Immunohistochemical Detection of Occult Lymph Node Metastases in Non-Small Cell Lung Cancer: Anatomical Pathology Results from Cancer and Leukemia Group B Trial 9761

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ABSTRACT

Purpose: Our purpose was to study the detection of occult metastases (OM) in regional lymph nodes using immunohistochemical stain for cytokeratin, and for this study we targeted clinical stage I patients with non-small cell lung cancer.

Experimental Design: The study comprised the first 193 patients entered onto Cancer and Leukemia Group B protocol 9761. All had clinically staged T1–2 N0 M0 non-small cell lung cancer, and all underwent curative resections of their primary tumors. Samples of the primary tumor and lymph nodes were taken from lymph node stations 2–12 and shipped to a central laboratory, where each lymph node was histologically processed and stained with H&E as well as with immunohistochemical stain using antibodies to cytokeratin (AE1/3).

Results: Altogether, we examined 825 lymph nodes. Whereas routine H&E staining allowed us to detect 18 positive lymph nodes, immunohistochemical staining allowed us to detect 45 positive lymph nodes (P < 0.0001). There were 28 OM [i.e., those detectable only by immunohistochemistry (IHC)], and there was 1 metastasis detected only by H&E staining. The OM included 9 OM in N1 stations and 19 OM in N2 stations. Twelve patients with OM had skip metastases. Routine H&E staining upstaged six patients to N1, and IHC added another five. Routine H&E upstaged 9 patients to N2, and IHC added another 11. We also uncovered new details about the way in which H&E detection depends on metastatic tumor burden. Specifically, for the probability of detecting metastases by H&E to exceed 0.50, the maximum diameter of the metastasis must be greater than 0.23 mm.

Conclusions: IHC detects greater than twice as many positive regional lymph nodes as does H&E staining, and the foci of tumor it detects are significantly smaller than those detected by H&E staining.

INTRODUCTION

The most important prognostic variables in NSCLC8 are the clinical and pathological stages. However, neither clinical nor pathological stage provides complete information about outcomes. For example, after complete resection, approximately 60–80% with pathological stage T1,N0,M0 (IA) and 50% of those with pathological stage T2,N0,M0 (IB) survive for at least 5 years; whereas the remaining patients suffer earlier recurrence of their cancer and die (1). Thus, routine examination using H&E stains does not tell us who among these patients will have recurrent tumor. From prior studies, we know that some patients with either pathological stages IA or IB have occult lymph node metastases, which for this paper we define as those detectable

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8 The abbreviations used are: NSCLC, non-small cell lung cancer; OM, occult metastases; CALGB, Cancer and Leukemia Group B; IHC, immunohistochemistry; CT, computed tomography; GEE, generalized estimating equation.
just by either immunohistochemical stains (2–14) or by molecular techniques (7, 9, 15), and in general those with OM had shorter disease-free intervals (3, 6, 8, 10, 12–14). Thus, OM may account for at least a proportion of T1–2N0M0 tumors that recur after curative surgical excision of the primary tumors.

To validate previous observations about the importance of OM in NSCLC and to gather further clinical and pathological information, the CALGB embarked on a prospective multi-institutional trial (CALGB 9761) of molecular and histocellular staging of patients with clinically early-stage NSCLC. Accrual is now complete at 502 patients, and full analysis of outcomes awaits further follow-up as well as analysis of additional tissues. Herein we report details about the pathological findings in 825 lymph nodes from the first 193 consecutive patients with tumor who were entered on the study, because preliminary analyses demonstrated that these comprised a sufficient number of tissues and patients to learn about the pathology of OM.

MATERIALS AND METHODS

Our study population consisted of the first 193 patients of CALGB 9761 with primary tumors documented to stain for cytokeratin by IHC. All had clinical stage I disease (T1–2N0M0), and all underwent complete surgical resection of their tumors. To be eligible for CALGB 9761, patients were required to have either mediastinal nodes that measured <1 cm per thoracic CT exam or nodes sampled by mediastinoscopy and proven histologically to be negative. Positron emission tomography scanning was not required and was used preoperatively in only a small percentage of these patients. All patients gave their written, informed consent, and each participating institution’s review board also approved the study.

