

Potential Economic Effects of Volume-Outcome Relationships in the Treatment of Three Common Cancers

Thomas N. Chirikos, PhD, Dustin D. French, PhD, and Stephen L. Luther, PhD

From the Department of Cancer Prevention and Control at the H. Lee Moffitt Cancer Center & Research Institute (TNC), the VISN-8 Patient Safety Center at the James A. Haley Veterans Administration Hospital (DDF), and the Center for Health Outcomes Research at the University of South Florida Health Sciences Center (SLL), Tampa, Florida.

Introduction

The cumulative results of more than a quarter-century of empirical research on the relationship between hospital/physician volumes and patient outcomes have finally caught the attention of policy makers, payers, and professional groups. Serious consideration of the policy tools that might be used to shift volume-sensitive medical procedures away from providers performing too few of them toward those with higher, more appropriate levels is now underway. Current discussion centers on the feasibility of establishing minimum caseload standards for certificate of need approval and insurance reimbursement as well as changing referral patterns through information campaigns targeting providers and patients.^{1,2} In a few cases, policies such as these have already been initiated by payer groups.³ Perhaps not surprisingly, the intended and unintended economic consequences of shifting volume-sensitive health care resources are increasingly part of this discussion.^{4,5}

Economics has been an inextricable part of the volume-outcome nexus from the beginning. Textbook concepts of scale economies, comparative advantage, and "learning by doing" have often been invoked in analytic studies testing volume-outcome hypotheses. Furthermore, empirical findings that volume and outcome vary together suggest to economists that cost-effectiveness ratios of key treatments must also vary across providers and health care markets. At the societal level, it follows that volume differences may be responsible for inefficiencies in delivering care and, correspondingly, that volume-related policy initiatives may facilitate cost-containment goals. At the provider/payer level, volume-related policies are likely to redistribute revenues and profit margins across institutions and practitioners, which in turn may shift market power and pricing practices. Indeed, the potential for dramatic changes in economic gains or losses of practitioners if volume-related policies are pursued more aggressively may well explain why this

line of research has taken so long to be translated into policy action.

Volume-outcome studies have focused almost from the beginning on various cancer procedures/treatments, so if policies suggested by these studies do indeed have economic effects, they are likely to be felt sooner and more intensely by oncology specialists/centers than in other parts of the medical delivery system. At the moment, there is reasonably compelling evidence that short-term mortality rates vary inversely with provider volumes for high-risk, generally rarer cancer surgeries such as esophagectomy and pancreatectomy; accordingly, there is general agreement that minimum volume standards and perhaps regionalized referral patterns should be promoted for these procedures.^{6,7} However, because relatively few such surgeries are performed each year, it is unlikely that volume-related policy initiatives would have much impact, either in terms of efficiency improvements at the system level or marked resistance to redistributions of revenues or market share at the provider level.

More pronounced economic effects might be expected if volume-sensitive treatments for highly prevalent malignancies are shifted, regulated, or regionalized. For instance, if treatments for more prevalent breast or lung cancers were subject to significant volume effects, a substantially greater number of cases and providers could be targeted by volume-related policies and the economic stakes associated with those policies would rise. If implemented successfully, a relatively larger number of low-volume practitioners would face shrinking patient flows and lower revenues. However, if volume initiatives either fail or are blocked by political means, significant cost inefficiencies would remain embedded in the medical delivery system. The likelihood that more pervasive economic effects of this sort will be realized anytime soon depends on at least two unknowns.

The first is whether the scientific evidence on the connection between volume and the manner in which more common malignancies are diagnosed and treated —

evidence that has been both slim and mixed in the past — turns out to be sufficiently powerful to mandate volume-related policy action. The number of studies conducted on the effects of volume on the treatment of more prevalent cancers has grown rapidly over the recent past, though most of this emerging literature has not yet been systematically reviewed, as in Halm et al.⁸ The scientific merit of this recent work is crucially important, for clearly there will be no basis for launching volume-related policies if the empirical evidence adduced on the volume-outcome relationship fails to reject the null hypothesis in convincing fashion. Indeed, we assume that in the absence of strong evidence, volume initiatives and the economic consequences they produce will never be given a prominent place on the national policy agenda.

