Published in final edited form as:

Ann Surg Oncol. 2014 July ; 21(7): 2129–2135. doi:10.1245/s10434-014-3692-8.

Differences in Perioperative Care at Low and High Mortality Hospitals with Cancer Surgery

Sha'Shonda L. Revels, MD MS MA, Sandra L. Wong, MD MS, Mousumi Banerjee, PhD, Huiying Yin, MS, and John D. Birkmeyer, MD

Department of Surgery (SLR, SLW, HY, JDB), Department of Biostatistics, School of Public Health (MB), University of Michigan, Ann Arbor

Abstract

Objective—To evaluate adherence to perioperative processes of care associated with major cancer resections.

Summary Background Data—Mortality rates associated with major cancer resections vary across hospitals. Because mechanisms underlying such variations are not well established, we studied adherence to perioperative care processes.

Methods—1,279 hospitals participating in the National Cancer DataBase (2005-2006) were ranked on a composite measure of mortality for bladder, colon, esophagus, stomach, lung and pancreas cancer operations. We sampled hospitals from among those with the lowest and highest mortality rates, 19 low mortality hospitals (LMHs, risk-adjusted mortality rate 2.84%) and 30 high mortality hospitals (HMHs, risk-adjusted mortality rate 7.37%). We then conducted onsite chart reviews. Using logistic regression we examined differences in perioperative care, adjusting for patient and tumor characteristics.

Results—Compared to LMHs, HMHs were less likely to use prophylaxis against venous thromboembolism, either preoperative or postoperatively (aRR 0.74, 95%CI 0.50-0.92 and aRR 0.80, 95%CI 0.56-0.93, respectively). The two hospital groups were indistinguishable with respect to processes aimed at preventing surgical site infections, such as the use of antibiotics prior to incision (aRR 0.99, 95%CI 0.90-1.04), and processes intended to prevent cardiac events, including use of β -blockers (1.00, 95%CI 0.81-1.14). HMHs were significantly less likely to use epidurals (aRR 0.57, 95%CI 0.32-0.93).

Conclusions—HMHs and LMHs differ in several aspects of perioperative care. These areas may represent opportunities for improving cancer surgery quality at hospitals with high mortality.

Correspondence: John D. Birkmeyer, MD Center for Healthcare Outcomes & Policy, University of Michigan, Building 16, 2800 Plymouth Road, Ann Arbor, MI 48109 734-998-7470 jbirkmey@umich.edu.

Disclosures:

John Birkmeyer has a financial interest in ArborMetrix, Inc., a clinical analytics company focused on hospital- and specialty-based care. The company was not involved with the study herein in any way.

Introduction

Major cancer resections are associated with considerable morbidity and mortality. Despite recent trends towards declining mortality rates overall, there remain significant differences in outcomes across hospitals.¹⁻³ For example, perioperative mortality rates for pancreatic cancer range from 1-16%.⁴ Although these data suggest that there is considerable room for quality improvement, how to best achieve this goal remains uncertain.^{2,5} Among many efforts intended to reduce such variation, professional organizations such as the American College of Surgeons, have implemented national outcomes registries aimed at providing hospitals with performance feedback. Others are pushing operative checklists designed to reduce errors and enhance teamwork in the operating room. Despite the potential benefits associated with these programs, none are designed to provide hospitals with insight on exactly how to improve outcomes.

A better understanding of how perioperative care differs at hospitals with low and high mortality might help fill this knowledge gap. Hospitals with low mortality rates may be more likely to adopt practice patterns known to be protective against adverse outcomes related to cancer surgery. Specifically, low mortality hospitals (LMHs) may deliver more effective medical prophylaxis aimed at reducing surgical site infections (SSIs), venous thromboembolism (VTE) and cardiopulmonary complications, among the leading causes of death in this patient population.⁶⁻⁸ LMHs may also be more aggressive with monitoring for hemodynamic instability, and the delivery of more effective pain control, which may lead to fewer cardiac and respiratory complications.⁹⁻¹¹

In this context we performed a national cohort study of 19 low mortality and 30 high mortality hospitals (HMHs). This study summarizes the extent to which low and high mortality hospitals differ in practice patterns in the management of patients undergoing major resections for bladder, colon, esophagus, stomach, lung and pancreas cancers.

