Oncology

Surgeon-, pathologist-, and hospital-level variation in suboptimal lymph node examination after colectomy: Compartmentalizing quality improvement strategies

Adan Z. Becerra, BA,[a,b] **Christopher T. Aquina, MD,**[b] **Mariana Berho, MD,**[c] **Francis P. Boscoe, PhD,**[d] **Maria J. Schymura, PhD,**[d] **Katia Noyes, PhD, MPH,**[e] **John R. Monson, MD,**[f] *and* **Fergal J. Fleming, MD,**[b] *Rochester, Albany and Buffalo, NY, and Weston and Orlando, FL*

Background. *The goals of this study were to characterize the variation in suboptimal lymph node examination for patients with colon cancer across individual surgeons, pathologists, and hospitals and to examine if this variation affects 5-year, disease-specific survival.*
Methods. *A retrospective cohort study was conducted by merging the New York State Cancer Registry with the Statewide Planning & Research Cooperative System, Medicaid, and Medicare claims to identify resections for stages I–III colon cancer from 2004–2011. Multilevel logistic regression models characterized variation in suboptimal lymph node examination (<12 lymph nodes). Multilevel competing-risks Cox models were used for survival analyses.*
Results. *The overall rate of suboptimal lymph node examination was 32% in 12,332 patients treated by 1,503 surgeons and 814 pathologists at 187 hospitals. Patient-level predictors of suboptimal lymph node examination were older age, male sex, nonscheduled admission, lesser stage, and left colectomy procedure. Hospital-level predictors of suboptimal lymph node examination were a nonacademic status, a rural setting, and a low annual number of resections for colon cancer. The percent of the total clustering variance attributed to surgeons, pathologists, and hospitals was 8%, 23%, and 70%, respectively. Increasing the pathologist and hospital-specific rates of suboptimal lymph node examination were associated with worse 5-year, disease-specific survival.*
Conclusion. *There was a large variation in suboptimal lymph node examination between surgeons, pathologists, and hospitals. Collaborative efforts that promote optimal examination of lymph nodes may improve prognosis for colon cancer patients. Given that 93% of the variation was attributable to pathologists and hospitals, endeavors in quality improvement should focus on these 2 settings. (Surgery 2017;161:1299-306.)*

From the Department of Public Health Sciences, Division of Epidemiology,[a] *and the Surgical Health Outcomes & Research Enterprise, Department of Surgery,*[b] *University of Rochester Medical Center, Rochester, NY; the Department of Laboratory Medicine, Cleveland Clinic Florida,*[c] *Weston, FL; the New York State Cancer Registry, Bureau of Cancer Epidemiology, New York State Department of Health,*[d] *Albany, NY; the Department of Epidemiology and Environmental Health, Division of Health Services Policy and Practice, School of Public Health and Health Professions,*[e] *University at Buffalo, Buffalo, NY; and the Center for Colon and Rectal Surgery, Florida Hospital Medical Group, Florida Hospital,*[f] *Orlando, FL*

The authors have no research support or other financial disclosures to report.

Accepted for publication November 22, 2016.

Reprint requests: Adan Z. Becerra, BA, University of Rochester Medical Center, 601 Elmwood Avenue, Box SURG, Rochester, NY 14642. E-mail: adan_becerra@urmc.rochester.edu.

0039-6060/$ - see front matter

http://dx.doi.org/10.1016/j.surg.2016.11.029

The American Society of Clinical Oncology reported recently that the US cancer care system is experiencing a transition phase characterized by improvements in cancer survival rates, while process failures continue to influence disparities in treatment and outcomes.[1] Cumulative evidence in colon cancer among other malignancies suggests the following concerns: turmoil in the care delivery system existing at multiple levels, lack of coordination among members of the provider team, and limited adherence to evidence-based guidelines.[2-4] A wide variation in the treatment of colon cancer and outcomes has been well documented.[5-9] Suboptimal management of colon cancer patients can lead to worse long-term outcomes, greater rates of postoperative complications, and wasteful cost.

