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Preoperative Laboratory Testing in Patients Undergoing Elective, Low-Risk Ambulatory Surgery

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Abstract

Background—Routine preoperative laboratory testing for ambulatory surgery is not recommended.

Methods—Patients who underwent elective hernia repair (N = 73,596) were identified from the National Surgical Quality Improvement Program (NSQIP) database (2005–2010). Patterns of preoperative testing were examined. Multivariate analyses were used to identify factors associated with testing and postoperative complications.

Results—A total of 46,977 (63.8%) patients underwent testing, with at least one abnormal test recorded in 61.6% of patients. In patients with no NSQIP comorbidities (N = 25,149) and no clear indication for testing, 54% received at least one test. In addition, 15.3% of tested patients underwent laboratory testing the day of the operation. In this group, surgery was done despite abnormal results in 61.6% of same day tests. In multivariate analyses, testing was associated with older age, ASA (American Society of Anesthesiologists) class >1, hypertension, ascites, bleeding disorders, systemic steroids, and laparoscopic procedures. Major complications (reintubation, pulmonary embolus, stroke, renal failure, coma, cardiac arrest, myocardial infarction, septic shock, bleeding, or death) occurred in 0.3% of patients. After adjusting for patient and procedure characteristics, neither testing nor abnormal results were associated with postoperative complications.

Conclusions—Preoperative testing is overused in patients undergoing low-risk, ambulatory surgery. Neither testing nor abnormal results were associated with postoperative outcomes. On the basis of high rates of testing in healthy patients, physician and/or facility preference and not only patient condition currently dictate use. Involvement from surgical societies is necessary to establish guidelines for preoperative testing.

Keywords

ambulatory surgery; low-risk surgery; overuse; preoperative evaluation; preoperative laboratory testing

Over the last 2 decades, the indications for ambulatory surgery have expanded, with an increasing number of surgical procedures performed in the ambulatory setting. Currently

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60% to 70% of the surgical procedures performed in the United States each year are performed in the ambulatory setting.^{1,2} Ambulatory surgical procedures are generally less than 1 to 2 hours in duration, have low expected blood loss and complication rates, minimal expected postoperative care, and are usually performed in patients with no medical problems or with stable chronic medical conditions.

As surgical and anesthetic techniques have evolved, evidence-based guidelines regarding preoperative testing have lagged. In the United States, current recommendations for preoperative testing are based on the 2002 Practice Advisory from the American Society of Anesthesiologists (ASA) Task Force on Preanesthesia Evaluation.³ These recommendations represent a synthesis of expert opinion and are not based on a sufficient number of adequately powered and controlled trials. Moreover, there are inconsistencies between authorities, and the language of current recommendations is imprecise. For example, “advanced age” is often used as an indication for testing without a clear minimum age. Table 1 summarizes the recommendations of the ASA,³ the Canadian Anesthesiologists’ Society (CAS),⁴ and the Ontario Preoperative Testing Group (OPTG).^{5,6} In addition, recommendations for preoperative testing vary widely on the basis of single-institution studies and systematic reviews.^{7–10}

While the cost of individual tests may be low, the aggregate costs can be substantial.^{11,12} In the United States, the current estimated cost of preoperative testing is \$3 billion to 18 billion annually.^{7,13,14} On the basis of single-institution studies and literature reviews, many advocate against routine preoperative laboratory testing in asymptomatic and clinically normal patients who are undergoing elective, low-risk surgery.^{5,7–12,14–17} It also has been shown that abnormal results in testing done before elective low-risk surgery change management in less than 3% of cases.^{5,11,15} Although these groups advocate against “routine” testing, they fail to outline clear and consistent guidelines or indications for specific tests. Several studies, including 2 randomized controlled trials, have evaluated the elimination of preoperative testing in patients undergoing low-risk surgery and have demonstrated no difference in adverse events.^{1,17,18}

Despite these data, several single-institution studies document overuse of preoperative testing in the low-risk, ambulatory setting.^{5,11,19} However, the use of preoperative testing has not been studied at the population level. Our study uses the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database to examine current patterns of preoperative laboratory testing in patients undergoing elective hernia repair, a representative low-risk ambulatory operation. Specifically, we examine preoperative testing in all patients and a subgroup with no NSQIP-measured comorbidities and, therefore, no clear indication for pre-operative testing. Finally, this study identifies factors associated with preoperative laboratory testing and examines 30-day outcomes in tested and untested patients and patients with normal and abnormal test results.

METHODS

Data Source

The NSQIP is a nationally validated, risk-adjusted, outcomes-based program designed to measure and improve the quality of surgical care. Sponsored by the American College of Surgeons, NSQIP collects data for patients undergoing inpatient and outpatient surgical procedures at participating institutions. In 2010, data were collected from 258 university and private sector medical centers.

