserving surgery followed by whole-breast radiotherapy, omitting ALND yielded overall and disease-free survival equivalent to that of patients who underwent completion ALND.[6] Notably, a majority of patients in the ALND arm of this trial would have had no residual nodal disease, reinforcing the concept that systemic therapy and radiotherapy effectively address the limited nodal disease burden in these individuals.[7]

In the post-Z0011 era, the clinical focus has shifted toward risk stratification. Identifying which patients with a positive SLNB harbor residual disease in non-sentinel nodes is critical for tailoring treatment.[8,9,10] Predictive tools like the Memorial Sloan Kettering (MSK) nomogram[11] and clinicopathological factors such as the size of the sentinel node metastasis, primary tumor characteristics, and the presence of lymphovascular invasion (LVI) or extracapsular extension (ECE) are used in many centers to support multidisciplinary decision-making.[12] At our institution, the MSK nomogram is routinely integrated into MDT discussions for this purpose.

Recent advances include targeted axillary dissection (TAD), which combines SLNB with excision of biopsy-proven metastatic nodes marked with clips, improving staging accuracy after neoadjuvant therapy.[13] The ongoing SOUND trial (NCT02167490) is prospectively evaluating whether SLNB alone provides equivalent outcomes to ALND in selected patients with early breast cancer and low-volume axillary disease.[14]

The observation that many patients with limited lymph node involvement have no further disease at ALND suggests that axillary treatment should be tailored to the individual patient.[15] Current evidence supports avoiding routine ALND in many patients with limited nodal involvement, particularly those receiving systemic therapy and radiation.[16] Refining patient selection remains an ongoing priority.[17]

This study aims to contribute a contemporary, real-world analysis from a UK-based institution to this evolving discourse. We sought to quantify the proportion of patients with no residual nodal disease after a positive SLNB and to evaluate the clinicopathological factors associated with additional nodal involvement, with the ultimate goal of informing selection criteria for axillary surgery. This study was reported in accordance with the STROBE reporting guidelines for observational cohort studies.

METHODS

Study design and patient selection

This single-center, retrospective cohort study was conducted at the Rotherham NHS Foundation Trust, United Kingdom. Approval was obtained from the local Trust’s Research and Audit Department (audit code: Breast Surgery/SE/2023-24/01).

Patients were included if they had a histologically confirmed invasive breast carcinoma, a clinically and radiologically node-negative (cN0) axilla at initial diagnosis, and a positive SLNB demonstrating macrometastasis, and had undergone completion ALND as part of standard management between January 2010 and December 2023.

Patients were excluded if they presented with clinically node-positive (cN+) disease at diagnosis, had distant metastatic disease at presentation, had prior ipsilateral axillary surgery, or had incomplete histopathology records.

Clinical practice during the study period

The study period (2010–2023) coincided with a period of significant change in axillary management following publication of the ACOSOG Z0011 trial in 2011.[6] It is important to clarify that the aim of this study was not to assess adherence to Z0011. During the study period, our institution did not fully comply with the Z0011 trial recommendations. Despite Z0011 eligibility (T1–2, ≤2 positive SLNs, breast-conserving surgery, planned whole-breast radiotherapy), ALND was routinely performed rather than omitted. Year of surgery was included as a covariate in sensitivity analyses to account for temporal trends.

Data collection and variables

Clinical and pathological data were extracted from the hospital’s electronic medical records and histopathology reports. Variables collected included patient demographics, primary tumor characteristics (tumor size, histological type and grade, estrogen receptor [ER], progesterone receptor [PR], human epidermal growth factor receptor-2 [HER2] status, and Ki-67 index), and sentinel node characteristics (number of nodes removed and number of nodes positive, size of largest metastasis, and presence of extranodal

extension [ECE] or lymphovascular invasion [LVI]).

The Nottingham Prognostic Index (NPI) was calculated for each patient using the validated formula combining tumor size, histological grade, and lymph node status.[18] The probability of additional non-sentinel node involvement was estimated using the Memorial Sloan Kettering Cancer Center (MSKCC) Breast Cancer Nomogram.[19] At our institution, this nomogram is routinely used in multidisciplinary team meetings to support axillary management decisions.

Missing data

Missing data were present for the following variables: HER2 status (n = 3, 1.9%), ECE (n = 2, 1.3%), and LVI (n = 1, 0.6%). Given the low proportion of missingness (<5%), complete-case analysis was performed.

Statistical analysis

All analyses were performed using IBM SPSS Statistics version 28.0 (IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test assessed normality. Continuous variables were summarized as mean ± standard deviation (SD) for normally distributed data or median (interquartile range) for non-normal data. Categorical variables were reported as frequencies and percentages.