Examination of an adequate number of mesenteric lymph nodes is critical for the staging and subsequent treatment of patients with colon cancer. According to evidence-based, clinical guidelines, an optimal lymph node examination has been endorsed as the examination of at least 12 lymph nodes.[10-12] Suboptimal lymph node examination (<12 lymph nodes examined) has been associated with worse, long-term prognosis.[13-15] While the mechanisms explaining this phenomenon have not been elucidated, adherence to the "12 lymph node rule" is used as a measure of hospital quality.[16-18]

Many of the previous studies addressing the rates of suboptimal lymph node examination in patients with colon cancer have focused on patient-level factors with limited attention given to variation in surgeon-, pathologist-, and hospital-level specific factors.[19-24] Given the complexity of colon cancer care, multilevel analytic approaches have been proposed to elucidate how different levels of care coordination contribute to disparities in outcomes.[25-28] Multilevel analyses can provide theoretic foundations for implementing targeted endeavors in quality improvement in an effort to provide optimal care. To date, however, only a limited number of studies have applied such an approach.[29-31] Furthermore, there is no study to date that has compared the effects of surgeon-, pathologist-, and hospital-specific rates of suboptimal lymph node examination on long-term prognosis.

The purpose of this study was to answer the following 3 questions: (1) What factors are independently associated with suboptimal lymph node examination? (2) How much of the variation in suboptimal lymph node examination is explained by differences between surgeons, pathologists, and hospitals? (3) Are surgeon-, pathologist-, and hospital-specific rates of suboptimal lymph node examination associated with 5-year, disease-specific survival?

METHODS

Data sources. We identified patients with stages I–III colon cancer diagnosed between 2004 and 2011 from the New York State (NYS) Cancer Registry. These data were merged with Medicare claims obtained from the Research Data Assistance Center at the University of Minnesota as done before.[32] These data were linked to the Statewide Planning and Research Cooperative System (SPARCS), a hospital discharge database maintained by the New York Department of Health. SPARCS reports data for all hospital admissions, ambulatory surgery procedures, and emergency department visits in NYS. These data include patient demographics, diagnostic codes, procedure codes, and unique patient, surgeon, and hospital identifiers. In addition, the data are linked to the National Death Index to obtain the specific cause and date of death for individual patients.

Patients with stages I–III colon cancer diagnosed between 2004 and 2011 were identified from the NYS Cancer Registry using the *International Classification of Diseases for Oncology* (ICD-O-3) codes (ICD-O-3: C180, C182–C189, C199, or Surveillance, Epidemiology, and End Results (SEER) Program site recode: 21041–21051). The study cohort included adenocarcinoma as the only histology (histology: 8140, 8210–8221, 8260–8263, or 8470–8490) and those who underwent resection for colon cancer identified by the *International Classification of Diseases, Ninth Edition* procedure codes (ICD-9: 17.31–17.39, 45.71–45.79, or 45.8–45.83).

To identify the pathologist for each patient, claims for surgical pathology specimen yield on the date of colectomy were identified using the Common Procedural Terminology (CPT) codes (CPT: 88302–88309 or 88321–88332) from the Medicare Physician/Supplier Part B claims files, and the Medicare unique physician number was extracted and used as the unique pathologist identifier. Cases with missing data were excluded.

In addition, patients were excluded when the unique surgeon identifier did not match with the American Medical Association (AMA) and American Board of Medical Specialties (ABMS) database, surgeon board-certification was neither surgery nor colorectal surgery, or when the surgeon year of completion of clinical residency or fellowship training was not documented. Approval by the institutional review board was obtained from both the NYS Department of Health and the University of Rochester Medical Center.

Definition of suboptimal lymph node examination. The NYS Cancer Registry contains a continuous variable that records the number of lymph nodes examined. Patients were dichotomized as having suboptimal examination (<12 lymph nodes examined) vs optimal (≥12 lymph nodes examined) based on well-established clinical guidelines.[13,14]

Definition of 5-year, disease-specific survival. The primary outcome of interest was colon cancer, disease-specific survival within 5 years of colectomy. A cause of death due to colon cancer or metastatic disease (ICD-10: C18–C19, C78.0–C80, C80.9, C26.0, C26.9, D37.4) was characterized as a colon cancer, disease-specific death. Patients who died from other causes were censored informatively on the date of death, and those who remained alive were censored at 5 years or December 31, 2013, whichever came first.

