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

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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

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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 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.

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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 preoperative 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.

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

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

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

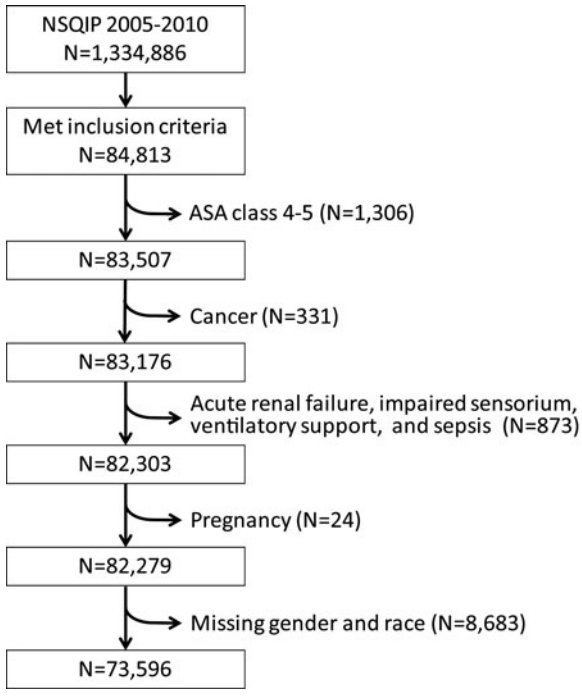

FIGURE 1. Cohort selection process. In the first step, inclusion criteria included patients undergoing open or laparoscopic inguinal hernia repair (49505, 49520, 49525, 49650, and 49651), femoral hernia repair (49550 and 49555), umbilical hernia repair (49585), and epigastric hernia repair (49570). We 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.

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/mm^3 and 12,000/mm^3, and platelets between 150,000/mm^3 and 400,000/mm^3 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 $\pm$ 16.0 years vs 48.6 $\pm$ 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

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%	39663	84.4%	
Race					
White	22,008	82.7%	37354	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%	34976	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
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.

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.

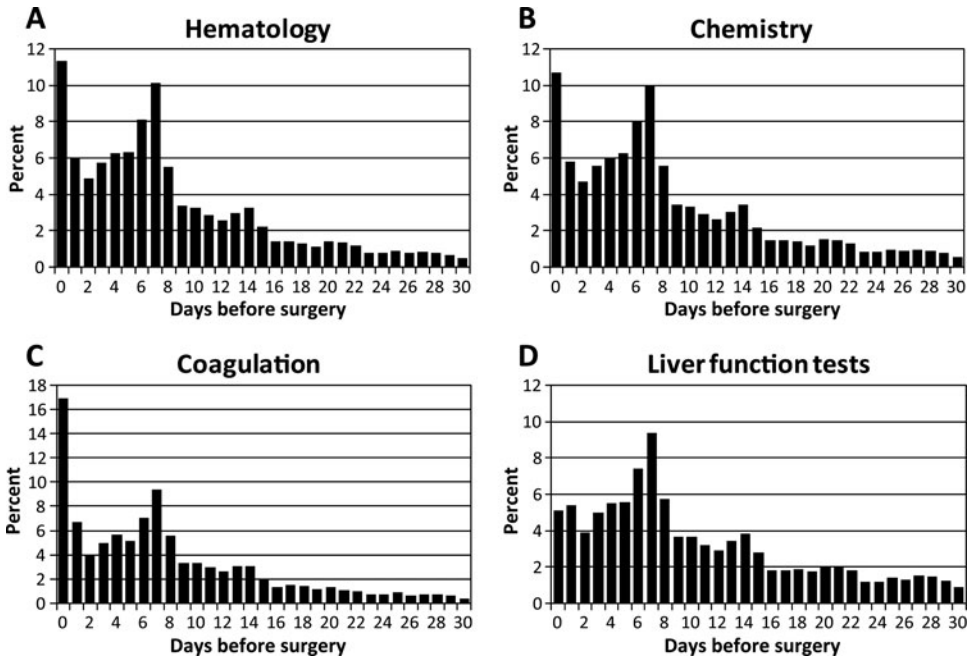

FIGURE 2. For each test type, days before surgery are shown on the *x*-axis and the percent of patients tested on the *y*-axis. A, Hematology; B, Chemistry; C, Coagulation; and D, Liver function tests. Peaks in testing were seen at 7 and 14 days before surgery. Over 10% of patients had hematology, chemistry, and coagulation tests drawn the morning of surgery.