Methods

Database and Subjects

The Commission on Cancer (CoC) National Cancer Database (NCDB) is a nationwide oncology outcomes program maintained by the American College of Surgeons and the American Cancer Society. The database represents over 1,200 cancer programs and over 70% of newly diagnosed cancer cases in the United States and Puerto Rico. Information on all types of cancer are prospectively tracked, analyzed and submitted to the NCDB. The database includes information on patient, tumor, treatment, survival and hospital characteristics.¹²

To identify the best and worst hospitals all 1,279 hospitals participating in the NCDB, 2005-2006, were identified and ranked according to a composite measure derived from operative volume and mortality for major resections of six cancers, including bladder, colon, esophagus, stomach, lung and pancreas. Methods used to define the composite measure have been previously described in detail by our group.¹³⁻¹⁵ Hospitals were ranked by their composite score and the highest and lowest hospitals were invited to participate. Starting at

the top with very low mortality hospitals and at the bottom with very high mortality hospitals, we enrolled facilities until we reached the number implied by our sample size calculations. From among 41 very low mortality hospitals recruited, 22 declined participation. As a result, a total of 19 LMHs (unadjusted mortality 1.96%) were enrolled in the study. Of the 77 very high mortality hospitals recruited, 47 declined to participate. Subsequently, 30 HMMs (unadjusted mortality 9.37%) were enrolled in the study. Participating hospitals were representative of the entire gamut of the lowest and highest ranking hospitals and even though a relatively large number of hospitals declined to participate (from both groups), those that did truly represent the “extremes.” Following the hospital selection process, onsite chart reviews were conducted at each facility. Due to inadequate data abstraction, 2 LMHS and 4 HMMs were excluded, and as a result 17 LMHs and 26 HMMs were included the analyses (Figure 1).

Trained data abstractors performed onsite chart reviews of patients undergoing major resections for bladder, colon, esophagus, gastric, lung and pancreas cancers, (2006-2007) at the 49 participating facilities. Abstractors received training and a detailed instruction manual and data dictionary prior to the start of data collection. We maintained an open contact with abstractors in case there were any questions during the data collection process. Among hospitals with 150 patients all records were abstracted. In higher volume hospitals with >150 patients a random sample of up to 150 patients were selected for review in order to minimize data collection burden at larger hospitals. A total of 5,632 patients were included in the study, with 2,708 patients treated in LMHs and 2,924 treated in HMMs.

Investigators and hospitals were blinded regarding the performance status of each center. A validated data collection tool was used to capture patient level information on the receipt of 11 clinical practices related to important aspects of general perioperative care.¹⁶ Seven of the 11 measures reflected aspects of complication prophylaxis, including 3 related to SSIs, 3 related to VTE and 1 related to cardiac events. In addition we collected 4 variables related to perioperative hemodynamic monitoring and pain control.

Analysis

Our primary goal was to compare practice patterns at HMMs and LMHs. Risk-adjusted adherence rates, by hospital rank (HMM or LMH), were estimated using standard logistic regression. A similar model was used to obtain risk-adjusted odds ratios of receipt of specified processes of care, based on hospital rank (HMM vs. LMH). The covariates used for risk-adjustment included race, gender, age, American Society of Anesthesiologists Physical Status Class (ASA), comorbid conditions,¹⁷ functional status, dyspnea, ischemic heart disease, congestive heart failure, diabetes, cancer type, cancer stage and receipt of emergency surgery. All variance inflation factors were less than 10, indicating minimal correlation among the independent variables. To better estimate the effect of hospital rank on the receipt of the selected process of care, adjusted risk ratios were approximated from the adjusted odds ratios using a method adopted from Zhang and colleagues.¹⁸ All analyses were adjusted for clustering of patients within hospitals using robust estimates for the standard error.