Patient-, surgeon-, and hospital-level factors. Several patient-level factors were evaluated as independent predictors of suboptimal lymph node examination and survival. These characteristics included age, sex, race, insurance status, type of operative procedure, scheduled admission, disease stage as defined by the American Joint Committee, and year of diagnosis. Surgeon-level factors included colorectal board certification, years of experience (tertiles), and annual number of resections for colon cancer, which was categorized into the following tertiles: 1–7 (low), 8–14 (medium), or >14 (high). Hospital-level factors were major academic institution (yes/no) as defined by the Council of Teaching Hospitals (COTH), urban hospital (yes/no), and annual number of resections for colon cancer categorized into the following tertiles: 1–35 (low), 36–71 (medium), or >71 (high). The number of colectomies for colon cancer for each surgeon and hospital was calculated for each calendar year to account for yearly changes in number of colectomies as done previously.[32-36]

Statistical analysis. Bivariate analyses as appropriate to the data compared the rate of suboptimal lymph node examination across patient-, surgeon-, and hospital-level factors. We decided a priori that factors with a P value $< .20$ in bivariate analyses would be adjusted for in multivariable analyses. Multilevel logistic regression models were used to identify patient-, surgeon-, and hospital-level factors independently associated with suboptimal lymph node examination (<12 lymph nodes vs ≥12 lymph nodes). These models controlled for clustering of patients by controlling for the unique surgeon, pathologist, and hospital identifiers as clustering variables.

Sequential building of the multilevel logistic regression models was done using a series of 4 nested models as is suggested.[37] Model 1 simply included the surgeon, pathologist, and hospital identifiers as clustering variables. Model 2 adjusted for patient-level factors. Model 3 further controlled for surgeon-level factors. Model 4, the final adjusted model, further evaluated the effect of hospital-level factors. The variances of the 3 clustering variables in Model 2 were summed to estimate the total clustering variability after controlling for case mix. These 3 clustering variances represent the amount of variation in suboptimal lymph node examination that is attributable to each level in the model. Greater clustering variances indicate greater variation at that level. The proportion of this total variability attributed to differences between surgeons, pathologists, and hospitals was calculated by dividing each variance by the total variance.

Unadjusted surgeon-, pathologist-, and hospital-specific rates of suboptimal lymph node examination were estimated from Model 1 using an inverse logit on the average patient predicted log odds for each surgeon, pathologist, and hospital. These rates represent the probability that an average patient will have a suboptimal lymph node examination for each individual surgeon, pathologist, and hospital. Subsequently, 3 separate, multilevel, competing-risks Cox models were used to evaluate the independent effect of these rates of suboptimal lymph node examination on disease-specific survival. The rates were modeled as tertiles of equal number of patients in each. Adjustment for potential confounding and selection bias was done using propensity score matching that employed a 1:1 nearest neighbor algorithm. Three separate propensity scores were estimated using a multilevel logistic regression model that predicted the probability of being in the third tertile of surgeon-, pathologist-, and hospital-specific rates of suboptimal lymph node examination as a function of all patient-, surgeon-, and hospital-level factors considered in the analysis.

Data management and bivariate analyses were performed with SAS software (version 9.3; SAS Institute, Cary, NC). The multilevel logistic models and the multilevel competing-risks Cox models were fit with R statistical software packages (lme4 and frailtypack, respectively; Foundation for Statistical Computing, Vienna, Austria).

RESULTS

A total of 12,332 patients treated at 187 hospitals by 814 pathologists and 1,503 surgeons met inclusion criteria. The overall rate of suboptimal lymph node examination was 32%. Table I provides distributions of patient-, surgeon-, and hospital-level factors in patients who had a suboptimal lymph node examination versus an optimal lymph node examination.

Table I. Bivariate analyses: Factors associated with suboptimal lymph node examination