The second unknown is whether the procedures/treatments of common cancers found empirically to be volume-sensitive turn out to be either relatively resource-intensive and/or routinely performed on most, or all, incident cases of these cancers. Much of the volume literature has tended to focus on short-term mortality as the endpoint of interest, though volume may also influence morbidity patterns, readmissions, length of stay (LOS), and other dimensions of health care utilization. These outcomes are perhaps more important from an economic perspective because they are more likely to be correlated with costs and revenues of service delivery and, thereby, are more likely to influence the economic performance of providers targeted by volume-related policies. Strong empirical evidence that these secondary proxies are influenced by volume would thus lead to the expectation that volume initiatives will produce significant economic sequelae.

The principal aim of this article is to cast some light on each of these unknowns. We review the recent literature on volume-outcome relationships in the treatment of three common cancers: breast, colorectal, and lung. We choose these cancers because they have high incidence rates and associated economic burdens; as a MEDLINE search demonstrates, they have also been the focal point of much of the recent US literature on this topic. In each case, our review pays close attention to the methodological strength of the empirical work, with special emphasis given to the interrelated issues of how volume is conceptualized and measured. We examine not only whether hospital or physician performance are included in tests of the volume hypothesis, but also whether policy-relevant features such as cut-points and ranges are treated in detail. Although space constraints preclude detailed discussion of the various technical aspects of the volume-outcome literature, we note that our methodological appraisal is sufficiently rigorous to ensure that the economic inferences we draw are reasonably robust. Since the economic effects of volume-outcome relationships are not themselves directly studied, we especially endeavor to generate indirect infer-

ences about potential economic effects based on the best information currently available.

The next section summarizes key characteristics and findings of recently published US studies on volume and outcomes in each of the three cancers. We then draw out some key *economic* implications of the recent literature, using these inferences to cast light on the feasibility and likelihood of volume-related policy options in the cancer area. The final section suggests priorities for future research.

Recent Empirical Evidence

Breast Cancer

Recent studies relating to breast cancer have focused primarily on the impact of physician and/or facility volume on the process and outcomes of surgical interventions. Additionally, researchers have studied the impact of physician volume on the accuracy of interpretation of screening mammograms and on the outcomes from a new surgical technique, sentinel lymph node biopsy (SLNB). We consider each in turn.

The recent literature on the surgical treatment of breast cancer suggests generally that volume is positively associated with better outcomes, though results are often mixed and the role of physician-volume vs facility-volume or the interaction of the two is ambiguous. Two recent studies illustrate the point in regard to mortality outcomes, one of the most common endpoints used to study volume effects. Skinner and colleagues⁹ studied nearly 30,000 cases of breast cancer treated in Los Angeles County between 1990 and 1998. Patients were stratified on the basis of surgeon and hospitalization specialization, as well as by race, stage, surgical procedure and surgeon, and hospital case volume. Treatment at a specialty center did not affect survival. However, multivariate analysis indicated that the type of surgeon (surgical oncologist) as well as both hospital and physician case volume were independent predictors of risk of death at 5 years. Treatment by a surgical oncologist resulted in a 33% reduction in the risk of death at 5 years. However, Harcourt and Hicks¹⁰ found no association between hospital volume and 5-year breast cancer survival. This study investigated the results for 2,409 cases treated between 1980 and 1995, separated into 5-year increments, in nine hospitals in the state of Washington. Average new cases per facility ranged from 3 to 52, with a median value of 15 cases. Using correlation techniques, no association between expected/observed mortality ratios and facility volume was detected. The observed mortality rates were also found to be almost identical to published SEER data. There was, however, a statistically significant association with stage of disease and 5-year mortality.