Comparisons between the no-residual-disease group (no further nodal disease) and the node-positive group were conducted using the *t* test for normally distributed continuous variables, the Mann-Whitney *U* test for non-normal data, and the χ^2 test or Fisher exact test for categorical data.

The primary dependent outcome variable for multivariable logistic regression was the presence versus absence of residual nodal metastasis on completion axillary lymph node dissection (coded as 1 for presence and 0 for absence).

Multivariable modeling strategy

To avoid collinearity, two separate multivariable logistic regression models were constructed:

- **Model 1 (clinicopathological model):** Candidate variables for inclusion were selected based on their established clinical relevance from the literature (tumor size, ECE, HER2 status, and LVI) and their univariate association with the outcome. Year of surgery was forced into the model as a continuous covariate to account for temporal trends in clinical practice. Although LVI did not demonstrate a statistically significant association with residual nodal metastasis in the univariate analysis ($P = .33$), it was retained in the multivariable model to assess an independent association with the outcome given its clinical relevance. The final model included tumor size (dichotomized at 35 mm, the sample median; a sensitivity analysis using continuous tumor size was performed), ECE (present vs absent), HER2 status (positive vs negative), and LVI (present vs absent). The 35 mm cutoff was chosen post hoc based on the sample median; this limitation is acknowledged.
- **Model 2 (Nomogram model):** Included the MSK nomogram probability as a continuous variable, with year of surgery forced into the model as a covariate to account for temporal trends. For illustrative comparison with the existing literature, a secondary analysis was also performed using a dichotomized cutoff of >0.5 versus ≤0.5.

Multicollinearity was assessed using variance inflation factor (VIF), with VIF < 5 considered acceptable.

The discriminatory performance of each model was evaluated using the area under the receiver operating characteristic curve (AUC). Model calibration was assessed using the Hosmer-Lemeshow goodness-of-fit test.

Given 64 outcome events, the number of predictors in each model was limited to ≤5 to maintain an events-per-variable ratio >10. A two-sided $P < .05$ was considered statistically significant. Correction for multiple comparisons across the primary analyses was performed using the Benjamini-Hochberg false discovery rate method with a *Q* threshold of .10; both corrected and uncorrected *P* values are reported.

Neoadjuvant chemotherapy subgroup analysis

A separate exploratory analysis was conducted for patients who received neoadjuvant chemotherapy. Given the small sample size (n = 15), these results are presented as hypothesis-generating only and no inferential conclusions are drawn.

RESULTS

Participant flow and cohort characteristics

Of 177 patients initially identified, 17 were excluded. Reasons for exclusion were: incomplete histopathology records (n = 9), prior ipsilateral axillary surgery (n = 5), and presentation with cN+ disease (n = 3). The final evaluable cohort comprised 160 patients.

Incidence of no residual nodal disease

Of the 160 evaluable patients who underwent completion ALND following a positive SLNB, 96 (60.0%) demonstrated no evidence of additional nodal metastasis.

Univariate analysis

Patients with no residual nodal disease exhibited a significantly lower mean NPI score (4.8 ± 0.9) compared with the node-positive group (5.06 ± 1.1; mean difference 0.26, 95% CI 0.01–0.51; $t = 2.05$, $P = .04$). The median primary tumor size was 33.7 mm (IQR 24.5–45.0) in the no-residual-disease group versus 39.1 mm (IQR 30.0–52.0) in node-positive cases ($U = 2635$, $P = .04$). HER2-positive tumors were more common in the no-residual-disease group (16.7%) compared to node-positive patients (6.3%; $P = .049$, Fisher exact). The presence of ECE was significantly lower in the no-residual-disease group (31.3% vs. 53.1%; $\chi^2 = 7.67$, $P = .006$). Complete univariate comparisons are presented in Table 1.

Multivariable analysis

Collinearity assessment showed acceptable VIF values (<3.0) for all variables in both models, with no

Table 1. Clinicopathologic comparison by nodal status

Variable	No residual disease (n = 96)	Node-positive (n = 64)	*P* value	*P* value (FDR-corrected)	Test used
NPI score (mean ± SD)	4.8 ± 0.9	5.06 ± 1.1	.04*	.07	$t = 2.05$
Tumor size (mm), median (IQR)	33.7 (24.5–45.0)	39.1 (30.0–52.0)	.04*	.07	$U = 2635$
ER+, n (%)	85 (88.5%)	59 (92.2%)	.44	.44	$\chi^2 = 0.59$
HER2+, n (%)	16 (16.7%)	4 (6.3%)	.049*	.07	Fisher exact
LVI present, n (%)	51 (53.1%)	29 (45.3%)	.33	.40	$\chi^2 = 0.95$
ECE present, n (%)	30 (31.3%)	34 (53.1%)	.006**	.03	$\chi^2 = 7.67$

ECE = extracapsular extension; FDR = false discovery rate; IQR = interquartile range; LVI = lymphovascular invasion; NPI = Nottingham Prognostic Index; SD = standard deviation.
*$P < .05$; **$P < .01$. FDR-corrected significance threshold $Q = .10$.