Characteristic	*Suboptimal lymph node examination* (*<12*) N = *3,985 (32%)*	*Optimal lymph node examination* (*≥12*) N = *8,347 (68%)*	P *value*
Age (mean ± SD)	78.2 ± 7.9	77.8 ± 8.4	.003
Sex			<.001
Male	1,810 (45.4)	3,435 (41.1)	
Female	2,175 (54.6)	4,912 (58.9)	
Race			.10
White	3,461 (86.9)	7,108 (85.2)	
Black	292 (7.3)	619 (7.4)	
Other	232 (5.8)	620 (7.4)	
Insurance			.33
Medicare	2,784 (69.9)	5,974 (71.6)	
Medicaid	1,201 (30.1)	2,373 (28.4)	
AJCC stage			<.001
I	1,492 (37.4)	1,864 (22.3)	
II	1,456 (36.5)	3,599 (43.1)	
III	1,037 (26.0)	2,884 (34.6)	
Procedure type			<.001
Right	2,294 (57.6)	5,857 (70.2)	
Left	1,513 (38.0)	2,099 (25.2)	
Total	24 (0.6)	94 (1.1)	
Colectomy, NOS	154 (3.9)	297 (3.6)	
Scheduled admission			<.001
No	1,627 (40.8)	3,145 (37.7)	
Yes	2,358 (59.2)	5,202 (62.3)	
Year of diagnosis			<.001
2004	892 (22.4)	905 (10.8)	
2005	789 (19.8)	967 (11.6)	
2006	622 (15.6)	992 (11.9)	
2007	501 (12.6)	1,095 (13.1)	
2008	344 (8.6)	1,135 (13.6)	
2009	320 (8.0)	1,094 (13.1)	
2010	291 (7.3)	1,098 (13.2)	
2011	226 (5.7)	1,061 (12.7)	
Grade			<.001
1	509 (12.8)	665 (8.0)	
2	2,602 (65.3)	5,430 (65.1)	
3	715 (17.9)	1,927 (23.1)	
4	159 (4.0)	325 (3.9)	
Colorectal surgeon			<.001
No	3,427 (86.0)	6,657 (80.0)	
Yes	558 (14.0)	1,690 (20.0)	
Practice years			<.001
0–12	1,180 (29.6)	2,678 (32.1)	
13–22	1,407 (35.3)	3,134 (37.5)	
23–54	1,398 (35.1)	2,535 (30.4)	
Surgeon annual Number of colon cancer resections			<.001
1–7 (low)	1,425 (35.8)	2,526 (30.3)	
8–14 (medium)	1,235 (31.0)	2,219 (26.6)	
15–59 (high)	1,325 (33.2)	3,602 (43.2)	
Academic hospital			<.001
No	3,047 (76.5)	4,694 (56.2)	
Yes	938 (23.5)	3,653 (43.8)	
Urban hospital			<.001

(*continued*)

Table I. (*continued*)

Characteristic	*Suboptimal lymph node examination* (<12) N = *3,985 (32%)*	*Optimal lymph node examination* (≥12) N = *8,347 (68%)*	P *value*
No	566 (14.2)	551 (6.6)	
Yes	3,419 (85.8)	7,796 (93.4)	
Hospital annual Number of colon cancer resections			<.001
1–35 (low)	1,719 (43.1)	2,313 (27.7)	
36–71 (medium)	1,259 (31.6)	2,546 (30.5)	
72–173 (high)	1,007 (25.3)	3,488 (41.8)	

AJCC, American Joint Committee on Cancer; *NOS*, not otherwise specified; *SD*, standard deviation.

Patient-, surgeon-, and hospital-level factors associated with suboptimal lymph node examination. Table II presents factors independently associated with suboptimal lymph node examination using the fully adjusted, multilevel logistic regression model (Model 4). Several patient-level characteristics were associated with increased odds of suboptimal lymph examination, including older age, male sex, lesser stage (I and II), lesser tumor grade, left colectomy procedure type, year of diagnosis, and nonscheduled admission.

There were no independent, surgeon-level characteristics (years of experience, colorectal board certification, and annual number of colon cancer resections) associated with suboptimal lymph node examination after multivariable adjustment. Patients treated at hospitals with low annual numbers of colon cancer resections, rural hospitals, and nonacademic hospitals had greater odds of suboptimal lymph node examination.

Surgeon, pathologist, and hospital variation in suboptimal lymph node examination. There was a large and significant variation between 1,503 surgeons, 814 pathologists, and 187 hospitals in lymph node examination. Surgeon-, pathologist-, and hospital-specific, unadjusted rates (Model 1) of suboptimal lymph node examination ranged from 18%–41%, 9%–74%, and 2%–96%, respectively. The tertiles of surgeon-specific rates of suboptimal lymph node examination were 18%–27%, 27%–35%, and 35%–41%. The tertiles of pathologist-specific rates of suboptimal lymph node examination were 9%–39%, 39%–59%, and 59%–74%. The tertiles of hospital-specific rates of suboptimal lymph node examination were 2%–32%, 32%–55%, and 55%–96%.

After risk adjusting for case mix, the total clustering variance was 0.89 (0.07 between surgeons + 0.20 between pathologists + 0.62 between hospitals). The proportion of the total clustering variance attributed to differences between surgeons, pathologists, and hospitals after adjusting for case mix was 7.9% (0.07/0.89), 22.5% (0.20/0.89), and 69.7% (0.62/0.89), respectively. Thus, approximately 93% of the total clustering variation in suboptimal lymph node examination is attributable to differences between pathologists and hospitals.