Analyses were performed using SAS [9.1] (SAS institute, Cary, NC) and STATA [12] (StataCorp, College Station, TX) software. $P < 0.05$ was considered statistically significant, and all tests were two-sided. The Institutional Review Board of the University of Michigan approved the study protocol.

Results

Patient characteristics

In general, patients treated at high mortality hospitals had greater illness severity, compared to those at low mortality hospitals. HMMs had more patients with >2 comorbid conditions (22.1% vs. 16.2%, $p < 0.001$), ASA class of 4 or 5 (13.1% vs. 5.7%, $p < 0.001$), and patients who were dependent in regards to functional status (12.9% vs. 5.4%, $p < 0.001$). Patients treated at HMMs were also more likely to have stage 4 cancer (12.1% vs. 9.3%, $p < 0.001$). We observed significant differences in the types of cancer resections performed at the two groups of hospitals. LMHs performed a higher proportion of complex resections, with higher baseline risk, compared with HMMs. For example, LMH hospitals performed significantly more esophagus (6.9% vs. 1.3%, $p < 0.001$) and pancreas (7.5% vs. 2.5%, $p < 0.001$) resections. Colectomies represented 69.0% of the procedures performed at HMMs. Overall, HMMs performed a higher percentage of emergency surgeries (6.3% vs. 3.3%, $p < 0.001$). Before risk-adjustment mortality rates at low and high mortality hospitals were, 1.96% and 9.37%, respectively. After risk adjustment, the difference in mortality rates narrowed, but was nonetheless substantial (LMHs 2.84% vs. HMMs 7.37, Table 1).

Hemodynamic Monitoring and Pain Control

Compared with patients at LMHs, those undergoing treatment at HMMs were less likely to receive hemodynamic monitoring with arterial lines (adjusted Relative Risk [aRR] 0.30, 95% CI 0.17-0.47). Overall, central venous and pulmonary artery catheters were used infrequently, and there were no measurable differences between the two hospital groups (Figure 2). HMMs also had significantly lower rates of epidural catheter usage for post-operative pain management (aRR 0.57, 95% CI 0.32-0.93, Figure 2).

Prophylaxis against Complications

Rates of preoperative VTE chemoprophylaxis were low overall, and did not differ significantly between high and low mortality hospitals (aRR 0.79, 95% CI 0.39-1.38). However, HMMs were significantly less likely to use sequential compression devices (SCDs) before surgery, compared with LMHs (aRR 0.64 95% CI 0.38-0.88). In the postoperative period, the adjusted rate of VTE chemoprophylaxis use was significantly lower among HMMs compared to LMHs, 41.7% and 63.7%, respectively (aRR 0.55, 95% CI 0.31-0.85). The adjusted rate of postoperative SCD use was also lower among HMMs, 62.8% compared to 76.2% in LMHs, though this did not reach statistical significance (aRR, 0.77 95% CI 0.47-1.01, Table 2).

The two hospital groups were similar in their use of SSI prophylaxis (Figure 3). There were no significant variations in the use of prophylactic antibiotics one hour prior to incision (aRR 0.99, 95% CI 0.90-1.04). Both groups were also equally likely to record glucose levels

on postoperative day 1 (aRR 1.03, 95%CI 0.89-1.09), and employ hyperglycemia management protocols (aRR 0.83, 95%CI 0.53-1.19). However, HMMs were more likely to continue antibiotics >24 hours after surgery (aRR 1.43, 95%CI 1.06-1.73). In terms of cardiovascular protective measures, LMHs and HMMs were indistinguishable in their continuation of β -blocker therapy in patients prescribed β -blockers prior to surgery (aRR 1.00, 95% CI 0.81-1.14).