Before the study began, participating surgeons met in committee several times and agreed on a uniform surgical approach, which was then monitored by the senior author (M. A. M.). Briefly, immediately after thoracotomy incision, the operating surgeons harvested all accessible mediastinal lymph nodes (see D’Cunha et al., Ref. 15), and then the appropriate pulmonary resection was done, and intrapulmonary nodes were harvested. Portions of each patient’s primary tumor as well as lymph nodes from several stations were shipped to the Thoracic Oncology Laboratory at the University of Minnesota. We did not have access to or use routine pathology materials processed by local pathology laboratories. Nor did we use the information from their reports, because our goal in this pathology study was to compare H&E results with IHC results—both done on the same tissue samples and in a controlled manner. For this study, patients were considered eligible so long as we received a sample of the primary tumor and a sample of at least one thoracic node and so long as both types of tissue were of sufficient size to allow staining for H&E and cytokeratin. At the central laboratory, the tissues were further processed for routine histological examination as well as for immunohistochemical staining. In preliminary and unpublished work9 on CALGB 9761 on approximately 60 cases, we observed that AE1/3 stained >95% of the primary tumors, whereas, cytokeratin antibody Cam5.2 stained just 74% of the primary tumors, and glycoprotein antibody BerEp 4 stained just 63% of the primary tumors. Therefore we relied on AE1/3.

First, we examined the primary tumor to confirm the diagnosis of NSCLC and that it was positive for AE1/AE3, and we found that all were positive. Then, each lymph node sample was handled in a uniform fashion so that H&E stains were matched to IHC slides. Specifically, three sections were cut, in order, from each block of tissue: the first for routine H&E staining; the second for cytokeratin by IHC; and the third as a control for the IHC. For IHC, we used the Dako prediluted AE1/AE3 product N1590 (Dako Corp., Carpinteria, CA), a 20-min pretreatment with protease 760-2018 (Ventana Medical Systems, Inc., Tucson, AZ), and 3,3′-diaminobenzidine detection kit 760-001 (Ventana Medical Systems, Inc.).

One pathologist (R. T. V.) evaluated all of the slides and decided the final status of the nodes. In addition, to study concordance in the interpretation of IHC, a second pathologist (N. Z. A.) evaluated a subset of 717 nodes, a number found sufficient for study of concordance. For each lymph node, we used the following sequence. First, the H&E slide was examined to determine the presence or absence of metastases. Next, the third or control slide was examined to make certain that no OM occurred at a deeper level. Finally, the IHC slide stained for AE1/3 was examined. Lymph nodes were considered positive for OM if both the first and third slides were found to be negative, and the IHC slide was found to be positive. If reexamination of the first or third slides demonstrated tumor, after it was first discovered by IHC, then the node was still counted as OM. Cells staining positive for AE1/3 were not counted as OM if they appeared to be contaminants on the surface or within artificial clefts in the tissues. Nor were they counted if they appeared to be mesothelial cells, that is, a thin cell layer outside the nodal architecture. Finally, we measured the maximum diameter of the largest metastatic focus in each IHC-positive node using a calibrated eyepiece micrometer.

Statistical Methods. We used GEEs based on the binomial distribution and the logit link function to account for correlation among lymph node results within individual patients. Specifically, GEE models were used to examine the relationship between H&E and IHC staining results, as well as the distribution of metastases between N1 and N2 lymph node stations found by H&E and OM. The GEE model was also used to estimate the relationship between the maximum diameter of the largest focus of metastatic tumor and H&E results. A χ2 test was used to compare the results from our study and prior studies relative to the prevalence of positive nodes assessed by IHC. k statistics, which adjusted for within-patient nodal correlation, were used to assess the interobserver agreement between the two pathologists.