Survival analyses. The results from the separate, multivariable survival analyses evaluating the effect of surgeon-, pathologist-, and hospital-specific rates of suboptimal lymph node examination on disease-specific survival are provided in Table III. There was an association between tertiles of increasing pathologist and hospital-specific rates of suboptimal lymph node examination and worse, disease-specific survival. There was less evidence of an association between surgeon-specific rates of suboptimal lymph node examination and disease-specific survival. Pathologist-specific rates in the highest tertile were associated with a 17% increase in the hazard of death relative to rates in the lowest tertile (hazard ratio [HR] = 1.17, 95% confidence interval [CI] = 1.06–1.35). Hospital-specific rates in the highest tertile were associated with a 26% increase in the hazard of death relative to rates in the lowest tertile (HR = 1.26, 95% CI = 1.21–1.36).

DISCUSSION

Recent attention has been given to understanding how variation in suboptimal lymph node examination may impact outcomes in patients with colon cancer. This study used population-based data from NYS to quantify the large variation in suboptimal lymph node examination between surgeons, pathologists, and hospitals. Furthermore, increasing pathologist and hospital-specific rates of suboptimal lymph node examination were associated with worse disease-specific survival. In other words, patients treated by pathologists and hospitals who were poor performers in lymph node examination had worse, long-term prognosis.

This study identified several independent factors thought to impact suboptimal lymph node examination. At the patient level, differences in case mix

Table II. Full, multilevel logistic regression model: Factors associated with suboptimal lymph node examination (Model 4)

Factor	*Adjusted odds ratio (95% CI)*
Age (per 10 y)	1.17 (1.12, 1.28)
Sex	
Female	1.00 (Reference)
Male	1.20 (1.15, 1.28)
Scheduled admission	
Yes	1.00 (Reference)
No	1.57 (1.47, 1.72)
Stage	
III	1.00 (Reference)
II	1.92 (1.85, 2.02)
I	1.61 (1.56, 1.70)
Type of colectomy	
Right	1.00 (Reference)
Left	1.58 (1.52, 1.67)
Total	1.00 (0.85, 1.17)
NOS	1.10 (0.97, 1.34)
Grade	
4	1.00 (Reference)
3	1.10 (1.01, 1.25)
2	1.22 (1.15, 1.33)
1	1.37 (1.30, 1.44)
Hospital annual number of colon cancer resections	
72–173 (high)	1.00 (Reference)
36–71 (medium)	1.18 (1.02, 1.40)
1–35 (low)	1.35 (1.25, 1.48)
Academic hospital	
Yes	1.00 (Reference)
No	1.18 (1.12, 1.26)
Urban hospital	
Yes	1.00 (Reference)
No	1.20 (1.13, 1.31)

NOS, not otherwise specified.

Table III. The relationship between surgeon-, pathologist-, and hospital-specific rates of suboptimal lymph node examination and disease-specific survival

	All patients (N = *12,332)*
Surgeon-rate model	
Tertile 1 (18%–27%)	1.00 (Reference)
Tertile 2 (27%–35%)	1.02 (0.89, 1.18)
Tertile 3 (35%–41%)	1.05 (0.94, 1.22)
Pathologist-rate model	
Tertile 1 (9%–39%)	1.00 (Reference)
Tertile 2 (39%–59%)	1.14 (1.04, 1.30)
Tertile 3 (59%–74%)	1.17 (1.06, 1.35)
Hospital-rate model	
Tertile 1 (2%–32%)	1.00 (Reference)
Tertile 2 (32%–55%)	1.09 (1.03, 1.19)
Tertile 3 (55%–96%)	1.26 (1.21, 1.36)

(age, sex, procedure type, stage, and scheduled admission) were associated with suboptimal lymph node examination. Interestingly, none of the 3 surgeon-level factors were associated with suboptimal lymph node examination, while at the hospital level, nonacademic institutions, rural hospitals, and hospitals performing a lesser number of colectomies for colon cancer were independently associated with greater odds of suboptimal lymph node examination. Cluster-level variances estimated by multilevel modeling revealed that 23% and 70% of the variability in suboptimal lymph node examination was attributed to differences between pathologists and hospitals, respectively. This observation suggests that there are quality-related factors inherent to these 2 settings that were influencing wide variation in suboptimal lymph node examination, which can affect ultimately the prognosis of patients.