Table 2. Multivariable predictors of residual nodal metastasis (model 1)

Predictor	Adjusted OR	95% CI	*P* value	*P* value (FDR-corrected)	Wald χ^2
Tumor size >35 mm	2.11	1.08–4.12	.03*	.04	4.83
ECE present	2.63	1.36–5.09	.004**	.01	8.33
HER2-negative	3.87	1.23–12.21	.02*	.04	5.30
LVI present	1.45	0.78–2.71	.24	.24	1.38

*Model AUC = 0.79 (95% CI 0.71–0.86). Hosmer-Lemeshow $\chi^2 = 6.23$, $P = .62$. ECE = extracapsular extension; LVI = lymphovascular invasion.
*$P < .05$; **$P < .01$.

evidence of problematic multicollinearity. Year of surgery was not a significant predictor in either model ($P = .34$), and its coefficient is not displayed in Table 2, which presents the clinicopathological predictors of primary interest.

In Model 1 (clinicopathologic predictors), tumor size >35 mm (adjusted OR = 2.11, 95% CI 1.08–4.12, $P = .03$), presence of ECE (adjusted OR = 2.63, 95% CI 1.36–5.09, $P = .004$), and HER2-negative status (adjusted OR = 3.87, 95% CI 1.23–12.21, $P = .02$) were independently associated with increased risk of further nodal disease (Table 2). When tumor size was analyzed as a continuous variable, the adjusted OR was 1.03 per mm (95% CI 1.01–1.05, $P = .01$).

In Model 2 (nomogram model), the MSK nomogram probability, analyzed as a continuous variable, was significantly associated with residual nodal disease (adjusted OR = 1.05 per 1% increase, 95% CI 1.03–1.07, $P < .001$). In a secondary analysis using a binary cutoff, an MSK score >0.5 was also associated with a higher risk (adjusted OR = 3.02, 95% CI 1.65–5.52, $P < .001$).

Model performance: The clinicopathological model demonstrated good discriminatory ability (AUC = 0.79, 95% CI 0.71–0.86). The MSK nomogram model showed similar performance (AUC = 0.81, 95% CI 0.74–0.88). The Hosmer-Lemeshow test indicated adequate calibration for both models (Model 1: $\chi^2 = 6.23$, $P = .62$; Model 2: $\chi^2 = 4.87$, $P = .77$).

Exploratory neoadjuvant chemotherapy subgroup analysis

A subgroup of 15 patients received neoadjuvant chemotherapy after initial SLNB and subsequently underwent ALND. No statistically significant differences were detected between those with and without further nodal involvement, and no inferential conclusions are drawn due to the small sample size (Table 3). These findings are exploratory only.

DISCUSSION

Our finding that 60% of patients undergoing completion ALND had no residual nodal disease aligns with the historical range of 40–60% reported in the literature.[4,5] This observation underscores the premise that a majority of these patients may not derive oncologic benefit from ALND, consistent with current de-escalation strategies.

Comparison with ACOSOG Z0011 and selection bias

An important consideration is how our cohort compares with patients who would have satisfied the ACOSOG Z0011 eligibility criteria. Although our institution did not fully adhere to the Z0011 recommendations during the study period, assessing adherence to Z0011 was not an objective of this study. Despite meeting Z0011 eligibility criteria (T1–T2 tumors, ≤2 positive SLNs, breast-conserving surgery, and planned whole-breast radiotherapy), patients routinely underwent ALND rather than omission. As a result, the present cohort—comprising patients who all underwent ALND—includes many who would have been considered low-risk by Z0011 criteria, not just a higher-risk subgroup. This lack of compliance means our observed 60% incidence of no residual disease after SLNB may reflect a broader, lower-risk population than would be

Table 3. Exploratory neoadjuvant chemotherapy subgroup analysis

Characteristic	No residual disease (n = 9)	Residual disease (n = 6)	*P* value	Test used
Post-NACT size (mm), mean ± SD	23.3 ± 18.1	25.3 ± 9.8	.72	$t = 0.37$
Grade 2, n (%)	9 (100%)	5 (83.3%)	.44	Fisher exact

These results are exploratory and hypothesis-generating only. NACT = neoadjuvant chemotherapy.

expected in a fully Z0011-adherent setting. Therefore, rather than underestimating the true population-wide phenomenon, our reported incidence may be more representative of the low-risk Z0011-eligible population. These findings should be interpreted with awareness of the institutional practice pattern during this era, recognizing that evaluating Z0011 adherence was not a goal of this study.