RESULTS

The median number of satisfactory nodes received from each patient was 4 (range, 1–8; in cases with fewer than 4 nodes, additional samples contained too little nodal tissue for complete study). Fig. 1 illustrates two nodes with OM (Fig. 1, B

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9 R. T. Vollmer, unpublished observations.
and D) and accompanying H&E stains (Fig. 1, A and C) for comparison. Because our primary observational units comprised lymph nodes, the main results are summarized in the top of Table 1. Routine H&E stain allowed us to detect 18 of 825 nodes as positive, and IHC allowed us to detect an additional 28 nodes as positive—a difference that was significant ($P < 0.0001$ by GEE). One node was detected just by H&E staining because the focus of tumor was too small to appear on the slide stained for IHC. Thus, the total number of positive nodes was 46 (i.e., 18 + 28). Of those 18 nodes detected by H&E, 8 were stage N1 (stations 10, 11, and 12), and the remaining 10 were stage N2 (stations 2–9). Of the 28 nodes with OM detected just by IHC, 9 were stage N1, and the remaining 19 were stage N2. The distribution of metastases in N1 versus N2 did not differ between those found by H&E staining versus those found by IHC ($P = 0.547$ by GEE). Whereas the prevalence of H&E-positive nodes was 2.2% of the total nodes, the prevalence of OM was 3.4%. Thus, our results suggest that IHC detected over twice as many foci of tumor as did routine H&E staining. The combined results of both stains on these study tissues indicated that among thoracic nodes either measuring $<$1 cm per CT or found to be negative by mediastinoscopy, approximately 6% (i.e., 46 of 825) contained tumor. Finally, if we subtract the lymph nodes with metastases detectable by H&E from the total, the rate of OM found in the remainder was 3.47% (i.e., 28 of 807).

To put these results into a patient perspective, the lower portion of Table 1 reexamines the results from the point of view of the patient rather than by tissue. By H&E stain, the 18 node metastases occurred in 15 patients. Among those 15 patients, 6 (3.1% of the total) had their N status increased from N0 to N1, and 9 (4.7% of the total) had their N status increased to N2. Eight of the 9 patients with N2 metastases had “skip” metastases, that is, their N1 nodes were negative by H&E. By immunohistochemical stain, 21 patients had OM. Among the 21 patients with OM, 7 (3.9% of the total patients) had their N stage increased from N0 to N1, and 14 (7.3% of the total) had their N stage increased to N2. Twelve of the patients with N2 nodes found positive by IHC had skip metastases, because their N1 nodes were not involved by either H&E or IHC. In some patients with OM, other nodes were positive by H&E, so that the IHC in such cases provided redundant information. Thus, the net number of patients increased to stage N1 by either H&E or IHC was 11, and the net number increased by either stain to stage N2 was 21. The total number of patients with nodal metastases found in these study tissues was 32, implying that approximately 17% of the patients had been clinically understaged (i.e., 32 of 193). The presence of lymph node metastasis, either by H&E or by IHC, was not associated with the number of nodes harvested ($P > 0.7$ by logistic regression).

Not surprisingly, we found that the threshold of metastatic tumor burden detected by IHC differed from that detected by H&E. Specifically, we found a significant relationship between detection of metastasis by H&E and the maximum diameter of

| No. Positive Patients (%) | 15 (7.8) | 21 (11) |
| Final N1 stage (%) | 6 (3.1) | 7 (3.9) |
| Final N2 stage (%) | 9 (4.7) | 14 (7.3) |
| Patients with skip metastases | 8 | 12 |

$^a$ Entries for the OM column include only nodes found to be negative by H&E.

Table 1 Comparison of metastases detected by H&E stain with OM detected by IHC for AE1/3
the largest focus of metastatic tumor present in the IHC slides ($P = 0.0002$ by GEE analysis). Furthermore, the fitted model suggested a continuous relationship between the natural logarithm of the maximum diameter of the metastatic tumor focus in millimeters and the probability of detection of tumor by H&E.

Fig. 2  Plot of the probability of detecting metastasis in a lymph node by H&E versus the natural logarithm of maximum tumor focus diameter (in millimeters). The smooth curve is derived from the logistic regression model fit to our data (Eqs. 1 and 2). The points at the top of the plot represent nodes with metastases detected by H&E and IHC, and the points at the bottom of the plot represent nodes with metastases detected by IHC but not by H&E.