TABLE 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.

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

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
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								
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.

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

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.

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 procedures 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 al[17] 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 preoperative 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 al[5] 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 al[9] 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 al[26] 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 Hospital[30] 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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DISCUSSANT

DR. LEIGH NEUMAYER (Salt Lake City, UT): Given that over 50% of patients without co-morbidities had at least one preoperative test, can you estimate the aggregate costs of this testing on a national basis?

The laboratory values available in NSQIP are in many hospitals pulled automatically from what is available in the system over the 90 days prior to the date of surgery, without regard to ordering physician. Do you have any indication from the date of the labs in relation to the date of surgery as to whether these were truly done as part of a preoperative work up or maybe were just part of a visit to another physician in the system such as their primary care physician?

My suspicion is that the genesis of this project came from an experience of three of one or more of your authors seeing what seemed to be a large number of preoperative testing in healthy patients at your facility. If this is the case, has this project led to any changes in the processes at your hospital or if not driven by local experience, what would you recommend as next steps for this almost universal problem of overtesting the rest of us are facing?

DR. TAYLOR RIALL: In answer to your first question, we grossly estimated the national cost. We did so by looking at the approximate number of hernia repairs in a year in the United States. Next, we looked at our NSQIP rates of testing in healthy patients, as well as the proportion of tests in healthy patients. Finally, we used Medicare reimbursement rates as our estimate for test costs.

We estimate, for hernia repairs only, in the test types we evaluated, cost savings would be at about $10 million per year. When you think about the overall potential savings, that figure is a gross underestimate because that is only one ambulatory procedure. If you expand that to all ambulatory procedures, it will be much higher.

In addition, we did not look at tests like EKGs and chest x-rays, which are even more costly and problematic in terms of overuse, as NSQIP does not allow us to do so. In addition, many tests in patients may not be indicated in patients who have mild or stable comorbidities such as hypertension. If you include those tests, savings would be even more significant.

In answer to your second question, you are correct. We cannot determine the reasons for testing in NSQIP patients–whether they were ordered as part of a routine physical exam by a PCP or for the surgery itself. However, we can determine the timing of lab tests relative to surgery. We excluded any labs that were done more than 30 days prior, thinking they could have been ordered by a primary care physician for routine screening purposes and were not intended as preoperative evaluation tests.

Fifty nine percent of patients were tested within one week of surgery, and 83% of patients were tested within two weeks of surgery, suggesting that labs were probably done for that intent, although you cannot be sure.

You also correctly point out that we cannot tell who is ordering the tests. In previous studies, what they found is that surgeons order approximately 80% of tests. In addition, of the tests that are considered inappropriate, about 80% of those are ordered by surgeons. When we look at Medicare data, where we can identify the ordering physician, we actually find the same patterns.

We also cannot tell if tests were repeated. NSQIP records the last test, or the test closest to surgery, so it is also possible that people had an abnormal test and then had that test repeated.

Finally, you are correct in thinking that this study was prompted by our clinical observations. I am as guilty as the next person. As a resident, you just order all these labs because you do not want your case canceled. Then you become faculty and you do the same thing and the residents think you want it as well. Our study was prompted by this observation. In fact, in our institution the testing rates are very similar to what we observe in NSQIP.

I certainly have changed my own practice. We are evaluating ways to incorporate preoperative testing recommendations into our electronic medical record, like they have in Ontario. However, when you look at data from Canada, despite implementation, physicians still do not do it.

I think one of the problems is that surgeons are ordering the tests, but anesthesiologists are setting the guidelines. So perhaps the current guidelines suggesting that preoperative labs are not necessary, are targeted at the wrong audience.

I think the next step is to develop clear guidelines. To do that, we can do comparative effectiveness studies. It is unlikely that we are going to do randomized control trials because of the very small incidence of adverse events and the large number of patients it would require.