Discussion

Among a nationwide sample of hospitals, we identified substantial variation in perioperative mortality for major lung, colon, esophagus, stomach, pancreas and bladder cancer resections. The highest and lowest mortality hospitals did have different types of patients, noting greater illness severity at high mortality hospitals. The highest mortality hospitals have older and sicker patients and perform more emergency surgery.

Onsite chart reviews performed at hospitals with very low mortality and hospitals with very high mortality also revealed significant variations in perioperative practice patterns. Specifically, HMMs were less likely to use intraoperative hemodynamic monitoring, preoperative SCDs, postoperative VTE chemoprophylaxis and epidural catheters. Conversely, HMMs and LMHs were virtually indistinguishable with regard to SSI prophylaxis, including the use of antibiotics 1 hour prior to incision, and cardio-protective measures, such as the continuation of β -blockers in the perioperative period. Among a small number of studies that have compared practices at hospitals according to their outcomes, this study is the most comprehensive to date and focuses on several evidence based practices across multiple domains of perioperative care.

Other studies have similarly compared practices at hospitals with low and high rates with surgery. Perhaps the most widely recognized of these is a two part study performed in the Department of Veterans Affairs based on its Surgical Quality Improvement Program (VAQIP). Daley and colleagues performed site visits at hospitals with higher than expected and lower than expected mortality rates. Quality ratings were consistently higher for low outlier hospitals across seven domains of quality, and were statistically significant for overall quality of care and the availability of surgical technology and equipment. There were no significant differences in regards to the collection and monitoring of performance indicators or in areas of communication and care coordination.¹⁹ A subsequent chart review by the same group aimed at validating the relationship between risk-adjusted outcomes and practice patterns did not identify measurable differences in adherence to processes of care between low and high mortality outliers.²⁰

Given the nature of the study design, our analysis was not aimed at addressing causal inference between practice patterns and surgical outcomes. In our study, hospitals were enrolled based on outcomes, hence assessing relationships between processes and outcomes would be tautological. In other words, our study does not necessarily imply that specific aspects of perioperative care are responsible for differences in outcomes between the two hospital groups. However, those relationships can be considered in the context of previous literature. For example, it should not be surprising that prophylactic strategies against VTE

are associated with hospital mortality. VTE, and more specifically pulmonary embolism, are among the leading causes of death among people undergoing cancer surgery.²¹ There is a large body of randomized clinical trials that have examined the effectiveness of various combinations of prophylaxis and have demonstrated reduced VTE rates with pharmacologic prophylaxis in cancer patients.²² Finally, previous hospital level studies have suggested that those with higher compliance rates with VTE prophylaxis have lower rates of VTE and mortality.^{23,24}

Our findings that LMHs employed hemodynamic monitoring more frequently are also consistent with the literature in this regard. A meta-analysis by Hamilton and colleagues revealed that invasive monitoring reduced surgical mortality and morbidity among high risk patients.²⁵ It is important to note that many of the randomized controlled trials included in this meta-analysis included interventions beyond hemodynamic monitoring, so there remains questions about the independent effect of monitoring alone.

With regard to epidurals, we found that LMHs had substantially higher rates of catheter placement. Although we found that LMHs had higher rates of epidural use the casual relationship between epidural catheters and surgical mortality remains unclear. Epidural catheters are often employed for major thoracic and abdominal cancer resections because there is evidence that epidurals provide superior pain control and reduce the incidence of pulmonary complications, compared to systemic opioids.^{9,26-29} While the results of a large number of clinical trials have been mixed, a meta-analysis of clinical trials among colectomy patients comparing epidural to parenteral opioids failed to identify any reduction in cardiopulmonary complications.²⁷ In this context, our findings suggest the possibility that the routine placement of epidurals maybe a proxy of other aspects of perioperative care or hospital resources related to better outcomes.

