

## ANESTHESIOLOGY

# Evaluation of Appropriate Use of Preoperative Echocardiography before Major Abdominal Surgery: A Retrospective Cohort Study

Allyson Tank, M.D., Robert Hughey, M.D.,  
R. Parker Ward, M.D., Peter Nagele, M.D., M.Sc.,  
Daniel S. Rubin, M.D., M.S.

*ANESTHESIOLOGY* 2021; 135:854–63

## EDITOR'S PERSPECTIVE

### What We Already Know about This Topic

- Resting echocardiography is often performed before noncardiac surgery, and its utilization can be evaluated using the American College of Cardiology Foundation Appropriate Use Criteria for Echocardiography
- The Center for Medicare and Medicaid Services will begin requiring providers to demonstrate adherence to appropriate use criteria when ordering advanced imaging studies beginning in 2022

### What This Article Tells Us That Is New

- Among 230,535 patients in a national claims database between 2005 and 2017, 13,936 (6.0%) underwent resting echocardiography within 60 days before surgery, and 12,638 could be classified using the Appropriate Use Criteria for Echocardiography
- More than a quarter of all resting echocardiograms (3,679 of 12,638; 29%) were deemed "rarely appropriate," while 71% (8,959 of 12,638) were deemed "appropriate"
- Surveillance of chronic ischemic heart disease and a diagnosis of uncomplicated hypertension accounted for 43% (1,588 of 3,679) of the "rarely appropriate" preoperative resting echocardiograms

Preoperative echocardiography is often performed before major noncardiac surgery in an effort to improve perioperative care, as major adverse cardiac events

## ABSTRACT

**Background:** Preoperative resting echocardiography is often performed before noncardiac surgery, but indications for preoperative resting echocardiography are limited. This study aimed to investigate appropriateness of preoperative resting echocardiography using the Appropriate Use Criteria for Echocardiography, which encompass indications from the guidelines on perioperative cardiovascular evaluation and management and nonperioperative indications independent of the perioperative period. The authors hypothesized that patients are frequently tested without an appropriate indication.

**Methods:** Records of patients in the Truven Health MarketScan Commercial and Medicare Supplemental Databases who underwent a major abdominal surgery from 2005 to 2017 were included. These databases contain de-identified records of health services for more than 250 million patients with primary or Medicare supplemental health insurance coverage through employer-based fee-for-service, point-of-service, or capitated plans. Patients were classified based on the presence of an outpatient claim for resting transthoracic echocardiography within 60 days of surgery. Appropriateness was determined via International Classification of Diseases, Ninth Revision—Clinical Modification, and International Classification of Diseases, Tenth Revision—Clinical Modification principal and secondary diagnosis codes associated with the claims, and classified as "appropriate," "rarely appropriate," or "unclassifiable" using the Appropriate Use Criteria for Echocardiography.

**Results:** Among 230,535 patients in the authors' cohort, preoperative resting transthoracic echocardiography was performed in 6.0% (13,936) of patients. There were 12,638 (91%) studies classifiable by the Appropriate Use Criteria for Echocardiography, and 1,298 (9%) were unable to be classified. Among the classifiable studies, 8,959 (71%) were deemed "appropriate," while 3,679 (29%) were deemed "rarely appropriate." Surveillance of chronic ischemic heart disease and uncomplicated hypertension accounted for 43% (1,588 of 3,679) of "rarely appropriate" echocardiograms.

**Conclusions:** More than one in four preoperative resting echocardiograms were considered "rarely appropriate" according to the Appropriate Use Criteria for Echocardiography. A narrow set of patient characteristics accounts for a large proportion of "rarely appropriate" preoperative resting echocardiograms.

(*ANESTHESIOLOGY* 2021; 135:854–63)

complicate 1 in 33 hospitalizations for noncardiac surgery.<sup>1</sup> The American College of Cardiology (Washington, D.C.) and the American Heart Association (Dallas, Texas) practice guidelines for perioperative cardiovascular evaluation for noncardiac surgery recommend preoperative resting transthoracic echocardiography for a narrow set of cardiac conditions that directly impact perioperative care, such as suspected valvular heart disease or left ventricular dysfunction.<sup>2</sup> A key tenet of the perioperative guidelines is that preoperative cardiovascular testing should be reserved for

Supplemental Digital Content is available for this article. Direct URL citations appear in the printed text and are available in both the HTML and PDF versions of this article. Links to the digital files are provided in the HTML text of this article on the Journal's Web site ([www.anesthesiology.org](http://www.anesthesiology.org)). This article has a visual abstract available in the online version.