For the time period studied, data were collected by trained research nurses at each institution using a systematic sampling of general and vascular operations performed in each

participating institution and submitted via the NSQIP Web site (www.acsnsqip.org). To ensure high-quality data, multiple training mechanisms have been developed for the research nurses, and regular interrater reliability audits of participating sites are performed. Results from audits completed to date reveal an overall disagreement rate of approximately 1.8% for all program variables. Multiple studies have previously validated the NSQIP data and methodology.^{20,21} Data are available for participating institutions on a yearly basis as Participant Use Data Files (PUF). Each PUF contains 240 Health Insurance Portability and Accountability Act (HIPAA) compliant variables for each case, including patient demographics, preoperative risk factors, baseline comorbidities, intraoperative variables, and 30-day postoperative morbidity and mortality. The list and definitions of variables collected in the database can be found at the American College of Surgeons NSQIP Web site.²² Patients are contacted either by letter or telephone survey after discharge to ensure a full 30-day follow-up period. All information in the database is de-identified.

Cohort Selection

The PUF files include 1,334,886 patients who underwent surgery at participating institutions between 2005 and 2010. Patients who underwent hernia repair were selected using current procedural terminology codes for open or laparoscopic inguinal hernia repair (49505, 49520, 49525, 49650, and 49651), femoral hernia repair (49550 and 49555), umbilical hernia repair (49585), and epigastric hernia repair (49570). We applied the following inclusion criteria: (1) age older than 18 years, (2) elective surgery, (3) same-day admission, (4) no surgical procedures in preceding 30 days, and (5) no additional surgical procedures at the time of the hernia repair. A total of 84,813 patients met our inclusion criteria. We eliminated patients with ASA physical status class 4 or 5, cancer-related conditions and therapies, acute renal failure, impaired sensorium, ventilatory support, and sepsis, where preoperative testing was clearly indicated and ambulatory surgery was not indicated. In addition, pregnant patients and patients with missing age, gender, or race were excluded. The final cohort included 73,596 patients (Fig. 1).

Patient characteristics included age, gender, race, height, weight, and presence of comorbidities. Procedure-related variables included year of surgical procedure, type of anesthesia received (general vs other), anatomical location of the hernia (inguinal, femoral, umbilical, epigastric hernias), use of laparoscopic versus open technique, and repair of initial versus recurrent hernia.

Laboratory Testing

Preoperative laboratory testing was defined as any laboratory test obtained within 30 days of surgery. Laboratory tests collected in NSQIP included hematocrit, white blood cell (WBC) count, platelet count, sodium, blood urea nitrogen (BUN), creatinine, partial thromboplastin time (PTT), prothrombin time (PT), International Normalized Ratio (INR), albumin, total bilirubin, aspartate aminotransferase (AST), and alkaline phosphatase. Preoperative tests were grouped by type. Hematology tests included hematocrit, WBC, and/or platelets. Chemistry tests included sodium, BUN, and/or creatinine. Coagulation tests included PTT, PT, and/or INR. Liver function test (LFT) panel included albumin, AST, total bilirubin, and/or alkaline phosphatase. The majority of the patients who had a hematology test (91.9%), chemistry tests (89.8%), and LFTs (89.0%) had all tests included in the panel. In the case of patients who had a coagulation test, the majority had either all tests (77.4%) or a combination of tests (18.1%) drawn at the same time.

Normal value ranges were defined using our institution's laboratory ranges. A hematocrit between 34% and 45%, a WBC count between 4000/mm³ and 12,000/mm³, and platelets between 150,000/mm³ and 400,000/mm³ were considered normal. Sodium levels between

135 and 145 mmol/L, BUN less than 23 mg/dL, and creatinine less than 1.04 mg/dL were considered normal. Coagulation tests were considered normal if PTT was less than 38 seconds, PT less than 14.7 seconds, and an INR less than 1.5. LFTs were considered normal if albumin was greater than 3.5 g/dL, total bilirubin less than 1.1 mg/dL, AST less than 40 Units/L, and alkaline phosphatase less than 122 units/L.

Outcomes

The primary outcome was the percentage of patients undergoing preoperative testing, both overall and by test type. Analyses were performed in the subgroups of patients with no comorbidities and those undergoing testing the day of surgery.

We also evaluated the incidence of major and wound-related complications. Major postoperative complications were defined as the incidence of unplanned intubation, pulmonary embolism, stroke, coma for greater than 24 hours, renal failure requiring dialysis, myocardial infarction, cardiac arrest, sepsis, septic shock, blood transfusions, or death. Wound-related complications included superficial and deep surgical site infections, organ space infections, and wound dehiscence.

Statistical Analysis

Summary statistics were performed for the overall cohort, and the use of preoperative testing (any and specific tests) was extensively described for the overall cohort and subgroups. Patient and procedure characteristics were compared between patients who received preoperative laboratory testing and those who did not. Although all the comorbidities recorded in the NSQIP database were used during the analyses, those with an incidence less than 1% in both groups (pneumonia, congestive heart failure, active angina, myocardial infarction, peripheral vascular disease, rest pain, active wound infection, dialysis, ascites, esophageal varices, preoperative blood transfusion, hemiplegia, paraplegia, quadriplegia, and recent weight loss) are not reported in the cohort description. Chi-square tests were used to compare categorical variables, and results were expressed as percentages. The student *t* test was used to determine differences between continuous variables, and results were expressed as the mean $\pm$ standard deviation. Subgroup analyses were performed in patients who were tested on the same day of surgery and within the subgroup of patients without comorbidities.