I cannot do this in NSQIP data because I do not have individual hospital identifiers; in Medicare data, we do. What we see is huge variation among providers. We could use that natural variation to study the comparative effectiveness. Patients are going to be randomized to somebody who does tests all the time, and somebody who does not do tests all the time. This will allow us to control for measured and unmeasured confounders.

Once we agree upon guidelines, as a specialty, we need to implement interdepartmental pathways so that you avoid this communication problem and minimize testing.

DISCUSSANT

DR. BARBARA BASS (Houston, TX): I expect you are aware of a national initiative by several leading professional organizations to look for those practices that sort of fall into that invisible obvious not best practice. Things like using fifth cycle chemotherapy for patients with terminal cancer.

It has been a national initiative and, unfortunately, I cannot remember the name of the system that has been promulgated by a variety of national organizations that have taken on low-value, costly procedures in a variety of common healthcare problems. This, I think, really is data that we need that could actually allow us to step into this space as an organization.

What I would like you to comment on, is do you think the strength of this is sufficient to warrant initiating that dialogue? I would say the answer to that is yes.

Second, what are our options where we can, as an organization, or as a national body, step into this space? Who do our partners need to be to pull this off? Many, many, many hospitals, surgeons, anesthesiologists are looking for that outside-of-their-place authority to make these kind of changes. There is a lot of defensive medicine in this kind of testing.

I just want you to speculate about what could those process steps be? How could we align other national organizations to actually implement these badly needed changes?

DR. TAYLOR RIALL (Galveston, TX): Certainly, the data are strong enough and demonstrate clear overuse of preoperative tests, especially if you look at that highly select group of patients with no comorbidities. Again, this is an underestimate of overuse. I think in order to change practice we really need to target the organizations that are most involved in preoperative care. We need to target anesthesiologists and surgeons and make sure that this is coordinated.

I think the other area where we really need to implement policies is in ambulatory surgery settings. ASCs are not subject to the same regulations has hospital outpatient facilities. Perhaps we can implement policies that monitor preoperative testing in that particular setting.

We cannot tell is how much of this is just mandated by institutional protocols. It may be that at some hospital they just require certain tests. I had a personal experience, where I underwent a knee biopsy in Houston, and they wanted a full set of labs, including a CMP and a PT, PTT. This is ridiculous in a healthy 40 year old undergoing a minor procedure. I think these are the things we need to target.

DISCUSSANT

DR. FRANK LEWIS, JR. (Philadelphia, PA): Among the various preoperative abnormalities that could be identified, some of them are not readily correctable. It is more an awareness of them that testing would reveal, like chronic lung disease and chronic renal disease, because you could not change much. On the other hand, there are a lot of other problems that could be improved: Coagulopathies, metabolic abnormalities, and so forth.

So my question is, could your study have overlooked the minority of patients with chronic disease who had a significant abnormality that was recognized and corrected prior to doing surgery, after which the surgery proceeded uneventfully in part because that was corrected?

In thinking about the methodology of your study, it would seem to me that that possibility is not reflected in the NSQIP database. Is it possible that your study is missing a significant, but albeit small population of people, who have chronic disease, where the preoperative testing actually led to a correction, and possibly delay of surgery while the correction was occurring, and therefore improved the outcome of surgery, and your study, of course, did not identify a complication which was prevented?

DR. TAYLOR RIALL (Galveston): I think you are absolutely right, Dr. Lewis. We are unable to identify changes in management. If a case was canceled or delayed because of an abnormal lab, we cannot tell, nor can we tell if abnormal values were corrected and tests were repeated.

However, when you look at the literature and you compare it to many other studies looking at preoperative testing, what they find is that, in this setting, a change in management occurs in about zero to 3% of cases, depending on the abnormal test. In this particular population, that is probably not as much of a concern. Inpatient testing would be more problematic. In addition, when we looked at same day testing, surgery proceeded despite abnormal values in a very high percentage of cases, suggesting they did not change management.