Perhaps more important from an economic perspective, several recent studies have investigated the associa-

tion between provider-volume and the patterns or processes of care, including the use of breast-conserving surgery (BCS), positive biopsy rates, and the likelihood of finding negative margins in lumpectomy. Luther and Studnicki¹¹ in a 2-year study of all surgeries in the state of Florida (more than 20,000 cases) found, for instance, that after controlling for selected patient and physician characteristics by means of multivariate regression techniques, the lowest-volume surgeons were nearly twice as likely to perform mastectomies than BCS compared with the highest-volume group. Other factors independently associated with the use of BCS were patient age, race (non-white), payer, and rurality. However, neither self-reported specialty training nor years in practice was associated with BCS use. McKee et al¹² in a community-wide study of over 1,000 cases also found physician practice volume to be positively associated with the use of BCS but not for positive biopsy rates. Staradub and colleagues¹³ studied 270 consecutive mammographically detected patients treated at a university hospital and found that physicians with higher caseloads were able to perform needle localization lumpectomy with negative margins while limiting the volume of normal breast tissue excised.

Turning now to the effect of volume on the accuracy of screening mammography, Esserman and colleagues¹⁴ studied the sensitivity (at a set specificity of 0.9) of reading a test set of 60 films by high-volume radiologists from the United Kingdom (UK) where mammography services are provided in centralized high-volume centers. The authors then compared the results with high-, medium-, and low-volume radiologists in the United States. Statistically speaking, low-volume US physicians were found to have significantly lower average sensitivity rates (0.648) than either high-volume US (0.756) or UK physicians (0.785). Medium-volume US physicians were found to have lower average sensitivity scores (0.702) than UK high-volume physicians only. These results clearly favor organizing or centralizing screening services in high-volume centers. Other recent studies, however, are less clear-cut. Freeman et al¹⁵ used linked Medicare/SEER data to estimate both sensitivity and the rate of follow-up diagnostic testing in low (100–300 weighted count), medium (320–700 weighted count), and high (720 or more weighted count) volume radiologists over the period 1993–1998. While no volume effect was observed in the earliest years of the study period, specificity improved and the rates of diagnostic testing decreased with higher volume between 1996–1998. In the most recent study, Beam et al¹⁶ studied a group of 110 US radiologists who interpreted mammograms from 148 randomly selected women. The associations between both physician-level and facility-level factors and the accuracy of mammographic interpretation were investigated using multiple regression techniques. Their results suggest that individual physician volume was not associated with better accuracy. However, being a more recent graduate of a resi-

dency program was significantly associated with accuracy as were several facility-level factors, including the number of diagnostic procedures conducted, classification as a comprehensive breast diagnostic and/or screening center, and practicing double-readings.

Finally, a new surgical technique used in staging breast cancer, SLNB has become increasingly popular in recent years and, though not yet a part of standard care, may nonetheless illustrate how volume should be considered in the diffusion of new therapeutic methods. Kelemen¹⁷ suggested that SLNB, while providing potential benefits to the patient, is a difficult technique to perform. Hence, it is imperative for surgeons to perform a series of cases in which SLNB is followed by standard axillary lymph node dissection. This would allow calculation of false positive rates and establish a track record of successfully performed SLNB before the technique is used exclusively for node-negative women. McMasters et al¹⁸ reported the results of a large multi-institutional trial including 226 surgeons and 2,148 patients. Multivariate analysis of false-negative rates suggested that surgeons should perform at least 20 SLNB cases with acceptable results before abandoning routine axillary dissection. Cox and colleagues¹⁹ studied success rates of 16 surgeons who had attended 2-day training sessions after they had treated more than 2,200 patients. Case volume was defined as the number of procedures performed in a 30-day period. Multivariate analysis found that surgeons performing more SLNBs had higher success rates, with those performing 6 or more per month having a corresponding rate of approximately 98%.

Colorectal Cancer

While most studies agree that volume influences outcomes in colorectal cancer as it does in other cancers, there is considerable variation in the magnitude of findings. This is most likely attributable to varying study design and data sources, which make it difficult to compare parameter estimates and odds ratios. Nevertheless, associations between reductions in morbidity, mortality, and costs with hospital and physician volume in the surgical treatment of colorectal cancer are well documented. Holm et al²⁰ found in 1,399 patients that those treated at higher-volume (>10 cases per year) or university hospitals had a lower incidence of risk-adjusted recurrence and deaths from rectal cancer. Hillner and colleagues²¹ found a dramatic decline in crude mortality with increased surgeon volume. Schrag and colleagues²² found pronounced associations between hospital volume and long-term survival for patients with stage II and particularly stage III colon cancer.