Multivariate logistic regression techniques were used to determine factors that independently predicted the use of laboratory testing. Additional multivariate logistic regression models were created to determine the effect of testing on major and wound-related complications. Backward selection methods were used to create logistic regression models using $P < 0.1$ as a cutoff for a covariate to remain in the model. Results were presented as odds ratios referenced to a single group specified for each variable with 95% confidence intervals. Statistical significance was considered to be less than 0.05. The study is overpowered because of large sample size. Therefore, the actual estimates reported here emphasize the clinical importance rather than the statistical significance of results.

Statistical analyses were performed using SAS for Windows (Version 9.2: SAS Institute Inc, Cary, NC).

RESULTS

Cohort Characteristics

Of the 73,596 patients undergoing elective hernia repair, 46,977 (63.8%) underwent some preoperative laboratory blood tests, whereas 26,619 (36.2%) were not tested before surgery.

Patients who underwent preoperative laboratory testing were older (57.7 ± 16.0 years vs 48.6 ± 15.9 years, $P < 0.0001$) and were more likely to be ASA class 3 (26.0% vs 11.4%, $P < 0.0001$) and to have at least 1 comorbidity (71.1% vs 56.6%, $P < 0.0001$). Cohort characteristics are summarized in Table 2.

Preoperative Testing use

The majority of patients were tested within 2 weeks of surgery, with 58.8% and 82.5% of patients being tested within 7 and 14 days of surgery, respectively. A total of 7209 patients (15.3% of tested patients) were evaluated on the same day as the surgical procedure. Peaks in testing were seen at 7 and 14 days before surgery (Fig. 2).

In the overall cohort, 63.8% of patients underwent at least one test, 58.6% received a hematology test, and 53.5% a chemistry panel. LFTs were obtained in 23.7% of patients and coagulation tests were performed in 18.7%. In the overall cohort, 9.9% of patients underwent all test types.

Although rates of testing were lower in patients with no NSQIP comorbidities, they were still high, with 54.0% of patients receiving at least one preoperative test. A total of 51.8% of patients without comorbidities had a hematology test, 41.9% had a chemistry test, 19.6% had LFTs, and 14.8% had a coagulation test. Among patients without comorbidities, 8.1% underwent all tests.

In the overall cohort, 61.6% of patients tested had at least one abnormal result, with hematology (39.3%) and chemistry (40.1%) abnormalities being the most common. To evaluate the impact of abnormal tests on management, we examined the subgroup of 7209 patients who underwent testing the day of surgery. Overall, 61.6% of patients who underwent laboratory testing the day of surgery had at least one abnormal result. Despite this, hernia repair was performed. The use of preoperative testing and abnormal results are summarized in Table 3.

The use of preoperative testing was also evaluated in conditions where it is likely to influence management, such as coagulation tests in patients with known bleeding disorders, chemistry tests in dialysis patients, and LFTs in patients with liver disease and alcohol abuse. In patients with bleeding disorders, 55.5% underwent coagulation tests. In the group of patients who underwent dialysis, 82.4% received chemistry tests. Finally, 78.4% of patients with liver disease and 26.7% of alcoholic patients underwent LFTs.

Factors Predicting Preoperative Testing

Table 4 presents the results of a multivariate logistic regression analysis evaluating factors independently associated with receipt of each preoperative laboratory test. Older patients, blacks, Hispanics, patients with ASA class 2 and 3, use of general anesthesia, use of a laparoscopic technique, hypertension, ascites, bleeding disorders, and use of steroid were associated with an increase in preoperative testing across all test types.

In addition, patients with diabetes were more likely to have had a hematology test, chemistry panel, and LFTs. Patients on dialysis also had an increase in use of a hematology test, chemistry panel, and LFTs before surgery. Patients with angina were more likely to have had a hematology test, whereas patients with a history of cardiac surgery or peripheral vascular disease were more likely to have had a coagulation panel during the preoperative evaluation. Patients with neurological conditions, such as transient ischemic attacks or stroke without remnant symptoms, were more likely to have had a coagulation panel during preoperative evaluation.

Unadjusted and Adjusted Outcomes

A total of 239 patients (0.3%) had a major complication, and 567 patients (0.8%) had wound-related complications in 30 days after hernia repair. A higher incidence of major complications was observed in patients who underwent any preoperative test compared with those who did not (0.4% vs 0.2%, $P < 0.0001$). No differences in wound-related complications were found between patients who underwent any preoperative test and those who did not (0.7% vs 0.8%, $P = 0.58$). In the subgroup of patients without comorbidities, there were no differences in major (0.2% vs 0.2%, $P = 0.99$) or wound-related (0.3% vs 0.5%, $P = 0.13$) complications between tested (any test) and untested patients.

Table 5 presents the results of a multivariate logistic regression analysis evaluating the association between preoperative testing and outcomes. In the overall cohort, after adjusting for patient demographics, comorbidities, and procedure characteristics, preoperative hematology, chemistry, LFT, and coagulation testing were not associated with major or wound-related complications. In addition, abnormal results did not predict postoperative complications when compared with patients with normal results. Finally, in the subgroup of patients without comorbidities, testing was not a predictor of major or wound-related complications after adjusting for patient and procedure characteristics.