Submitted for publication August 3, 2020. Accepted for publication August 16, 2021. Published online first on September 20, 2021. From the Department of Pediatrics, Montefiore Medical Center, Bronx, New York (A.T.); and the Department of Anesthesia and Critical Care (R.H., P.N., D.S.R.) and Section of Cardiology (R.P.W.), University of Chicago, Chicago, Illinois.

Copyright © 2021, the American Society of Anesthesiologists. All Rights Reserved. *Anesthesiology* 2021; 135:854–63. DOI: 10.1097/ALN.0000000000003984

clinical scenarios that would warrant testing independent of upcoming surgery. Thus, to accurately assess the appropriateness of preoperative resting echocardiography, a broad understanding of all reasonable indications for resting echocardiography outside the perioperative setting is required.

The American College of Cardiology Foundation established Appropriate Use Criteria for Echocardiography in response to marked increases in the utilization of cardiac imaging.<sup>3</sup> The 2011 Appropriate Use Criteria for Echocardiography outlined common clinical scenarios and designated them, using the recommended updated nomenclature, as “appropriate,” “may be appropriate,” or “rarely appropriate.”<sup>4,5</sup> While the Appropriate Use Criteria for Echocardiography overlap with the preoperative cardiovascular guidelines, they provide a more comprehensive scope of indications for echocardiography independent of the perioperative period. Previous population-based studies have evaluated preoperative echocardiography utilization before noncardiac surgery and its impact on postoperative outcomes. These studies did not identify an association between preoperative resting echocardiography and improved 30-day mortality or major adverse cardiac events, even in high-risk patients.<sup>6,7</sup> However, there has been no large-scale effort to assess the use of resting echocardiography in the context of the appropriate use criteria. This information is particularly important as we approach the implementation of Centers for Medicare and Medicaid Services (Baltimore, Maryland) Appropriate Use Criteria Program in 2022, which will require providers to demonstrate adherence to appropriate use criteria when ordering advanced imaging studies.<sup>8</sup> We therefore determined the appropriateness of preoperative echocardiography by applying the Appropriate Use Criteria for Echocardiography in a population-based study.

The current study utilizes the Truven Health MarketScan Commercial and Medicare Supplemental Databases (Truven Health Analytics, USA) to investigate the frequency of preoperative resting echocardiography for major abdominal procedures from 2005 to 2017 and to assess the appropriateness of these tests according to the Appropriate Use Criteria for Echocardiography. We hypothesize that patients are frequently tested for indications deemed unnecessary by the Appropriate Use Criteria for Echocardiography.

## Materials and Methods

### Data Source

Data were obtained from the Truven Health MarketScan Commercial and Medicare Supplemental Databases from 2004 through 2017. These databases contain de-identified records of health services for more than 250 million patients with primary or Medicare supplemental health insurance coverage through employer-based fee-for-service, point-of-service, or capitated plans. The University of Chicago Institutional Review Board (Chicago, Illinois) considered