More important from an economic perspective is the finding by Marusch et al²³ that higher hospital caseload in colorectal surgery was associated with fewer postoperative complications. The comprehensive colorectal litera-

ture review by Hodgson and colleagues²⁴ confirmed the association of reductions in morbidity as well as mortality with increased hospital and physician volume. Harmon et al²⁵ studied a cross-section of all adult patients who underwent resection for colorectal cancer using Maryland state hospital discharge data from 1992 to 1996. These researchers found increased surgeon volume was associated not only with improvements in mortality but also with reductions in LOS and hospital charges. After case mix adjustment, risk of in-hospital death was reduced by 36% and LOS fell from 10.1 to 9 days in the high-volume surgeon group (>10) compared with the low-volume group (≤5), respectively. With respect to hospital charges, case mix-adjusted average total charges were significantly reduced in both the medium-volume (\$11,735) and high-volume (\$11,642) surgeon groups compared with the low-volume surgeon group (\$13,025) ($P<.01$ for both comparisons). In the hospital volume group, they found total charges were significantly reduced in both the medium-volume (\$12,111) and high-volume (\$11,784) hospital groups compared with the low-volume group (\$12,583) ($P<.01$). It is worth noting in this regard that LOS, morbidity, mortality, and hospital charges/costs tend to be highly, and directly, correlated. Thus, finding lower hospital charges in higher-volume facilities tends to confirm the favorable impact that volume has on a range of crucial outcomes of medical care delivery.

As pointed out earlier, differences in study design and the potential bias of omitted or confounding variables raise concerns about the magnitude of the measured effects of volume on the outcomes of interest. For instance, because of data limitations or study design, many analyses did not include the interaction effect of surgeon and hospital volume. Furthermore, the exact definition of high volume and low volume, as well as the techniques used for risk adjustment, tended to vary from one study to another. While we are not aware of any study that has used statistical methods or other meta-analytic concepts to explain differences across studies, such an endeavor should be a high priority for future research.

Lung Cancer

Available evidence on the volume-outcome relationship in the surgical treatment of lung cancer is mixed, perhaps even more so than the other cancers thus far reviewed.

On the one hand, some studies have detected statistically significant differences in short-term mortality outcomes by the volume of such surgery at the hospital level, at the physician level and in the interrelated effects of surgeon volume and specialty. In an early study, Romano and Mark²⁶ detected a significant relationship between the number of lung resections done in California hospitals and the in-hospital mortality rate. They reported 40% lower probability of dying in the hospital anytime or within 30 days of the index surgery for patients who had pulmonary

resection for lung and bronchial tumors in hospitals doing at least 25 such resections per year compared with patients treated in low-activity hospitals (eight or fewer procedures per year). Similarly, Bach and colleagues²⁷ showed that patients with stage I, II, and IIIA non-small-cell lung cancer (NSCLC) undergoing lung resection at the highest-volume hospitals were significantly more likely to be alive 5 years after the index surgery than those operated on at the lowest-volume hospitals. This population-based study also showed that patients at high-volume hospitals had lower rates of postoperative complications and lower 30-day mortality than those treated in low-volume hospitals. Finally, Silvestri et al²⁸ detected differences between general and thoracic surgeons on the rate of in-hospital mortality of lobectomies for lung cancer in South Carolina between 1991 and 1995, which they interpret as a volume effect because specialists were more likely by a wide margin to perform these lung cancer surgeries than were general surgeons.