DISCUSSION

To our knowledge, ours is the first population-based study to evaluate the use of preoperative laboratory testing before elective, low-risk ambulatory surgery. Our study demonstrates laboratory testing for ambulatory surgery is neither driven by evidence-based guidelines nor determined on the basis of patients' individual and disease characteristics. Despite evidence demonstrating that routine preoperative testing before elective, low-risk ambulatory surgery is not indicated, more than 60% of all patients underwent at least one laboratory test during their preoperative evaluation. In addition, more than half of the patients with no documented NSQIP comorbidities underwent preoperative testing. On the basis of high rates of testing, especially in the subset of healthy patients, physician and/or facility preference and not the patient's condition currently dictate use. The documented overuse of testing is likely a reflection of the lack of level 1 evidence, consensus, and clear guidelines in the use of preoperative testing.^{2,4,5,7–10}

The goal of preoperative testing is to detect abnormalities that will alter management and lead to better outcomes. The overall incidence of complications in our study was less than 1% and, after controlling for patient comorbidities and operative procedure, we found that neither testing nor abnormal results were associated with postoperative complications. Previous studies have shown that routine preoperative testing might not be necessary,^{1,3,17,18} and several authors have evaluated outcomes after no preoperative testing at all. In 2000, Schein et al¹⁷ reported the results of a randomized controlled trial comparing routine versus no preoperative testing in patients undergoing cataract surgery, a procedure generally performed in older patients with a high prevalence of comorbid conditions. They demonstrated no difference in outcomes between the 2 groups. Likewise, a 2009 randomized controlled trial in Canada demonstrated no difference in outcomes among ambulatory surgery patients who underwent "indicated" testing, according to their preoperative protocol, versus no testing.¹ These findings suggest that a large proportion of pre-operative testing for low-risk ambulatory surgery, even in patients with stable comorbid illness, is of questionable clinical benefit and can be eliminated without significant adverse medical consequences. This will translate into decreased costs, both for initial testing and additional unnecessary testing due to false-positive results or abnormal results, with limited clinical significance. In addition, patient satisfaction may improve by limiting patient discomfort and anxiety related to false-positive or abnormal but clinically insignificant results.

The NSQIP data do not allow us to identify patients who had planned elective surgery that was cancelled or delayed because of abnormal preoperative laboratory values. However, in the subset of patients tested the day of surgery, we found that hernia repair was performed despite abnormal results in 61% of patients, suggesting that abnormal results obtained during routine testing are of questionable significance and do not alter management. Although this can be questioned given that we do not have the true denominator, previous single-institution studies support this finding.^{5,11,14,23} In a study by Kaplan et al,¹¹ only 0.2% of discovered abnormalities detected on preoperative testing had management implications and none were acted upon. Likewise, Bryson et al⁵ found that action was taken in 2.6% of patients with abnormal results, with no surgical cases being cancelled. In both cases, abnormal results were not associated with adverse consequences. Smetana et al⁹ systematically reviewed the current literature and found that the incidence of abnormalities in laboratory tests that changed management ranged from less than 0.1% of the time (CBC) to 2.6% of the time (renal function tests). These results have important medicolegal implications, as there is a significant legal risk for ignoring an abnormal result and for not ordering a test that may not be indicated.^{16,24}

Unnecessary preoperative testing may be influenced by several factors, such as practice tradition, lack of communication between physicians, medicolegal worries, concerns about surgical delay or cancellation, institutional policies and procedures, and lack of awareness of evidence and guidelines.²⁵ In 1999, Fischer described the key steps to cost-effective preoperative evaluation and testing.⁷ These included (1) physician education and modification of practice, (2) review and adaptation of guidelines, (3) development of clinical pathways, (4) information sharing to avoid duplication of testing, (5) economic analyses, (6) medical resource management, and (7) outcomes assessment. Increased physician awareness is the first step. Stuebing et al²⁶ demonstrated that increasing awareness among health care providers decreased the number of daily inpatient tests ordered and resulted in significant savings for the hospital. Our study suggests that previous studies arguing against routine preoperative testing have not had a significant impact on the use of testing, but perhaps they were targeted at the wrong audience. Although most of the studies regarding preoperative testing originate in the anesthesia literature, it has been shown that approximately 80% of preoperative tests are ordered by surgeons and that the majority of these tests are not clinically indicated.⁵

With regard to the second step, we must define the appropriate use of testing and develop clear guidelines. Given the low incidence of complications in ambulatory surgery, randomized controlled trials would require large numbers of patients and may not be feasible. The NSQIP data set does not provide individual hospital identifiers. Therefore, we cannot examine variation among providers (hospitals or surgeons). However, we suspect that significant variation exists, as is often the case when guidelines are unclear.^{27,28} This variation can be used as a tool to study the comparative effectiveness of preoperative laboratory testing to provide strong evidence for the creation of new guidelines. Comparing outcomes among “high” and “low” users provides a natural study, with patients essentially being “randomized” to testing or no testing. The goal should be to evaluate the comparative effectiveness of testing in specific clinical situations, allowing for identification of clear clinical situations in which preoperative testing is effective and should be performed.