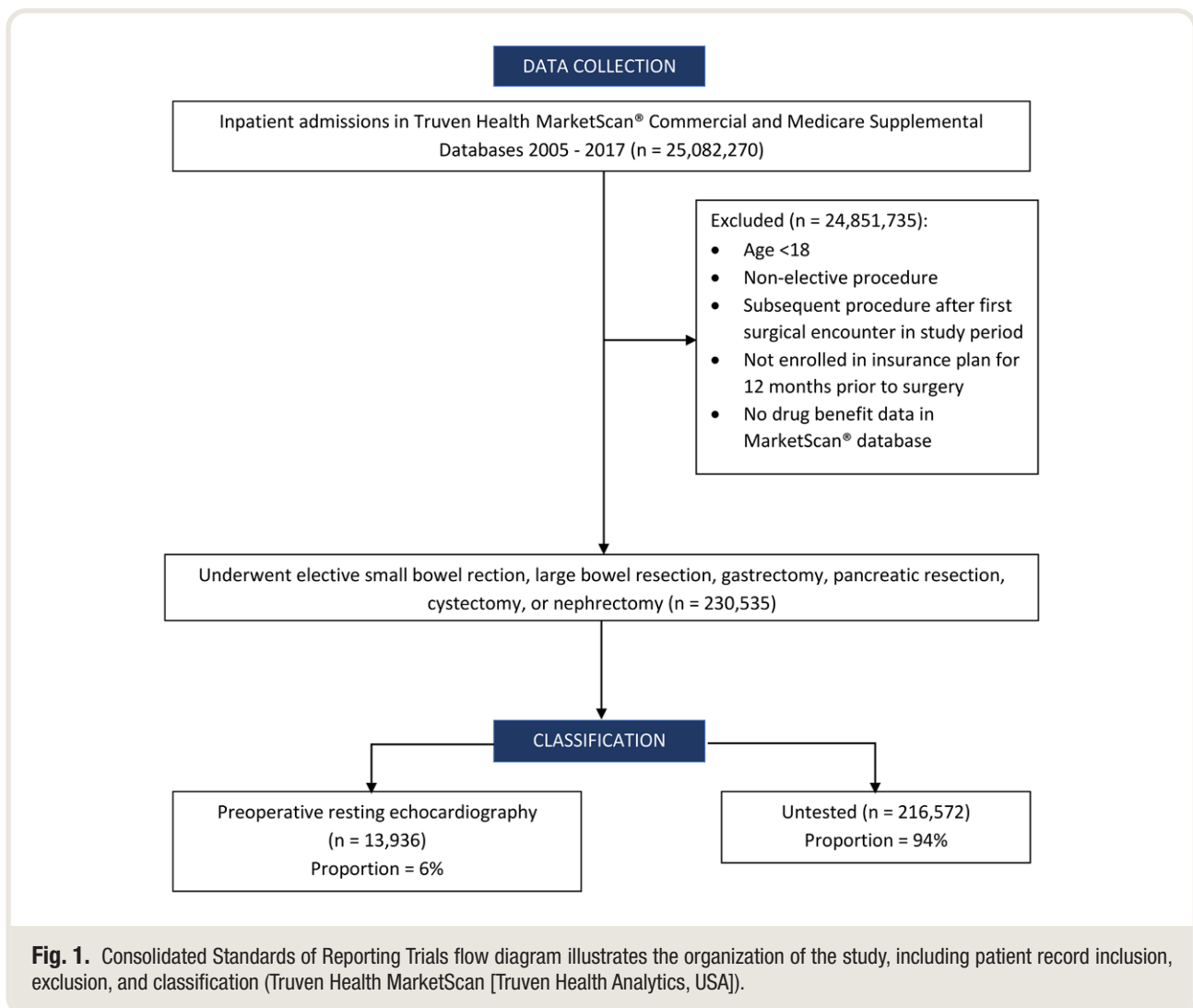
this study exempt from review as there are no patient identifiers in the MarketScan databases (IRB19-1891).

### Data Classification

Our analysis included records of patients with an International Classification of Diseases, Ninth Revision–Clinical Modification or International Classification of Diseases, Tenth Revision–Clinical Modification principal procedure code for a major abdominal surgical procedure (fig. 1). We focused on major abdominal procedures as they are a high-risk procedure for major adverse cardiac events as per the Revised Cardiac Risk Index.<sup>2</sup> We did not include intrathoracic and suprainguinal vascular procedures as there may be procedure-specific indications that warranted a resting echocardiogram. Procedures included open or laparoscopic small bowel resections, large bowel resections, gastric resections, pancreatic resections, cystectomies, and nephrectomies from 2005 to 2017 (Supplemental Digital Content table 1, <http://links.lww.com/ALN/C688>). Subjects were excluded from the analysis if (1) they were under 18 yr old ( $n = 7,327$ ), (2) the surgery was emergent (identified by correlation with an emergency room service claim from the same date as the surgery;  $n = 83,227$ ), (3) the surgery was not the first procedure of interest that the patient underwent during the study period ( $n = 9,476$ ), (4) the subject was not enrolled in an insurance plan for 1 yr before the surgery ( $n = 132,939$ ), and (5) there was no drug benefit data available in the MarketScan database for the patient ( $n = 85$ ).