The model also suggested that the probability of detection of metastatic tumor by H&E is given as:

\[
\text{Probability} = \frac{1}{1 + E}
\]

(Eq. 1)

with $E$ given as:

\[
E = \exp(-5.49 - 3.78\log(\text{diameter}))
\]

(Eq. 2)

Here, diameter refers to the metastatic focus and is given in millimeters. In Fig. 2, the smooth line is a plot of Eqs. 1 and 2, and the points at the top and bottom are observed results for H&E detection (1 for detected and 0 for undetected). The logistic model suggests that when tumor foci are $>0.23$ mm, there is a $>50\%$ chance that they will be detected by H&E stain. The model also suggested that $<4\%$ of tumor foci measuring 0.1 mm will be detectable by H&E, and in fact the smallest tumor focus we found by H&E was 0.15 mm.

Finally, in an analysis of a subset of 717 lymph nodes, we found that there was a 3.8% rate of discordance (i.e., 27 nodes) between two pathologists for the detection of metastases by IHC, with modest agreement as measured by $k$ statistic ($k = 0.19$; $P = 0.06$). All of the discordant cases were reviewed and found to be due to several circumstances. In a few cases, one observer detected a single positive staining cell; whereas the other did not. In the remaining cases, one observer counted the node positive when the other judged the staining to be surface contaminants, staining of mesothelial cells, or background staining of nonneoplastic cells or stroma. There was no discordance in the interpretation of the H&E slides.

DISCUSSION

Our study is unique in several respects. It comprises the largest number of patients with NSCLC analyzed for OM in regional lymph nodes, and it comes from multiple institutions. Its results validate the observations of some prior studies, but not others. Finally, it provides new details on the subject of OM in NSCLC.

Table 2 compares our rate of nodes with OM with the rates of positive nodes reported by nine other studies, and it includes data only for patients with negative nodes as determined by routine H&E staining. Our observed rate of 3.47% nodes with OM was close to three previously published rates of 3.84% (3), 5.02% (10), and 3.41% (12). However, some authors have reported rates of positive nodes less than 1% (5, 8), and others have reported rates greater than 10% (2, 9). In fact, a test for equality of proportions among these 10 studies showed that their differences in the rate of OM were significant, that is, the differences were unlikely to be due to random effects alone ($P < 0.0001$). Such differences are important and may translate into different rates of clinical outcomes for patients with OM. The different reported rates are likely due to several factors. For example, Chen et al. (2) collected data retrospectively from surgical pathology records; whereas other studies like ours were done prospectively on patients identified by surgeons. Chen et al. (2) used data collected in the 1980s; whereas most of the other studies including ours used data largely collected in the 1990s, when more modern practices for staging and sampling of N2 nodes were in place (16). Of all of the 1990s studies, ours is the only one specifying the requirement that the N2 nodes be either $<1$ cm per CT or negative by mediastinoscopy. Another potential explanation for the differences in the rates of OM may be due to the different IHC antibody-antigen systems used. Five studies of Table 2 including ours used the AE1/3 mixture for cytokeratin (8, 10, 12, 13); whereas others used different antibodies such as BerEp 4 (3), A575 (2), Cam5.2 (9, 14), or MNF116 (5). Because in preliminary and unpublished work on CALGB 9761 we found that AE1/3 stained more of the primary tumors, we believe that the best results for detecting OM in NSCLC are obtained with AE1/3.

Different reported rates of OM are also likely due to variation in the practice among surgical pathologists. Clearly, interpretation of IHC staining is subjective, and we have docu-

<table>
<thead>
<tr>
<th>Author (ref. no.)</th>
<th>No. of patients</th>
<th>Total lymph nodes</th>
<th>% Nodes with OM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chen et al. (2)</td>
<td>60</td>
<td>588</td>
<td>17.3</td>
</tr>
<tr>
<td>Passlick et al. (3)</td>
<td>72</td>
<td>391</td>
<td>3.84</td>
</tr>
<tr>
<td>Nicholson et al. (5)</td>
<td>49</td>
<td>1447</td>
<td>0.276</td>
</tr>
<tr>
<td>Goldstein et al. (8)</td>
<td>80</td>
<td>573</td>
<td>0.523</td>
</tr>
<tr>
<td>Hashimoto et al. (9)</td>
<td>22</td>
<td>170</td>
<td>27.6</td>
</tr>
<tr>
<td>Ohta et al. (10)</td>
<td>122</td>
<td>2030</td>
<td>5.02</td>
</tr>
<tr>
<td>Wu et al. (12)</td>
<td>103</td>
<td>1438</td>
<td>3.41</td>
</tr>
<tr>
<td>Gu et al. (13)</td>
<td>49</td>
<td>474</td>
<td>7.38</td>
</tr>
<tr>
<td>Maruyama et al. (14)</td>
<td>49</td>
<td>973</td>
<td>9.35</td>
</tr>
<tr>
<td>This study</td>
<td>178</td>
<td>807</td>
<td>3.47</td>
</tr>
</tbody>
</table>