Once clear guidelines have been established, creation of interdepartmental clinical pathways can facilitate information sharing and reduce duplicate or unnecessary testing.^{7,29} However, for this to succeed, physician (especially surgeon) awareness must be increased and all parties must be willing to participate. In Ontario, hospitals attempted to adopt the Ontario Preoperative Testing Grid, recommended by the Ontario Preoperative Testing Group Guidelines Advisory Committee.^{5,6} However, studies demonstrate that despite adoption by

the hospitals, physicians were not following the recommendations. In addition, 67% of inappropriately ordered tests were ordered by surgeons.⁵ Alternatively, some institutions have transitioned the preoperative care of surgical patients to a dedicated preoperative evaluation clinic. Investigators at Stanford University Hospital³⁰ found a 55% decrease in the number of preoperative tests after transferring preoperative care from surgeons to anesthesiologists in dedicated preoperative evaluation clinics, without changes in patient outcomes, operating room cancellations, or delays.

Our study has several limitations in addition to those already listed. There is clear selection bias. Patients who underwent preoperative testing had more comorbidities, were more likely to be ASA class 3, and had increased 30-day morbidity. The increased rate of major complications reflects the increased severity of illness in patients who underwent testing and may indicate appropriate patient selection for preoperative laboratory evaluation. Even so, after adjusting for patients' comorbidities, testing was not predictive of outcomes in any group. In addition, reporting testing patterns and outcomes in the more homogeneous group of patients without comorbidities allowed us to minimize selection bias and document clear overuse. The NSQIP database does not report all tests types, including electrocardiography and chest radiography. In addition, if repeat testing was done for abnormal results, we are unable to detect this, as only the laboratory values closest to surgery are reported. Finally, we are unable to identify ordering physicians nor can we evaluate variation among providers.

In summary, our study demonstrates the overuse of preoperative laboratory testing in the evaluation of patients undergoing elective, low-risk ambulatory surgery. High rates of testing in patients with no clear indication reveal that physician and/or facility preference rather than patient characteristics are the key determinants of use, reflecting the uncertainty of indications and lack of guidelines. Our findings, in combination with previous research, suggest that a large proportion of preoperative testing for ambulatory surgery, even in patients with stable comorbid illness, is of questionable clinical benefit and can be eliminated without significant adverse medical consequences. Future studies must evaluate the comparative effectiveness of testing allowing for the creation of clear guidelines that will allow for physician education and implementation of pathways. The long-term goal is to change physician behavior, thereby decreasing unnecessary testing, decreasing associated cost, and increasing patient satisfaction.

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References

1. Chung F, Yuan H, Yin L, et al. Elimination of preoperative testing in ambulatory surgery. *Anesth Analg*. 2009; 108:467–475. [PubMed: 19151274]
2. Cullen, KA.; Hall, MJ.; Golosinskiy, A. National Health Statistics Reports, Number 11. Washington, DC: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics; 2009. Ambulatory Surgery in the United States, 2006; p. 1-25.
3. Practice advisory for preanesthesia evaluation: a report by the American Society of Anesthesiologists Task Force on Preanesthesia Evaluation. *Anesthesiology*. 2002; 96:485–496. [PubMed: 11818784]
4. Merchant R, Bosenberg C, Brown K, et al. Guidelines to the practice of anesthesia: revised edition 2011. *Can J Anaesth*. 2011; 58:74–107. [PubMed: 21191680]