On the other hand, a larger number of studies have failed to detect any volume effect whatsoever or have detected only weak or mixed effects. For instance, Birkmeyer and colleagues²⁹ found only weak effects for lobectomy and pneumonectomy, the latter differing only between the absolute highest volume and the very lowest, but no gradient in between. Begg et al,³⁰ Khuri and colleagues,³¹ and Hannan et al³² also failed to find statistically significant effects of hospital and/or physician volume on pneumonectomy. Because of its importance from the viewpoint of economic effects, it is worth noting finally that a recently published study by Goodney and colleagues³³ failed to find significant effects of hospital volume on postoperative LOS and 30-day readmission rates for 14 procedures, including lobectomy and pneumonectomy for lung cancer. Their analysis of national Medicare data for the period 1994-1999 found inconsistent results for most procedures, including the two types of lung cancer surgery. For readmission, lobectomy had a significant volume gradient, but pneumonectomy did not. Mean LOS for pneumonectomy (in days) was 10.3 for volume strata 9-17 and >46 procedures per year; it was 10.1 for volume strata <9 and 18-27 and 9.8 for volume strata 28-46. Because of very large sample size, these differences are statistically significant ($P<.05$), though as the authors noted, the findings were neither consistent nor very meaningful. They concluded that while hospital volume may be an important predictor of operative mortality, it is not associated with resource use as reflected in LOS or readmission rates. This problem is further compounded by the failure in the lung cancer-related studies to test for the direction or causal pathways of the relationship, eg, whether the effects that are detected result from technical conditions governing quality improvements or selected referrals. A key omission in the lung studies is the failure of all but two of them to control for the stage of disease and/or comorbidities.

Economic Implications

The foregoing review provides little basis for supposing that volume-related policies will markedly improve the overall economic efficiency of breast, colorectal or lung cancer diagnosis and treatment, though if pursued, such policies may influence revenue streams and market share of some providers. The essential conclusion is that the empirical evidence still tends to be mixed, a matter that surely guarantees continuing debate between proponents and opponents of volume-related policy efforts. Of the three common cancers considered, perhaps the strongest empirical case for such policies can be made with respect to colorectal cancer. The evidence for this cancer was generally stronger than the other two, and it detected volume effects in a larger range of outcomes, including especially charges/costs and morbidity patterns. The influence of volume on charges is consistent with the concept of scale economies and thus suggests that efficiency improvements would accrue to policy efforts aimed at shifting resources from low- to high-volume providers. In contrast, the case is perhaps the weakest for lung cancer, where short-term mortality rates only infrequently varied with volume; other more relevant effects on LOS and morbidity were not detected and, in any case, have not been well studied according to Handy et al.³⁴ Furthermore, while the surgical treatment for (early stage) lung cancer may vary with provider volumes, only about 1 in 4 lung cancer patients is currently treated by surgical means and, while that proportion has remained steady over time, the character of such surgery has not.^{35,36} Volume policies in lung cancer are not likely to improve efficiency and, in fact, could adversely influence the way the disease is currently treated.

The results for breast cancer are somewhere in between. Some of the variation in results obtained may be due to substantial differences in research methodology and to the wide variety of treatment processes that have been examined. Studies reviewed in this paper range from clinical trials with only a few hundred patients to the analysis of large administrative data sets with tens of thousands of records. Outcomes have been studied in the university setting, in large metropolitan areas, and in primarily rural settings. The definition of high- vs low-volume provider also varies widely in these studies, depending on the medical process studied (diagnosis or treatment). Yet, the majority of studies reviewed suggested that volume is positively associated with better outcomes for the diagnosis and surgical treatment of this disease, though the role of physician volume vs facility volume or the interaction of the two is not clear. Perhaps of greater importance, recent studies have detected differences in the pattern of treatment, specifically the greater likelihood of BCS in higher-volume providers. The policy responses to these findings must nonetheless take actual practice patterns into account. Luther and Studnicki,¹¹ for instance, found

that 63% of all breast surgeries in Florida (including one in five mastectomies) were conducted in the outpatient setting. The likelihood that volume-related policies targeting hospitals would have much of an impact is thus questionable. On the other hand, these investigators also found that nearly two-thirds of the physicians performing breast surgery (n = 816) performed fewer than one per month and that 24% (n = 312) performed only one procedure during the 2-year study period. This suggests that volume-related policies targeting physicians may have widespread effects, which might also then create significant resistance to the policy effort. Indeed, it seems likely that the large number of practitioners performing low-volume breast surgery will be one of the first groups to feel threatened by volume-related program efforts and, thereby, the first to engage policy makers and payers in resisting the implementation of such policies.