Likewise, our null findings regarding SSI prophylaxis are consistent with what is known in this area. While process measures regarding antibiotic prophylaxis in surgical patients have been widely accepted, numerous large population based studies have failed to demonstrate that hospitals with high compliance rates with Surgical Care Improvement Project SSI measures (SCIP-SSI) have lower SSI rates.³⁰⁻³² For example, Campbell et al examined practices at hospitals with low and high SSI rates, respectively. Low outlier hospitals were easily identified by site visitors. However, there were no measurable differences in the employment of SCIP measures designed to prevent SSIs, such as the use of antibiotics 1 hour prior to incision.³⁰ Furthermore, since most SSIs are not fatal, it is not surprising that this process measure is not strongly linked with mortality.

With regards to beta-blocker use, our findings that LMHs and HMHs have similar compliance rates are consistent with the current literature. The literature about the effectiveness of beta-blocker administration is mixed.^{33,34} While some studies document advantages for high risk patients³⁵, subgroups analyses of broader population groups failed to confirm the benefit of perioperative beta-blockers, specifically suggesting harm in low risk patients.³⁴

Our study has several limitations. First, only CoC accredited hospitals were enrolled in the project. Hospitals participating in the NCDB are not a random sample of facilities performing cancer surgery in the US. Even though we are examining very high and very low mortality hospitals which do demonstrate variation in illness severity, it is possible that CoC hospitals as a group are more committed to quality improvement and that compliance rates and outcomes are not generalizable to other hospitals that provide cancer care. Secondly, for practical reasons, only hospitals at the extremes of mortality were sampled, thus practice patterns at the large majority of hospitals with intermediate levels of mortality are unknown. However, our findings about clinical practice patterns should be relevant across the entire spectrum of performance. Third, this study only focuses on a subset of perioperative practices and there are no doubt many other aspects of practice, in and outside of the operating room, which could help explain differences in mortality rates across hospitals.

Based on our own analysis of the National Inpatient Sample, over 5,000 patients die annually after major cancer resections.³⁶ These large variations in mortality across hospitals suggest the possibility that some of these deaths could be avoided with quality improvement. Although our study does not provide definitive evidence about the effectiveness of particular practices, it does highlight several potential opportunities for further implementation and evaluation.

Acknowledgments

This work was supported by the National Cancer Institute at the National Institutes of Health (NCI R01 CA098481 to JDB) and the National Cancer Institute at the National Institutes of Health (2T32 CA009672-21 to SLR).

References

1. Finks JF, Osborne NH, Birkmeyer JD. Trends in hospital volume and operative mortality for high-risk surgery. *The New England journal of medicine*. 2011; 364(22):2128–2137. [PubMed: 21631325]
2. Birkmeyer JD, Finlayson SR, Tosteson AN, Sharp SM, Warshaw AL, Fisher ES. Effect of hospital volume on in-hospital mortality with pancreaticoduodenectomy. *Surgery*. Mar; 1999 125(3):250–256. [PubMed: 10076608]
3. Ghaferi AA, Birkmeyer JD, Dimick JB. Hospital volume and failure to rescue with high-risk surgery. *Medical care*. 2011; 49(12):1076–1081. [PubMed: 22002649]
4. National Cancer Institute National Institutes of Health. [October 15, 2012] Pancreatic Cancer Treatment. <http://www.cancer.gov/cancertopics/pdq/treatment/pancreatic/HealthProfessional/page5>.
5. Begg CB, Cramer LD, Hoskins WJ, Brennan MF. Impact of hospital volume on operative mortality for major cancer surgery. *JAMA : the journal of the American Medical Association*. Nov 25; 1998 280(20):1747–1751. [PubMed: 9842949]
6. Anderson DJ, Kaye KS, Classen D, et al. Strategies to prevent surgical site infections in acute care hospitals. *Infect Control Hosp Epidemiol*. Oct; 2008 29(Suppl 1):S51–61. [PubMed: 18840089]
7. U.S. Centers for Disease Control and Prevention. [November 19, 2012] Healthcare-associated Infections (HAIs). www.cdc.gov/HAI/burden.html.
8. Kirkland KB, Briggs JP, Trivette SL, Wilkinson WE, Sexton DJ. The impact of surgical-site infections in the 1990s: attributable mortality, excess length of hospitalization, and extra costs. *Infect Control Hosp Epidemiol*. Nov; 1999 20(11):725–730. [PubMed: 10580621]
9. Zingg U, Smithers BM, Gotley DC, et al. Factors associated with postoperative pulmonary morbidity after esophagectomy for cancer. *Annals of surgical oncology*. May; 2011 18(5):1460–1468. [PubMed: 21184193]