5. Bryson GL, Wyand A, Bragg PR. Preoperative testing is inconsistent with published guidelines and rarely changes management. *Can J Anaesth*. 2006; 53(3):236–241. [PubMed: 16527786]
6. Ontario Preoperative Testing Group, Guidelines Advisory Committee. [Accessed July 18, 2012.] Ontario Preoperative Testing Grid. https://docs.google.com/viewer?a=v&q=cache:Y-93_brVlQ0J:www.gacguidelines.ca/site/GAC_Guidelines/assets/docs/Projects_Preop_Grid.doc+ontario+preoperative+testing+grid&hl=en&gl=us&pid=bl&srcid=ADGEESiDPHsrLGTQYKD9f7RwfZEF9QgH2ryBXo22rE39I5BRdS8tnZMQdRCtosw_13jZKgfkhHHqpmufKH414GPDnrhM5Zxu7SXalWxWMxY30nVIFN-VRxXIxlAlAp-nCM8CcrhiWEX&sig=AHIEtbQW4k_HRASByVh48PPKgLJPpZqUKQ
7. Fischer SP. Cost-effective preoperative evaluation and testing. *Chest*. 1999; 115(suppl):96S–100S. [PubMed: 10331340]
8. Munro J, Booth A, Nicholl J. Routine preoperative testing: a systematic review of the evidence. *Health Technol Assess*. 1997; 1:i–iv. 1–62.
9. Smetana GW, Macpherson DS. The case against routine preoperative laboratory testing. *Med Clin North Am*. 2003; 87:7–40. [PubMed: 12575882]
10. Velanovich V. Preoperative laboratory screening based on age, gender, and concomitant medical diseases. *Surgery*. 1994; 115:56–61. [PubMed: 8284762]
11. Kaplan EB, Sheiner LB, Boeckmann AJ, et al. The usefulness of preoperative laboratory screening. *JAMA*. 1985; 253:3576–3581. [PubMed: 3999339]
12. Allison JG, Bromley HR. Unnecessary preoperative investigations: evaluation and cost analysis. *Am Surg*. 1996; 62:686–689. [PubMed: 8712570]
13. Johnstone RE, Martinec CL. Costs of anesthesia. *Anesth Analg*. 1993; 76:840–848. [PubMed: 8466028]
14. Richman DC. Ambulatory surgery: how much testing do we need? *Anesthesiol Clin*. 2010; 28:185–197. [PubMed: 20488389]
15. Delahunt B, Turnbull PR. How cost effective are routine preoperative investigations? *N Z Med J*. 1980; 92:431–432. [PubMed: 6782527]
16. Roizen MF. More preoperative assessment by physicians and less by laboratory tests. *N Engl J Med*. 2000; 342:204–205. [PubMed: 10639549]
17. Schein OD, Katz J, Bass EB, et al. The value of routine preoperative medical testing before cataract surgery. Study of Medical Testing for Cataract Surgery. *N Engl J Med*. 2000; 342:168–175. [PubMed: 10639542]
18. Narr BJ, Warner ME, Schroeder DR, Warner MA. Outcomes of patients with no laboratory assessment before anesthesia and a surgical procedure. *Mayo Clin Proc*. 1997; 72:505–509. [PubMed: 9179133]
19. Vogt AW, Henson LC. Unindicated preoperative testing: ASA physical status and financial implications. *J Clin Anesth*. 1997; 9:437–441. [PubMed: 9278827]
20. 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 Surg*. 1997; 185:341–351. [PubMed: 9328382]
21. Gibbs J, Clark K, Khuri S, et al. Validating risk-adjusted surgical outcomes: chart review of process of care. *Int J Qual Health Care*. 2001; 13:187–196. [PubMed: 11476143]
22. [Accessed July 18, 2012.] American College of Surgeon National Surgical Quality Improvement Program user guide for the 2010 participant use data file. <http://site.acsnsqip.org/participant-use-data-file/>
23. Charpak Y, Blery C, Chastang C, et al. Usefulness of selectively ordered preoperative tests. *Med Care*. 1988; 26:95–104. [PubMed: 3339918]
24. Hepner DL. The role of testing in the preoperative evaluation. *Cleve Clin J Med*. 2009; 76(suppl 4):S22–S27. [PubMed: 19880831]
25. Brown SR, Brown J. Why do physicians order unnecessary preoperative tests? A qualitative study. *Fam Med*. 2011; 43:338–343. [PubMed: 21557104]
26. Stuebing EA, Miner TJ. Surgical vampires and rising health care expenditure: reducing the cost of daily phlebotomy. *Arch Surg*. 2011; 146:524–527. [PubMed: 21576605]

27. Shahinian VB, Kuo YF, Freeman JL, et al. Determinants of androgen deprivation therapy use for prostate cancer: role of the urologist. *J Natl Cancer Inst.* 2006; 98:839–845. [PubMed: 16788157]
28. Sheffield KM, Han Y, Kuo YF, et al. Variation in the use of intraoperative cholangiography during cholecystectomy. *J Am Coll Surg.* 2012; 214:668–679. [PubMed: 22366491]
29. Wu AH. Improving the utilization of clinical laboratory tests. *J Eval Clin Pract.* 1998; 4:171–181. [PubMed: 9744706]
30. Fischer SP. Development and effectiveness of an anesthesia preoperative evaluation clinic in a teaching hospital. *Anesthesiology.* 1996; 85:196–206. [PubMed: 8694365]

FIGURE 1.

Cohort selection process. In the first step, inclusion criteria included patients undergoing open or laparoscopic inguinal hernia repair (49505, 49520, 49525, 49650, and 49651), femoral hernia repair (49550 and 49555), umbilical hernia repair (49585), and epigastric hernia repair (49570). We applied the following inclusion criteria—age > 18 years, elective surgery or same-day admission, no surgical procedures in preceding 30 days, and no additional surgical procedures at the time of the hernia repair. The final cohort had 73,596 patients.

FIGURE 2.

For each test type, days before surgery are shown on the *x*-axis and the percent of patients tested on the *y*-axis. A, Hematology; B, Chemistry; C, Coagulation; and D, Liver function tests. Peaks in testing were seen at 7 and 14 days before surgery. Over 10% of patients had hematology, chemistry, and coagulation tests drawn the morning of surgery.

TABLE 1
Summary of Current ASA, CAS, and OPTG Recommendations for Testing in Patients Undergoing Ambulatory Surgery

Indication	Test			
	Hg/CBC	Creatinine	Electrolytes	LFTs Coagulation parameters
Advanced age	ASA OPTG	OPTG	OPTG	
Anemia	ASA CAS			ASA CAS OPTG OPTG
Bleeding disorders	ASA			
Other hematologic disorders	ASA			
Cardiovascular disease	CAS OPTG			
Pulmonary disease	CAS OPTG			
Renal disease	CAS OPTG	CAS OPTG	ASA CAS OPTG	ASA
Liver disease	CAS OPTG			ASA CAS OPTG
Endocrine disease		CAS	ASA	
Malignancy	CAS OPTG			
Hypertension	OPTG	CAS OPTG OPTG	CAS OPTG CAS OPTG CAS	
Diabetes				
Recent upper respiratory infection				
Smoking	OPTG			
Alcohol abuse	OPTG			OPTG