Results from this study agree generally with previous studies identifying risk factors for suboptimal lymph node examination, which suggests that the quality of the data is strong and reliable. For example, the well-established effects of age, stage, and other characteristics were observed in our study.[19-24] In addition, the only other study that evaluated surgeon-, pathologist-, and hospital-level variation reported that 19% and 73% of the total clustering variability is accounted by differences between pathologists and hospitals. The estimates obtained from our analysis are strikingly similar and suggest that the majority of the variation in suboptimal lymph node examination is attributed to differences between pathologists and differences between hospitals.

It is important to note that some institutions utilize pathology technicians to conduct lymph node examinations. Thus, the entire staff of pathology laboratories as well as hospitals may serve as primary targets for initiatives in quality improvement, and these endeavors should be prioritized to address problems and challenges in these 2 settings. While our results indicate that there was variation in rates of suboptimal lymph node examination between surgeons, there was even wider variation between pathologists and hospitals, and thus targeting surgeons to improve quality in lymph node examination rate may not be as beneficial as focusing on pathologists and hospitals.

Given the critical role that the practices of the pathologist and hospital play in managing the care of patients with colon cancer, future endeavors may foster supportive and collaborative relationships between pathology laboratories and hospitals.[38-40] These partnerships and programmatic relationships may serve as a foundation for delivering optimal care and improving the outcomes among patients with colon cancer transitioning between different levels of care.

Despite extensive literature and evidence-based clinical guidelines supporting its implementation, some investigators have called into question the relevance of suboptimal lymph node examination as a measure of hospital quality.[41] The current study, however, did support evidence of an effect of hospital-specific rates of suboptimal lymph node examination on disease-specific survival. In the former study by Wong et al,[41] researchers did not use multilevel modeling to adjust for the clustering of patients. These limitations in their study could introduce bias that would underestimate the effect of hospital-specific rates of suboptimal lymph node examination.

Furthermore, our study is the first to investigate and report a relationship between pathologist-specific rates of suboptimal lymph node examination and disease-specific survival. The null association for the surgeon-specific rates does not indicate that surgeon ability does not influence survival, but rather that the effect of suboptimal lymph node examination on survival is less dependent on the surgeon. Surely, there are other factors that affect survival that are dependent predominantly on the surgeon, such as the quality of their resections and differences in preoperative management.

Our study had several limitations. First, the data sources did not contain explicit, pathologist-level factors, thus restricting the analysis to only known patient-, surgeon-, and hospital-level factors. Given the integral role of the pathologist in the execution of the lymph node examination, future studies will need to evaluate the extent to which these characteristics explain the variability due to clustering of patients. Second, the analysis only includes patients diagnosed in NYS. While it is important to evaluate these patterns at the state-level, practice patterns may vary geographically, thus limiting the utility of a state-level practice pattern in generalizing to other patient populations in the United States. Finally, the possibility of confounding by other pertinent characteristics cannot be excluded. Many factors that predict survival may be related to surgeon-, pathologist-, and hospital-specific rates of suboptimal lymph node examination, thus overestimating the effect of these rates. Our study, however, employed rigorous multilevel analyses and propensity score adjustment to decrease the possibility of confounding and selection bias.

Notwithstanding these limitations, our study has several important strengths that contribute to previous literature. This is the first study to date to assess the impact of surgeon-, pathologist-, and hospital-specific rates of suboptimal lymph node examination on long-term outcome. Understanding how the phenomenon of suboptimal lymph node examination at different levels affects prognosis provides insight into the mechanisms underlying variation in care coordination. Second, previous studies have assessed overall survival as the relevant outcome; however, overall survival includes death due to other causes, which may introduce bias that could produce artificial results. This study used disease-specific survival, which is a more relevant oncologic outcome.

In conclusion, there was large variation in suboptimal lymph node examination, in particular between pathologists and between hospitals. This marked variation suggests that strategies of quality improvement need to be prioritized and compartmentalized to address challenges in these 2 settings in order to improve the management of colon cancer. Future efforts should focus on identifying coordinated efforts between hospitals and pathologists that decrease the rate of suboptimal lymph node examination. Under a multilevel framework, hierarchical partnerships advocating for evidence-based practice in colon cancer may decrease the downstream consequences and provide an improved benefit in disease-specific survival. These endeavors should implement specific and targeted interventions to improve quality of care and ultimately long-term outcomes among patients with resected colon cancer.