The overall mixed results in the recent literature also mean that volume-related inefficiencies are doubtless still present in cancer diagnosis and treatment, so failure to come to grips with the issue also has risks and implicit costs. The risks or threats to the quality of cancer care are straightforward, though they should be tempered by the concern of some analysts that shifting referrals to high-volume institutions might actually stimulate unnecessary surgery.⁴ The cost impact of sustaining low-volume providers, while hardly insignificant, is nonetheless only one source, and not necessarily the most important one, of economic inefficiency in cancer care. Means other than volume-related policies may be more effective in achieving cost-containment goals. What is perhaps needed now is a broadly gauged cost-benefit analysis that attempts to quantify the economic consequences of pursuing vs ignoring volume-related policy initiatives, including the implicit costs of diminished quality of care for some patients.

Implications for Future Research

Building a stronger case either for or against the use of volume-related policies in cancer care requires additional research along at least four interrelated lines.

First, the effect of surgeon or hospital volume as the dominant predictor of outcomes must be examined in greater detail, as does the interaction between the two. In colorectal cancer, only one study³⁷ assessed the relative impact of the two levels of volume, and it found that hospital volume may exert a stronger effect than surgeon-specific procedure volume. Volumes must also be delineated by type of policy-relevant categories. For example, Prysowsky and colleagues³⁸ found that after adjusting for risk patients receiving a colon resection by surgeons without American Board of Surgery certification had significantly higher mortality and complication rates. Singh et al³⁹ suggest that specialist units differ from generalists in colorectal morbidity and mortality outcomes. These more

detailed relationships must be examined in future studies of other cancers.

Second, a broader range of outcomes needs to be taken into account. Most studies looked at just short-term mortality, and the few that examined additional variables had only a limited range: preoperative evaluation, adjuvant chemotherapy in stage III disease, or actual patterns of follow-up care, as noted by Hillner and colleagues.²¹ It is important, nonetheless, to recognize that in some cases, especially breast cancer, some measures may not be relevant. To illustrate, outcome measures used with more complex procedures such as in-hospital LOS are not relevant for the vast majority of breast cancer cases. Interestingly, no studies were found that investigated the use of adjuvant radiation therapy (recommended following BCS) related to provider volume. This may relate to the fact that there were no major changes in the recommendations for adjuvant therapies during the period. Nonetheless, measures such as readmission rates or LOS should be examined in more detail.

Third, the manner in which the volume variable is defined or constructed differs considerably. In the lung resection studies, the most common procedure was to divide volume into quartiles or quintiles, but the distributions differed across the studies so that, say, the lowest group used as a referent in hospital volume was 38 in one study but fewer than 5 in another. These differences imply that inflection points in the scale gradient differ, leading to inconsistent inferences in respect to specifying minimal volume standards. Similarly, the characteristics of physicians need to be modeled better. In simply comparing laparoscopic to open surgery for colon cancer, Marusch et al^{40,41} found decreased morbidity and mortality rates with above-average experience and caseload. However, it is unclear what surgical threshold experience level constitutes risk equivalence.

Finally, multivariate modeling of volume effects must be carried out, where physician certification, specialization, patient age, and comorbidities may serve as important covariates. Chen and colleagues⁴² suggest that older age and comorbidities do not necessarily lead to more severe toxic effects from chemotherapy compared with younger patients. However, they conclude that a physician's knowledge about efficacy and treating older and comorbid cancer patients with chemotherapy is an important issue. While this has been studied in relation to morbidity and mortality, the influence of volume, certification, specialization, patient age, and comorbidities in conjunction with adjuvant chemotherapy has yet to be studied. In addition, the occurrence or nonoccurrence of adjuvant chemotherapy/radiation therapy may also rest on the patient's economic and/or time constraints, particularly if a patient faces considerable travel time. The influence of opportunity costs on the decision for adjuvant chemotherapy as well as comprehensive cost-benefit analysis of adjuvant chemotherapy for cancer management may hold promise for future research.