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Indication	Test				
	Hg/CBC	Creatinine	Electrolytes	LFTs	Coagulation parameters
Steroid use			OPTG		
Anticoagulant therapy	OPTG				ASA CAS OPTG

TABLE 2

Cohort Characteristics

	No Labs (N = 26,619)		Labs (N = 46,977)		
	N	% or SD	N	% or SD	P
Age (mean, SD), yrs	48.6	±16.0	57.7	±15.9	<0.0001
Gender					
Female	4176	15.7%	7314	15.6%	0.66
Male	22,443	84.3%	39,663	84.4%	
Race					
White	22,008	82.7%	37,354	79.5%	<0.0001
Black	2000	7.5%	4651	9.9%	
Hispanics	1768	6.6%	3737	8.0%	
Other	843	3.2%	1235	2.6%	
LOS (mean, SD), d	0.09	±1.1	0.18	±1.9	<0.0001
Procedure					
Access					
Open	22,013	82.7%	38,328	81.6%	0.0002
Laparoscopic	4606	17.3%	8649	18.4%	
Location					
Inguinal	19,337	72.6%	34,976	74.5%	<0.0001
Umbilical	6406	24.1%	10,588	22.5%	
Epigastric	607	2.3%	948	2.0%	
Femoral	269	1.0%	465	1.0%	
Recurrence					
No	24,836	93.3%	43,537	92.7%	0.0015
Yes	1783	6.7%	3440	7.3%	
ASA classification					
Class 1	8281	31.1%	7290	15.5%	<0.0001
Class 2	15,298	57.5%	27,486	58.5%	
Class 3	3040	11.4%	12,201	26.0%	
Anesthesia					
General	20,255	76.1%	36,694	78.1%	<0.0001

	No Labs (N = 26,619)		Labs (N = 46,977)		P
	N	% or SD	N	% or SD	
Other	6364	23.9%	10,283	21.9%	
Comorbidities					
At least 1	15,061	56.6%	33,386	71.1%	<0.0001
Obesity *	6505	24.8%	12,398	26.6%	<0.0001
Smoking	5539	20.8%	8751	18.6%	<0.0001
Alcohol	862	3.2%	1770	3.8%	0.0002
Diabetes	823	3.1%	3961	8.4%	<0.0001
HTN	5542	20.8%	20,133	42.9%	<0.0001
Dyspnea	721	2.7%	2486	5.3	<0.0001
COPD	355	1.3%	1326	2.8%	<0.0001
PCI	670	2.5%	2604	5.5%	<0.0001
Cardiac surgery	560	2.1%	2680	5.7%	<0.0001
Bleeding disorders	144	0.5%	1147	2.4%	<0.0001
Hx TIA	202	0.8%	864	1.8%	<0.0001
CVA with symptoms	111	0.4%	527	1.1%	<0.0001
CVA without symptoms	154	0.6%	668	1.4%	<0.0001
Steroid use	176	0.7%	757	1.6%	<0.0001

* With available data.

COPD indicates chronic obstructive pulmonary disease; CVA, cerebrovascular accident; HTN, hypertension; PCI, percutaneous coronary intervention; TIA, transient ischemic attack.

TABLE 3**Use of Preoperative Laboratory Testing and Abnormal Results**

	Total	%	Abnormal	%*
Overall cohort (N = 73,596)				
Any test	46,977	63.8%	28,938	61.6%
Hematology	43,153	58.6%	16,944	39.3%
Chemistry	39,402	53.5%	15,824	40.2%
Coagulation	13,746	18.7%	1556	11.3%
LFT	17,433	23.7%	3974	22.8%
All	7291	9.9%	5419	74.3%
Subgroup without comorbidities (N = 25,149)				
Any test	13,591	54.0%	7361	54.1%
Hematology	13,018	51.8%	4708	36.2%
Chemistry	10,504	41.8%	3460	33.0%
Coagulation	3720	14.8%	220	5.9%
LFT	4931	19.6%	905	18.4%
All	2038	8.1%	1348	66.1%
Labs performed same day of surgery (N = 7,209)				
Any test	7209	100.0%	4443	61.6%
Hematology	6198	86.0%	2595	41.9%
Chemistry	5516	76.5%	2257	40.9%
Coagulation	2554	35.4%	586	22.9%
LFT	1859	25.8%	618	33.2%
All	971	13.5%	808	83.2%

Among patients with specific test.