### Outcomes

The primary outcome measure was the presence of a “rarely appropriate” resting echocardiogram performed within 60 days before a major abdominal surgery. A 60-day period was chosen as echocardiograms performed within this time period are likely preoperative tests consistent with previous analyses.<sup>9–11</sup> Outpatient resting transthoracic echocardiograms were identified using Current Procedural Terminology codes (Supplemental Digital Content table 2, <http://links.lww.com/ALN/C688>). The indications for the preoperative echocardiograms were determined based on the International Classification of Diseases, Ninth Revision–Clinical Modification or International Classification of Diseases, Tenth Revision–Clinical Modification principal or secondary diagnosis code associated with the echocardiography claim. Indications were categorized as “appropriate” if they were clearly specified as “appropriate” in the Appropriate Use Criteria for Echocardiography, such as a resting echocardiogram ordered for dyspnea or acute heart failure (e.g., International Classification of Diseases, Ninth Revision–Clinical Modification code 786.05 or 428.x, respectively; Supplemental Digital Content table 3, <http://links.lww.com/ALN/C688>). Indications were categorized as “rarely appropriate” if they were specified as



“rarely appropriate” in the Appropriate Use Criteria for Echocardiography, such as a resting echocardiogram ordered for chronic heart failure (e.g., International Classification of Diseases, Ninth Revision—Clinical Modification code 428.22) without any additional new symptom identified in a patient with an echocardiogram performed in the previous year, or a resting echocardiogram ordered for coronary atherosclerosis (International Classification of Diseases, Ninth Revision—Clinical Modification code 414.0x). No studies in our cohort were found to be “may be appropriate” as there are very few overall indications that are classified as “may be appropriate” in the Appropriate Use Criteria for Echocardiography, and they could not be correlated to International Classification of Diseases, Ninth Revision—Clinical Modification/International Classification of Diseases, Tenth Revision—Clinical Modification codes. Echocardiograms were considered “unclassifiable” if the indication did not allow appropriateness classification according to the Appropriate Use Criteria for

Echocardiography (e.g., heart disease, unspecified). While all the indications for the echocardiograms were based on the 2011 Appropriate Use Criteria for Echocardiography document, the recommended updated classification terminology from the 2013 methodology update was applied. This update did not change the classification of tests from the 2011 document, but rather adjusted the terminology used to describe these classifications in order to more closely reflect their application in practice.<sup>5</sup> In particular, “inappropriate” and “uncertain” indications from the 2011 document are now referred to as “rarely appropriate” and “may be appropriate,” respectively, in the 2013 document.

If records of patients included multiple resting echocardiograms, only the claim for the test performed on the date closest to the surgery was analyzed. If records included multiple claims for the same resting echocardiogram with disparate principal diagnosis codes, the claim used for analysis was determined using the following criteria: (1) if there were claims for both physician and

facility fees, the claim for the physician fee was analyzed; (2) if claims were paid on different dates, the claim with the earlier paid date was analyzed; and (3) if claims differed only in principal diagnosis, then the claim with the most specific diagnosis code or the code most closely aligned with Appropriate Use Criteria for Echocardiography was analyzed.

Secondary outcomes were major adverse cardiac events that included a diagnosis of myocardial infarction, cardiac arrest, or new heart failure during the inpatient claim associated with the major abdominal surgery. Outcomes were identified using International Classification of Diseases, Ninth Revision–Clinical Modification and International Classification of Diseases, Tenth Revision–Clinical Modification codes and can be found in the Supplemental Digital Content table 4 (<http://links.lww.com/ALN/C688>). Outcomes were stratified based on the appropriateness classification of the echocardiogram as outlined in the Appropriate Use Criteria for Echocardiography.

### Patient Characteristics

Patient characteristics analyzed were age, sex, geographical region, comorbid conditions, and Elixhauser score. Elixhauser comorbidities can be assessed as a single numeric score that summarizes disease burden and is adequately discriminative for in-hospital mortality.<sup>12</sup> Consistent with previous analyses of MarketScan, comorbidity diagnoses were included for cohort subjects if the International Classification of Diseases, Ninth Revision–Clinical Modification and International Classification of Diseases, Tenth Revision–Clinical Modification codes were present at least once in inpatient or outpatient claims from the year before the procedure.<sup>11</sup> Diagnosis codes used to classify comorbidities can be found in the Supplemental Digital Content table 5 (<http://links.lww.com/ALN/C688>).