References

1. Epstein AM. Volume and outcome: it is time to move forward. *N Engl J Med*. 2002;346:1161-1164.
2. Shahian DM, Normand ST. The volume-outcome relationship: from Luft to Leapfrog. *Ann Thorac Surg*. 2003;75:1048-1058.
3. Leapfrog Patient Safety Standards: The Potential Benefits of Universal Adoption. Available at: www.leapfroggroup.org/PressEvent/birkmeyer.pdf (May 6, 2002).
4. Birkmeyer JD, Skinner JS, Wennberg DE. Will volume-based referral strategies reduce costs or just save lives? *Health Aff (Millwood)*. 2002;21:234-241.
5. Phillips KA, Luft HS. The policy implication of using hospital and physician volumes as "indicators" of quality of care in a changing health care environment. *Int J Qual Health Care*. 1997;9:341-348.
6. Smith TJ, Hillner BE, Bear HD. Taking action on the volume-quality relationship: how long can we hide our heads in the colostomy bag? *J Natl Cancer Inst*. 2003;95:695-697.
7. Begg CB, Scardino PT. Taking stock of volume-outcome studies. *J Clin Oncol*. 2003;21:393-394.
8. Halm EA, Lee C, Chassin MR. Is volume related to outcome in health care? A systematic review and methodologic critique of the literature. *Ann Intern Med*. 2002;137:511-520.
9. Skinner KA, Helsper JT, Deapen D, et al. Breast cancer: do specialist make a difference? *Ann Surg Oncol*. 2003;10:606-615.
10. Harcourt KE, Hicks KL. Is there a relationship between case volume and survival in breast cancer? *Am J Surg*. 2003;185:407-410.
11. Luther SL, Studnicki J. Physician practice volume and alternative surgical treatment for breast cancer in Florida. *Health Serv Res*. 2001;36:166-179.
12. McKee MD, Cropp MD, Hyland A, et al. Provider case volume and outcome in the evaluation and treatment of patients with mammogram-detected breast cancer. *Cancer*. 2002;95:704-712.
13. Staradub VL, Rademaker AW, Morrow M. Factors influencing outcomes for breast conservation therapy of mammographically detected malignancies. *J Am Coll Surg*. 2003;196:518-524.
14. Esserman L, Cowley H, Eberle C, et al. Improving accuracy of mammography: volume and outcome relationships. *J Natl Cancer Inst*. 2002;94:369-375.
15. Freeman J, Goodwin JS, Zhang D, et al. Measuring the performance of screening mammography in community practice with Medicare claims data. *Women Health*. 2003;37:1-15.
16. Beam CA, Conant EF, Sickles EA. Association of volume and volume-independent factors with accuracy in screening mammogram interpretation. *J Natl Cancer Inst*. 2003;95:282-290.
17. Kelemen PR. Comprehensive review of sentinel lymphadenectomy in breast cancer. *Clin Breast Cancer*. 2000;1:111-125.
18. McMasters KM, Wong SL, Chao C, et al. Defining the optimal surgeon experience for breast cancer sentinel lymph node biopsy: a model for implementation of new surgical techniques. *Ann Surg*. 2001;234:292-299.
19. Cox CE, Salud CJ, Cantor A, et al. Learning curves for breast cancer sentinel lymph node mapping based on surgical volume analysis. *J Am Coll Surg*. 2001;193:593-600.
20. Holm T, Johansson H, Cedermark B. Influence of hospital- and surgeon-related factors on outcome after treatment of rectal cancer with or without preoperative radiotherapy. *Br J Surg*. 1997;84:657-663.
21. Hillner BE, Smith TJ, Desch CE. Hospital and physician volume or specialization and outcomes in cancer treatment: importance in quality of cancer care. *J Clin Oncol*. 2000;18:2327-2340.
22. Schrag D, Cramer LD, Bach PB, et al. Influence of hospital procedure volume on outcomes following surgery for colon cancer. *JAMA*. 2000;284:3028-3035.
23. Marusch F, Koch A, Schmidt U, et al. Effect of caseload on the short-term outcome of colon surgery: results of a multicenter study. *Int J Colorectal Dis*. 2001;16:362-369.
24. Hodgson DC, Fuchs CS, Ayanian JZ. Impact of patient and provider characteristics on the treatment and outcomes of colorectal cancer. *J Natl Cancer Inst*. 2001;93:501-515.