TABLE 4

Multivariate Analysis of Factors Predicting Preoperative Laboratory Testing

	Model 1 Hematology			Model 2 Chemistry			Model 3 Coagulation			Model 4 LFT		
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Age—10-yr increments	1.26	1.24–1.27	1.29	1.27–1.30	1.15	1.13–1.16	1.16	1.15–1.18				
Gender												
Male	Reference group											
Female	1.11	1.06–1.17	NS	NS	0.88	0.83–0.93	NS	NS				
Race												
White	Reference group											
Black	1.58	1.50–1.68	1.56	1.47–1.65	1.78	1.67–1.89	1.32	1.25–1.41				
Hispanic	1.70	1.60–1.81	1.59	1.49–1.68	2.18	2.03–2.33	1.34	1.25–1.43				
ASA classification												
ASA 1	Reference group											
ASA 2	1.23	1.18–1.29	1.33	1.27–1.38	1.22	1.15–1.30	1.23	1.17–1.30				
ASA 3	1.51	1.42–1.61	1.77	1.66–1.88	2.01	1.86–2.17	1.59	1.49–1.71				
Anesthesia												
Other	Reference group											
General	1.29	1.25–1.35	1.41	1.35–1.46	1.28	1.22–1.35	1.29	1.24–1.35				
Procedure												
Access												
Open	Reference group											
Laparoscopic	1.22	1.17–1.27	1.19	1.14–1.24	1.06	1.01–1.12	1.21	1.15–1.27				
Location												
Inguinal	Reference group											
Umbilical	NS	NS	NS	NS	NS	NS	NS	NS				
Epigastric	NS	NS	NS	NS	0.70	0.60–0.82	NS	NS				
Femoral	NS	NS	NS	NS	NS	NS	NS	NS				
Recurrence												
No	Reference group											
Yes	NS	NS	1.10	1.03–1.17	NS	NS	NS	NS				
Comorbidities												

	Model 1 Hematology		Model 2 Chemistry		Model 3 Coagulation		Model 4 LFT	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Obesity*	NS	NS	NS	NS	0.88	0.84–0.93	NS	NS
Alcohol	NS	NS	NS	NS	NS	NS	1.14	1.04–1.25
Diabetes	1.21	1.13–1.30	1.63	1.51–1.76	NS	NS	1.19	1.12–1.28
HTN	1.20	1.15–1.25	1.84	1.77–1.91	1.09	1.04–1.14	1.12	1.07–1.16
Dyspnea	NS	NS	1.10	1.01–1.20	NS	NS	NS	NS
Angina	1.47	1.01–2.13	NS	NS	NS	NS	NS	NS
Cardiac surgery	NS	NS	NS	NS	1.20	1.10–1.31	NS	NS
PVD	NS	NS	NS	NS	1.33	1.08–1.62	NS	NS
Dialysis	1.39	1.01–1.92	1.71	1.20–2.45	NS	NS	1.67	1.27–2.18
Ascites	3.20	2.02–5.06	5.29	3.12–8.99	10.06	6.79–14.89	10.22	6.83–15.30
Esophageal varices	2.08	1.13–3.83	NS	NS	5.53	3.17–9.65	3.37	2.05–5.55
Bleeding disorders	1.40	1.22–1.60	1.37	1.19–1.57	3.57	3.17–4.03	1.27	1.12–1.43
TIA	NS	NS	NS	NS	1.22	1.07–1.41	NS	NS
CVA without symptoms	NS	NS	NS	NS	1.38	1.19–1.61	NS	NS
Steroid use	1.43	1.22–1.66	1.49	1.28–1.74	1.21	1.04–1.40	1.36	1.18–1.56
10% Weight lost	NS	NS	NS	NS	1.52	1.11–2.09	1.59	1.18–2.13

Patients from other races, with chronic obstructive pulmonary disease, pneumonia, congestive heart failure, myocardial infarction, history of previous percutaneous coronary intervention, active wound infection, hemiplegia, stroke with remnant symptoms, paraplegia, and quadraplegia were not associated to an increase in use of any test.

CVA indicates cerebrovascular accident; HTN, hypertension; NS, not significant; PVD, peripheral vascular disease; TIA, transient ischemic attack.

TABLE 5

Multivariate Logistic Regression Analysis Predicting Outcomes After Preoperative Testing

	Major Complications [*]		Wound-Related Complications [†]	
	OR	95% CI	OR	95% CI
Overall cohort (tested vs not tested) [‡]				
Hematology	1.17	0.88–1.56	0.99	0.83–1.18
Chemistry	1.30	0.97–1.75	1.03	0.87–1.24
Coagulation	1.25	0.93–1.67	1.05	0.84–1.30
Liver function test	1.02	0.77–1.36	1.07	0.88–1.30
Overall cohort (abnormal vs normal) [‡]				
Hematology	1.29	0.95–1.75	0.96	0.76–1.20
Chemistry	1.28	0.93–1.75	1.15	0.90–1.46
Coagulation	1.52	0.86–2.66	1.16	0.66–2.05
Liver function test	1.50	0.90–2.49	1.14	0.79–1.65
Without comorbidities (tested vs not tested) [§]				
Hematology	0.77	0.40–1.49	1.36	0.91–2.03
Chemistry	1.00	0.52–1.96	1.35	0.91–2.02
Coagulation	1.38	0.63–3.05	1.04	0.60–1.78
Liver function test	0.94	0.42–2.08	1.07	0.66–1.75

^{*} Major complications include: unexpected reintubation, pulmonary embolism, acute renal failure, stroke, prolonged coma, myocardial infarction, cardiac arrest, sepsis or septic shock, bleeding requiring blood transfusion, and death.

[†] Wound complications include: superficial and deep wound infections, organ space infections and wound dehiscence.

[‡] Models adjusted for patient's demographics, comorbidities, and procedure characteristics.

[§] Model adjusted for patient's demographics and procedure characteristics.