Predictors of residual nodal disease

Our analysis identified a profile associated with a lower likelihood of residual metastases. Patients with no additional nodal disease typically presented with smaller primary tumors (≤35 mm), lower NPI scores, and absence of extracapsular extension in the sentinel node. These findings are biologically intuitive and consistent with the understanding that a smaller tumor burden and confined nodal disease are less likely to have metastasized further. The strong predictive value of ECE is particularly notable; its presence suggests a more aggressive tumor biology with a greater propensity for spread beyond the lymph node, making it a critical factor in surgical planning.[10] These observations are consistent with prior work identifying clinicopathologic predictors of non-sentinel node metastasis, including the seminal analysis by Degnim *et al.*[20].

Performance of the MSK nomogram

The MSK nomogram demonstrated good discriminatory ability (AUC = 0.81) in our cohort, consistent with its performance in external validations.[11] This supports its utility as a quantitative tool to aid multidisciplinary teams in risk-stratifying patients. Our analysis further demonstrates that using the nomogram as a continuous probability provides a precise, incremental measure of risk, which may be more valuable for clinical decision-making than a simple binary cutoff. At our institution, the nomogram is routinely used in MDT discussions, and our findings confirm its value in this local context. However, we acknowledge that the nomogram is not universally adopted, and its predictive performance may vary across different populations.

The HER2-negative finding

The association between HER2-negative status and increased risk of residual nodal disease (adjusted OR 3.87) warrants cautious interpretation. This finding may reflect changes in neoadjuvant treatment strategies over the long study period. HER2-positive patients in our cohort were more likely to receive neoadjuvant chemotherapy (particularly after 2015), which may have downstaged nodal disease prior to ALND. Additionally, the small number of HER2-positive events (n = 20 total) limits precision. We therefore consider this finding hypothesis-generating rather than definitive.

Limitations

This study has several limitations. First, its retrospective, single-center design may limit generalizability. Second, as detailed above, the institutional practice of routinely performing ALND despite Z0011 eligibility means our cohort includes many low-risk patients. This should be considered when interpreting the absolute incidence of no residual disease. Third, the arbitrary dichotomization of tumor size at 35 mm based on the sample median may not represent an optimal or externally validated cutoff. Fourth, the small neoadjuvant subgroup (n = 15) precludes any definitive conclusions for that population. Fifth, although the number of positive sentinel nodes and the size of sentinel node metastases were collected to calculate the NPI and MSK nomogram scores, they were not included as standalone covariates in Model 1. Finally, potential unmeasured confounding cannot be excluded.

Generalizability and clinical implications

Despite these limitations, our findings may be generalizable to similar patient populations within comparable healthcare systems where ALND continues to be performed in Z0011-eligible patients. The identified predictive factors—tumor size, ECE, and MSK score—are objective, reproducible measures that can be integrated into clinical decision-making. They provide an evidence-based framework for considering ALND omission in patients with low-risk features, particularly those who meet Z0011 criteria and will receive adjuvant radiotherapy and systemic therapy.

CONCLUSION

Our data support the modern paradigm of de-escalating axillary surgery. The clinicopathological factors we identified—particularly small tumor size and absence of ECE—may help guide personalized risk assessment. By leveraging these tools, clinicians may be able to avoid the morbidity of ALND in a carefully selected low-risk group, reserving ALND for those patients most likely to benefit. These findings should be interpreted with awareness of the institutional practice pattern during this era, recognizing that evaluating Z0011 adherence was not a goal of this study. Prospective validation in contemporary cohorts is warranted.

ETHICAL CONSIDERATIONS

Informed consent for treatment and open-access publication was obtained from all participants or waived in accordance with institutional policy. Local clinical audit and research approval was obtained from the Rotherham NHS Foundation Trust Research and Audit Department (code: Breast Surgery/SE/2023-24/01). All authors have confirmed that this study did not involve animal subjects or tissue and have completed the ICMJE uniform disclosure form.

DATA AVAILABILITY

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

CONFLICT OF INTERESTS

All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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AI DISCLOSURE

AI was not used in the writing of this manuscript or in the creation of tables/figures.

AUTHOR CONTRIBUTIONS

RO: Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing, Supervision. DL: Data curation, Formal analysis, Writing – original draft, Writing – review & editing, Supervision. SMJ: Data curation, Formal analysis, Writing – original draft, Writing – review & editing, Supervision. AM: Conceptualization, Writing – original draft, Supervision. BIH: Conceptualization, Writing – original draft, Supervision. LC: Data curation, Formal analysis, Writing – original draft, Writing – review & editing, Supervision. TM: Data curation, Formal analysis, Writing – review & editing, Supervision.

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