10. Warschkow R, Steffen T, Luthi A, et al. Epidural analgesia in open resection of colorectal cancer: is there a clinical benefit? a retrospective study on 1,470 patients. *Journal of gastrointestinal surgery : official journal of the Society for Surgery of the Alimentary Tract*. Aug; 2011 15(8): 1386–1393. [PubMed: 21647766]
11. Popping DM, Elia N, Marret E, Remy C, Tramer MR. Protective effects of epidural analgesia on pulmonary complications after abdominal and thoracic surgery: a meta-analysis. *Arch Surg-Chicago*. Oct; 2008 143(10):990–999. discussion 1000. [PubMed: 18936379]
12. [November 2, 2012] American College of Surgeons Cancer Programs National Cancer Data Base. <http://www.facs.org/cancer/ncdb/>.
13. Staiger DO, Dimick JB, Baser O, Fan Z, Birkmeyer JD. Empirically derived composite measures of surgical performance. *Medical care*. Feb; 2009 47(2):226–233. [PubMed: 19169124]
14. Dimick JB, Staiger DO, Baser O, Birkmeyer JD. Composite measures for predicting surgical mortality in the hospital. *Health affairs*. Jul-Aug;2009 28(4):1189–1198. [PubMed: 19597221]
15. Dimick JB, Ghaferi AA, Osborne NH, Ko CY, Hall BL. Reliability adjustment for reporting hospital outcomes with surgery. *Annals of surgery*. Apr; 2012 255(4):703–707. [PubMed: 22388108]
16. Waljee JF, Windisch S, Finks JF, Wong SL, Birkmeyer JD. Classifying cause of death after cancer surgery. *Surg Innov*. 2006; 13(4):274–279. [PubMed: 17227926]
17. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. *Medical care*. Jan; 1998 36(1):8–27. [PubMed: 9431328]
18. Zhang J, Yu KF. What's the relative risk? A method of correcting the odds ratio in cohort studies of common outcomes. *JAMA : the journal of the American Medical Association*. Nov 18; 1998 280(19):1690–1691. [PubMed: 9832001]
19. Daley J, Forbes MG, Young GJ, et al. Validating risk-adjusted surgical outcomes: site visit assessment of process and structure. *National VA Surgical Risk Study*. *J Am Coll Surgeons*. Oct; 1997 185(4):341–351.
20. Gibbs J, Clark K, Khuri S, Henderson W, Hur K, Daley J. Validating risk-adjusted surgical outcomes: chart review of process of care. *Int J Qual Health Care*. Jun; 2001 13(3):187–196. [PubMed: 11476143]
21. Geerts WH, Pineo GF, Heit JA, et al. Prevention of venous thromboembolism: the Seventh ACCP Conference on Antithrombotic and Thrombolytic Therapy. *Chest*. Sep; 2004 126(3 Suppl):338S–400S. [PubMed: 15383478]
22. Leonardi MJ, McGory ML, Ko CY. A systematic review of deep venous thrombosis prophylaxis in cancer patients: implications for improving quality. *Annals of surgical oncology*. Feb; 2007 14(2): 929–936. [PubMed: 17103259]
23. Kwon S, Meissner M, Symons R, et al. Perioperative pharmacologic prophylaxis for venous thromboembolism in colorectal surgery. *J Am Coll Surgeons*. Nov; 2011 213(5):596–603. 603, e591.
24. Amin AN, Lin J, Johnson BH, Schulman KL. Clinical and economic outcomes with appropriate or partial prophylaxis. *Thrombosis research*. Jun; 2010 125(6):513–517. [PubMed: 19931121]
25. Hamilton MA, Cecconi M, Rhodes A. A systematic review and meta-analysis on the use of preemptive hemodynamic intervention to improve postoperative outcomes in moderate and high-risk surgical patients. *Anesthesia and analgesia*. Jun; 2011 112(6):1392–1402. [PubMed: 20966436]
26. Rigg JR, Jamrozik K, Myles PS, et al. Epidural anaesthesia and analgesia and outcome of major surgery: a randomised trial. *Lancet*. Apr 13; 2002 359(9314):1276–1282. [PubMed: 11965272]
27. Marret E, Remy C, Bonnet F. Meta-analysis of epidural analgesia versus parenteral opioid analgesia after colorectal surgery. *The British journal of surgery*. Jun; 2007 94(6):665–673. [PubMed: 17514701]
28. Brettmann RD, Kniesel B, Herden HN, Teichmann W. [The effect of continuous thoracic peridural anesthesia on the pulmonary function of patients undergoing colon surgery. Results of a randomized study of 116 patients]. *Reg Anaesth*. Jan; 1991 14(1):2–8. [PubMed: 2006346]