REFERENCES

1. The state of cancer care in America, 2015: a report by the American Society of Clinical Oncology. J Oncol Pract 2015;11:79-113.
2. Spinks T, Albright HW, Feeley TW, Walters R, Burke TW, Aloia T, et al. Ensuring quality cancer care: a follow-up review of the Institute of Medicine's 10 recommendations for improving the quality of cancer care in America. Cancer 2012;118:2571-82.
3. IOM (Institute of Medicine). Delivering high-quality cancer care: charting a new course for a system in crisis. Washington (DC): The National Academies Press; 2013.
4. The state of cancer care in America, 2014: a report by the American Society of Clinical Oncology. J Oncol Pract 2014;10:119-42.
5. Becerra AZ, Probst CP, Tejani MA, Aquina CT, González MG, Hensley BJ, et al. Opportunity lost: adjuvant chemotherapy in patients with stage III colon cancer remains underused. Surgery 2015;158:692-9.
6. Laryea JA, Siegel E, Klimberg S. Racial disparity in colorectal cancer: the role of equal treatment. Dis Colon Rectum 2014;57:295-302.

7. Paulson EC, Wirtalla C, Armstrong K, Mahmoud NN. Gender influences treatment and survival in colorectal cancer surgery. Dis Colon Rectum 2009;52:1982-91.
8. Weeks JC, Uno H, Taback N, Ting G, Cronin A, D'Amico TA, et al. Interinstitutional variation in management decisions for treatment of 4 common types of cancer: a multi-institutional cohort study. Ann Intern Med 2014;161:20-30.
9. Chagpar R, Xing Y, Chiang YJ, Feig BW, Chang GJ, You YN, et al. Adherence to stage-specific treatment guidelines for patients with colon cancer. J Clin Oncol 2012;30:972-9.
10. Compton CC, Fielding LP, Burgart LJ, Conley B, Cooper HS, Hamilton SR, et al. Prognostic factors in colorectal cancer. College of American Pathologists Consensus Statement 1999. Arch Pathol Lab Med 2000;124:979-94.
11. National Comprehensive Cancer Network. Colon cancer (Version 2.2015). 2011. Available from: http://www.nccn.org/professionals/physician_gls/pdf/colon.pdf.
12. Nelson H, Petrelli N, Carlin A, Couture J, Fleshman J, Guillem J, et al. Guidelines 2000 for colon and rectal cancer surgery. J Natl Cancer Inst 2001;93:583-96.
13. Swanson RS, Compton CC, Stewart AK, Bland KI. The prognosis of T3N0 colon cancer is dependent on the number of lymph nodes examined. Ann Surg Oncol 2003;10:65-71.
14. Le Voyer TE, Sigurdson ER, Hanlon AL, Mayer RJ, Macdonald JS, Catalano PJ, et al. Colon cancer survival is associated with increasing number of lymph nodes analyzed: a secondary survey of intergroup trial INT-0089. J Clin Oncol 2003;21:2912-9.
15. Chen SL, Bilchik AJ. More extensive nodal dissection improves survival for stages I to III of colon cancer: a population-based study. Ann Surg 2006;244:602-10.
16. Bilimoria KY, Bentrem DJ, Stewart AK, Talamonti MS, Winchester DP, Russell TR, et al. Lymph node evaluation as a colon cancer quality measure: a national hospital report card. J Natl Cancer Inst 2008;100:1310-7.
17. Baxter NN. Is lymph node count an ideal quality indicator for cancer care? J Surg Oncol 2009;99:265-8.
18. Mcdonald JR, Renehan AG, O'dwyer ST, Haboubi NY. Lymph node yield in colon and rectal cancer: current considerations. World J Gastrointest Surg 2012;4:9-19.
19. Bilimoria KY, Stewart AK, Palis BE, Bentrem DJ, Talamonti MS, Ko CY. Adequacy and importance of lymph node evaluation for colon cancer in the elderly. J Am Coll Surg 2008;206:247-54.
20. Nedrebø BS, Søreide K, Nesbakken A, Eriksen MT, Søreide JA, Kørner H, et al. Risk factors associated with poor lymph node yield after colon cancer surgery in a national cohort. Colorectal Dis 2013;15:e301-8.
21. Wright FC, Law CH, Berry S, Smith AJ. Clinically important aspects of lymph node assessment in colon cancer. J Surg Oncol 2009;99:248-55.
22. Moro-Valdezate D, Pla-Martí V, Martín-Arévalo J, Belenguer-Rodrigo J, Aragó-Chofre P, Ruiz-Carmona MD, et al. Factors related to lymph node yield: does a recovery of more than 12 improve the outcome of colorectal cancer? Colorectal Dis 2013;15:1257-66.