DISCUSSANT

DR. NORMAN ESTES (Peoria, IL): I suspect that the problem is really anesthesia and the need for the preoperative visit. Anesthesiologists are supposed to see the patient in consultation prior to operation. In large centers, patients are coming from a distance; so it is difficult for them to do that in advance. They make the requirements for surgeons to order "standard" tests, which they use for a screening. At five minutes before the operation, that is when the consultation occurs.

My question is, can you determine if those are orders desired by surgeons for laboratory tests? I suspect almost all of them were requirements of the anesthesiologists. DR. TAYLOR RIALL (Galveston, TX): I think that is absolutely true. We have the same problem at our institution. When we look at Medicare data where I am able to determine who is ordering the tests, it is the surgeons. What I found as we tried to implement this in our institution is that surgeons are ordering 80% of the tests. We are ordering the tests because we think anesthesia will cancel our case if we do not. However, I talked to the anesthesiologists; they actually do not require it. When I stopped testing, I have had no problems. I think that is where communication is key. All the anesthesia literature says we do not need to test. I think it is a communication problem.

DISCUSSANT

DR. NAMIR KATKHOUDA (Los Angeles, CA): We are getting rid of chest x-rays and EKGs in healthy patients. Your study seems to suggest that maybe we should also get rid of labs. So patients come in in the morning, get their surgery, and go.

I am concerned, as a person who operates on hernias laparoscopically with wide dissections that maybe there is some need for coagulation tests, platelet count, and if you are performing a laparoscopic cholecystectomy, maybe liver function tests the day of surgery.

Could you address these two specific labs?

DR. TAYLOR RIALL (Galveston, TX): I think that is certainly reasonable. I think that is why we need to conduct comparative effectiveness studies, determining the usefulness of particular labs in particular settings. To answer your question, we would need to look at all the patients who are undergoing laparoscopic hernia and compare outcomes centers that use testing all the time and centers that do not use testing all the time, and really see, in specific clinical situations, where it is indicated.

There is a need develop clear guidelines that surgeons can agree upon. To do so we need good comparative effectiveness studies. Right now, I think we do not know the correct answer, leading to the observed variation in practice.

DISCUSSANT

DR. LAWRENCE WAY (San Francisco, CA): This excellent study has many companions in the literature, as mentioned by the author. There are studies on inpatients, on medical services, studies on preoperative patients undergoing major surgery. They all come to the same conclusions. In our hospital at the University of California San Francisco, there was a large study implemented by the department of anesthesia about 20 years ago that showed the tremendous overuse of laboratory tests. The interesting point was that the individual anesthesiologists did not align themselves with the findings. In other words, their behavior contradicted the scientific evidence that the tests were useless.

I think it is a very interesting cultural phenomenon that it takes such a long time to get practice to change after the clear-cut proof of a scientific study. I think we have gone through similar experiences, for example, in the use of prophylactic nasogastric tubes as a routine practice, whereas it took about 20 years before practice really changed in that regard. I certainly hope that the profession can deal with this as a cultural phenomenon and work out a way to make some change. It is time.

DR. TAYLOR RIALL (Galveston, TX): Behavior is difficult to change, but perhaps in this era of cost savings, maybe the time is ripe to present the data again.

DISCUSSANT

DR. ANDREW WARSHAW (Boston, MA): Dr. Riall, your data is overwhelming; obvious in the sense that one cannot escape the conclusions. However, it is only applied to hernias. As you point out, the number of ambulatory procedures far exceeds, in number and type, the operations that are now done as an outpatient. Do you have evidence that this same overwhelming conclusion can be applied to larger operations that are now done in the outpatient setting? Cholecystectomy has been mentioned, but there are obviously many more.

DR. TAYLOR RIALL (Galveston, TX): In doing this analysis, we tried to make a clean cohort. We looked at other procedures such as arthroscopy and choleycstectomy in Medicare and NSQIP and see the same exact patterns.

As was pointed out earlier, in some cases, such as cholecystectomy, you can certainly make an argument that labs might be needed in a particular setting, for example, to identify elevated LFTs, which might change management. In order to keep our cohort clean, we did not include cholecystectomy. Certainly, we can move in that direction. Overall, we are seeing the same patterns across disease processes.