*In this table, only those patients (and nodes) with lymph nodes found to be negative by H&E stain are included.*
Occult Lymph Node Metastases in NSCLC

relied on the 4treated these nodes the same as routine clinical specimens and
/ H11003

OM, and the reported observed percentage surviving 4 years in those with
OM surviving 4 years, and the Kaplan-Meier curves for those with OM
provides the percentage of those without OM surviving 4 years. The points come
from six previously published series (6, 9, 10, 12–14). The line shows
where the points should fall if the survivals for the two groups of
patients were the same.

The differences in reported rates of OM detailed in Table 2
discussed above undoubtedly cause differences in reported
outcomes. For example, Fig. 3 compares the overall survival
reported at 4 years after surgery for six studies, which were the
ones with most updated data in Table 2 and which provided
Kaplan-Meier curves for those with OM versus those without
OM (6, 9, 10, 12–14). In Fig. 3, the vertical axis gives the reported
observed percentage surviving 4 years in those with
OM, and the horizontal axis gives the percentage surviving 4
years in those without OM. The line shows where the points
would be if the survival curves were the same. Whereas all six
studies found that the presence of OM shortened survival time
(that is, the points fell below the line), the scatter of the points
demonstrates that the observed survival times for those with or
without OM varied greatly. The drop in percentage surviving to
4 years for patients with OM ranged from 13% to 48% (median,
18%). This degree of variation must be due to differences in the
patients studied or to the methods used for detecting OM. Such
differences make it difficult to develop treatments for OM, and
our hope is that our large prospective, multi-institutional study
will narrow this range in expected outcomes for patients with
OM. Survival analysis in our study, however, must wait until the
follow-up of our patients is longer.

Our results have made quantitative the conjecture that the
threshold of tumor burden detected by routine H&E differs from
that detected by IHC. The logistic regression model predicts that
routine H&E has a >50% chance of detecting metastases meas-
uring over 0.23 mm in maximum diameter, >85% chance of
detecting those over 0.4 mm, and nearly 100% chance of de-
tecting those over 1 mm. On the other hand, H&E stain allows
us to detect <4% of tumor foci measuring 0.1 mm and virtually
none of single cells positive for IHC. Thus there is a different
threshold of tumor burden for detection of metastasis by H&E
versus by IHC, and our results provide significant detail about
this difference. The tumor burden threshold for detecting tumor
by IHC in comparison with molecular techniques such as quan-
titative PCR for mRNA of carcinoembryonic antigen (15) is not
known, but subsequent follow-up studies of CALGB 9761 may
help establish this.

Before either IHC or quantitative PCR can be adopted to
detect OM, we must first demonstrate that the diagnosis of OM
can be matched by effective treatment and is cost effective.
What must be demonstrated is that there is a treatment that can
improve survival in those approximately 18% of patients with
OM who suffer a shortened survival while not adversely affect-
ing the quality of life of the others with OM who do not have
shortened survival. It is possible that the measured size of the
H&E-detected metastasis will help decide who can benefit from
adjuvant treatment, but such questions require further study as
well as randomized clinical trials. Finally, detecting OM with
IHC is expensive. If we assume a technical cost of $30.00
(United States) and a professional cost of $75.00 per IHC stain,
then our study suggests that the cost of detecting each OM by
IHC is over $3000.00. The pathology costs for detecting OM
with IHC could be reduced if the IHC were restricted to just
sentinel nodes, which have recently been described in NSCLC
(17); however, our results suggest that skip metastases are
common, so that one would need to prove that sentinel technol-
ogy detects skip metastases. Altogether, these cost consider-
ations suggest that prospective trials designed to optimize the
best treatment for patients with OM will require many patients
and be expensive to conduct.

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