23. Shen SS, Haupt BX, Ro JY, Zhu J, Bailey HR, Schwartz MR. Number of lymph nodes examined and associated clinicopathologic factors in colorectal carcinoma. Arch Pathol Lab Med 2009;133:781-6.
24. Morikawa T, Tanaka N, Kuchiba A, Nosho K, Yamauchi M, Hornick JL, et al. Predictors of lymph node count in colorectal cancer resections: data from US nationwide prospective cohort studies. Arch Surg 2012;147:715-23.
25. Taplin SH, Anhang Price R, Edwards HM, Foster MK, Breslau ES, Chollette V, et al. Introduction: understanding and influencing multilevel factors across the cancer care continuum. J Natl Cancer Inst Monographs 2012;2012:2-10.
26. Taplin SH, Rodgers AB. Toward improving the quality of cancer care: addressing the interfaces of primary and oncology-related subspecialty care. J Natl Cancer Inst Monogr 2010;40:3-10.
27. Sussman J, Baldwin LM. The interface between primary and oncology specialty care: from diagnosis through primary treatment. J Natl Cancer Inst Monogr 2010; 40:18-24.
28. Yano EM, Green LW, Glanz K, Ayanian JZ, Mittman BS, Chollette V, et al. Implementation and spread of interventions into the multilevel context of routine practice and policy: implications for the cancer care continuum. J Natl Cancer Inst Monogr 2012;44:86-99.
29. Nathan H, Shore AD, Anders RA, Wick EC, Gearhart SL, Pawlik TM. Variation in lymph node assessment after colon cancer resection: patient, surgeon, pathologist, or hospital? J Gastrointest Surg 2011;15:471-9.
30. Rhoads KF, Ackerson LK, Ngo JV, Gray-Hazard FK, Subramanian SV, Dudley RA. Adequacy of lymph node yield in colorectal surgery: contribution of the hospital versus the surgeon. Med Care 2013;51:1055-62.
31. Becerra AZ, Berho ME, Probst CP, Aquina CT, Tejani MA, Gonzalez MG, et al. Variation in hospital-specific rates of suboptimal lymphadenectomy and survival in colon cancer: evidence from the National Cancer Data Base. Ann Surg Oncol 2016. [Epub ahead of print].
32. Becerra AZ, Aquina CT, Mohile SG, Tejani MA, Schymura MJ, Boscoe FP, et al. Variation in delayed time to adjuvant chemotherapy and disease-specific survival in stage III colon cancer patients. Ann Surg Oncol 2016. [Epub ahead of print].
33. Aquina CT, Probst CP, Kelly KN, Iannuzzi JC, Noyes K, Fleming FJ, et al. The pitfalls of inguinal herniorrhaphy: surgeon volume matters. Surgery 2015;158:736-46.
34. Aquina CT, Blumberg N, Probst CP, Becerra AZ, Hensley BJ, Iannuzzi JC, et al. Significant variation in blood transfusion practice persists following upper GI cancer resection. J Gastrointest Surg 2015;19:1927-37.
35. Aquina CT, Probst CP, Becerra AZ, Hensley BJ, Iannuzzi JC, Noyes K, et al. High variability in nosocomial Clostridium difficile infection rates across hospitals after colorectal resection. Dis Colon Rectum 2016;59:323-31.
36. Aquina CT, Blumberg N, Probst CP, Becerra AZ, Hensley BJ, Noyes K, et al. Large variation in blood transfusion use after colorectal resection: a call to action. Dis Colon Rectum 2016;59:411-8.
37. Gelman A, Hill J. Data analysis using regression and multilevel/hierarchical models. Cambridge (UK): Cambridge University Press; 2007.
38. Bamboat ZM, Deperalta D, Dursun A, Berger DL, Bordeianou L. Factors affecting lymph node yield from patients undergoing colectomy for cancer. Int J Colorectal Dis 2011;26:1163-8.
39. Leung AM, Scharf AW, Vu HN. Factors affecting number of lymph nodes harvested in colorectal cancer. J Surg Res 2011;168:224-30.
40. Rieger NA, Barnett FS, Moore JW, Ananda SS, Croxford M, Johns J, et al. Quality of pathology reporting impacts on lymph node yield in colon cancer. J Clin Oncol 2007;25: 463; author reply 463-4.
41. Wong SL, Ji H, Hollenbeck BK, Morris AM, Baser O, Birkmeyer JD. Hospital lymph node yield rates and survival after resection for colon cancer. JAMA 2007;298:2149-54.