29. Halabi WJ, Jafari MD, Nguyen VQ, et al. A Nationwide Analysis of the Use and Outcomes of Epidural Analgesia in Open Colorectal Surgery. *Journal of gastrointestinal surgery : official journal of the Society for Surgery of the Alimentary Tract*. Apr 18.2013
30. Campbell DA Jr, Henderson WG, Englesbe MJ, et al. Surgical site infection prevention: the importance of operative duration and blood transfusion--results of the first American College of Surgeons-National Surgical Quality Improvement Program Best Practices Initiative. *J Am Coll Surgeons*. Dec; 2008 207(6):810–820.
31. Ingraham AM, Cohen ME, Bilimoria KY, et al. Association of Surgical Care Improvement Project Infection-Related Process Measure Compliance with Risk-Adjusted Outcomes: Implications for Quality Measurement. *J Am Coll Surgeons*. Dec; 2010 211(6):705–714.
32. Hawn MT, Richman JS, Vick CC, et al. Timing of Surgical Antibiotic Prophylaxis and the Risk of Surgical Site Infection. *JAMA Surg*. Mar 20.2013 :1–8.
33. Lindenauer PK, Fitzgerald J, Hoople N, Benjamin EM. The potential preventability of postoperative myocardial infarction: underuse of perioperative beta-adrenergic blockade. *Archives of internal medicine*. Apr 12; 2004 164(7):762–766. [PubMed: 15078646]
34. Bangalore S, Wetterslev J, Pranesh S, Sawhney S, Gluud C, Messerli FH. Perioperative beta blockers in patients having non-cardiac surgery: a meta-analysis. *Lancet*. Dec 6; 2008 372(9654):1962–1976. [PubMed: 19012955]
35. London MJ, Hur K, Schwartz GG, Henderson WG. Association of perioperative beta-blockade with mortality and cardiovascular morbidity following major noncardiac surgery. *JAMA : the journal of the American Medical Association*. Apr 24; 2013 309(16):1704–1713. [PubMed: 23613075]
36. Finlayson EV, Goodney PP, Birkmeyer JD. Hospital volume and operative mortality in cancer surgery: a national study. *Arch Surg-Chicago*. Jul; 2003 138(7):721–725. discussion 726. [PubMed: 12860752]

Figure 1.
Study Design and Hospital Enrollment

CVC: Central venous catheter

Figure 2.
Risk-Adjusted Rates of Hemodynamic Monitoring and Pain Control in Low and High Mortality Hospitals.