25. Harmon JW, Tang DG, Gordon TA, et al. Hospital volume can serve as a surrogate for surgeon volume for achieving excellent outcomes in colorectal resection. *Ann Surg.* 1999;230:404-411.
26. Romano PS, Mark DH. Patient and hospital characteristics related to in-hospital mortality after lung cancer resection. *Chest.* 1992; 101:1332-1337.
27. Bach PB, Cramer LD, Schrag D, et al. The influence of hospital volume on survival after resection for lung cancer. *N Engl J Med.* 2001;345:181-188.
28. Silvestri GA, Handy J, Lackland D, et al. Specialists achieve better outcomes than generalists for lung cancer surgery. *Chest.* 1998; 114:675-680.
29. Birkmeyer JD, Siewers AE, Finlayson EV, et al. Hospital volume and surgical mortality in the United States. *N Engl J Med.* 2002;346: 1128-1137.
30. Begg CB, Cramer LD, Hoskins WJ, et al. Impact of hospital volume on operative mortality for major cancer surgery. *JAMA.* 1998;280: 1747-1751.
31. Khuri SF, Daley J, Henderson W, et al. Relation of surgical volume to outcome in eight common operations: results from the VA Surgical Quality Improvement Program. *Ann Surg.* 1999;230:414-432.
32. Hannan EL, Radzyner M, Rubin D, et al. The influence of hospital and surgeon volume on in-hospital mortality for colectomy, gastrectomy, and lung lobectomy in patients with cancer. *Surgery.* 2002;131:6-15.
33. Goodney PP, Stukel TA, Lucas FL, et al. Hospital volume, length of stay, and readmission rates in high-risk surgery. *Ann Surg.* 2003; 238:161-167.
34. Handy JR, Asaph JW, Skokan L, et al. What happens to patients undergoing lung cancer surgery? Outcomes and quality of life before and after surgery. *Chest.* 2002;122:21-30.
35. Fry WA, Phillips JL, Menck HR. Ten-year survey of lung cancer treatment and survival in hospitals in the United States: a national cancer data base report. *Cancer.* 1999;86:1867-1876.
36. Rubins JB, Ewing SL, Leroy S, et al. Temporal trends in survival after surgical resection of localized non-small cell lung cancer. *Lung Cancer.* 2000;28:21-27.
37. Schrag D, Panageas KS, Riedel E, et al. Surgeon volume compared to hospital volume as a predictor of outcome following primary colon cancer resection. *J Surg Oncol.* 2003;83:68-78.
38. Prystowsky JB, Bordage G, Feinglass JM. Patient outcomes for segmental colon resection according to surgeon's training, certification, and experience. *Surgery.* 2002;132:663-670.
39. Singh KK, Barry MK, Ralston P, et al. Audit of colorectal cancer surgery by non-specialist surgeons. *Br J Surg.* 1997;84:343-347.
40. Marusch F, Gastineger I, Schneider C, et al. Experience as a factor influencing the indications for laparoscopic colorectal surgery and the results. *Surg Endosc.* 2001;15:116-120.
41. Marusch F, Gastineger I, Schneider C, et al. Importance of conversion for results obtained with laparoscopic colorectal surgery. *Dis Colon Rectum.* 2001;44:207-214.
42. Chen H, Cantor A, Meyer J, et al. Can older cancer patients tolerate chemotherapy? A prospective pilot study. *Cancer.* 2003;97:1107-1114.