Figure 3.
Risk-Adjusted Rates of Prophylaxis Against Surgical Site Infections in Low and High Mortality Hospitals.

Table 1

Characteristics of Patients Undergoing Major Cancer Resections in Low and High Mortality Hospitals.

Characteristics	Low Mortality Hospitals	High Mortality Hospitals	p-value
Number of patients	2,708	2,924	
Number of hospitals	19	30	
Patient Characteristics			
Age, mean	67.8	69.1	<0.01
Race (black)	136 (5.0%)	324 (11.1%)	<0.01
Gender (female)	1291 (47.7%)	1394 (47.7%)	1.00
Comorbid Conditions (>2)	440 (16.2%)	647 (22.1%)	<0.01
ASA Class (4/5)	155 (5.7%)	384 (13.1%)	<0.01
Functional Status (partially/totally dependent)	146 (5.4%)	377 (12.9%)	<0.01
Ischemic Heart Disease	464 (17.1%)	551 (18.8%)	0.018
Congestive Heart Failure	116 (4.3%)	251 (8.6%)	<0.01
Diabetes	456 (16.8%)	655 (22.4%)	<0.01
BMI	27.29	27.83	<0.01
Albumin	3.81	3.46	<0.01
Creatinine	1.05	1.08	<0.01
Hematocrit	36.88	34.95	<0.01
Platelets	270.30	284.54	<0.01
Emergency Surgery	89 (3.3%)	183 (6.3%)	<0.01
Tumor Characteristics			
Cancer Types			
Lung	927 (34.2%)	572 (19.6%)	<0.01
Colon	1006 (37.1%)	2019 (69.0%)	
Esophagus	186 (6.9%)	37 (1.3%)	
Stomach	197 (7.3%)	132 (4.5%)	
Pancreas	204 (7.5%)	72 (2.5%)	
Bladder	188 (6.9%)	92 (3.1%)	
Stage			
0/I	941 (34.7%)	980 (33.5%)	<0.01
II	659 (24.3%)	796 (27.2%)	
III	531 (19.6%)	650 (22.2%)	
IV	252 (9.3%)	355 (12.1%)	
Mortality			
Unadjusted Mortality	1.96%	9.37%	
Risk-Adjusted Overall Mortality*	2.84%	7.37%	

Table 2

Risk-Adjusted Venous Thromboembolism (VTE) Prophylaxis in Low Mortality and High Mortality Hospitals.

Venous Thromboembolism (VTE) Prophylaxis	Low Mortality Hospitals	High Mortality Hospitals	Relative Risk (95% Confidence Interval)
Preoperative VTE Prophylaxis			
Any Chemoprophylaxis, %	29.5	24.4	0.79 (0.39-1.38)
Lovenox, %	2.3	9.6	--
Unfractionated Heparin, %	25.8	14.2	--
Sequential compression devices (SCDs), %	81.7	61.3	0.64 (0.38-0.88)
Both chemoprophylaxis and SCDs, %	23.3	13.7	0.49 (0.20-1.13)
Either chemoprophylaxis or SCDs, %	87.8	72.0	0.74 (0.50-0.92)
Postoperative VTE Prophylaxis			
Any Chemoprophylaxis, %	63.7	41.7	0.55 (0.31-0.85)
Lovenox, %	16.6	22.2	--
Unfractionated Heparin, %	47.8	19.5	--
Sequential compression devices (SCDs), %	76.2	62.8	0.77 (0.47-1.01)
Both chemoprophylaxis and SCDs, %	48.1	25.5	0.43 (0.21-0.78)
Either chemoprophylaxis or SCDs, %	91.6	78.9	0.80 (0.56-0.93)