Records of patients who underwent nonpreoperative resting echocardiography within 1 yr (*i.e.*, between 61 days and 365 days) of the procedure were also identified, as the Appropriate Use Criteria for Echocardiography specify that a repeat resting echocardiogram is unnecessary within 1 yr of a previous study in the absence of new symptoms or a change in clinical status.<sup>4</sup> This guidance for repeating a resting echocardiogram applies for patients undergoing preoperative evaluation who have had an echocardiogram in the last year.

Other cardiac tests, including exercise or pharmacologic stress tests, myocardial nuclear imaging, stress magnetic resonance imaging, and transesophageal echocardiograms, performed between 61 and 365 days before the procedure were also identified *via* Current Procedural Terminology codes in outpatient claims (Supplemental Digital Content table 2, <http://links.lww.com/ALN/C688>). These tests can influence the decision to pursue a preoperative echocardiogram and were included in the analysis.

Data were complete except for region of service ( $n = 1,576$ ). Apart from this, there were no missing data for any of the variables that were used for the analysis.

### Statistical Analysis

The data analysis was completed using SAS software, Version 9.4 (SAS Institute Inc., USA). A data analysis and statistical plan was written after the data were accessed. As this is a retrospective cohort study, the sample size was based on the available data, and no statistical power calculation was conducted. The Cochran–Armitage test was used to identify any trends in the frequency of “rarely appropriate” echocardiograms throughout the study period. Chi-square and unpaired *t* tests were used to compare patient characteristics between subjects who underwent preoperative resting echocardiography and those who did not, and chi-square and one-way ANOVA tests were used to compare patient characteristics between subjects who had “appropriate,” “rarely appropriate,” or “unclassifiable” indications for resting echocardiography and outcomes.

We conducted three sensitivity analyses. The first compared the incidence of “appropriate” resting echocardiograms between the preoperative period and outside of the preoperative period to determine if there was a higher frequency of “rarely appropriate” resting echocardiograms performed in the preoperative period. We applied the Appropriate Use Criteria for Echocardiography in the same manner as resting echocardiograms performed more than 60 days before the operative procedure and compared the appropriateness using a chi-square test. Second, we evaluated the incidence of resting echocardiograms over the 12-month period before surgery in the entire cohort to confirm that resting echocardiograms performed 60 days before the procedure were in response to the upcoming surgical procedure. The third sensitivity analysis evaluated comorbidity burden and cardiac outcomes of patients who underwent a repeat echocardiogram in the 60 days before surgery to evaluate if patients who underwent a repeat echocardiogram had a higher comorbidity burden and higher frequency of major adverse cardiac events. Significance for these analyses was set at  $P \leq 0.01$  with Bonferroni correction for multiple comparisons and two-tailed hypothesis testing where appropriate.

## Results

### Patient Characteristics

The study cohort consisted of 230,535 reports of patients, and characteristics of these patients are presented in table 1. Overall, 13,936 reports of patients (6%) included a preoperative resting echocardiogram in the 60 days before a major abdominal surgical procedure. Patients who underwent preoperative resting echocardiography were older, with a



**Table 1.** Characteristics of Patients Who Underwent Preoperative Resting Echocardiography (within 60 Days of Procedure) *versus* Patients Who Did Not Undergo Testing in Subjects Undergoing Elective Intra-abdominal Surgeries from MarketScan Commercial and Medicare Supplemental Databases 2005 to 2017

Characteristics	Preoperative Echocardiography Cohort (No. [%] or Mean $\pm$ SD)	Untested Cohort (No. [%] or Mean $\pm$ SD)	P Value
Patients	13,936 (6%)	216,599 (94%)	
Age, yr	63 $\pm$ 14	57 $\pm$ 14	< 0.001
Sex			< 0.001
Male	7,012 (50%)	99,915 (46%)	—
Female	6,924 (50%)	116,684 (50%)	—
Procedure type			< 0.001
Small bowel resection	485 (3%)	12,216 (6%)	—
Large bowel resection	6,162 (44%)	114,918 (53%)	—
Pancreatic resection	477 (3%)	4,695 (2%)	—
Gastrectomy	3,186 (23%)	42,746 (20%)	—
Cystectomy	713 (5%)	6,444 (3%)	—
Nephrectomy	2,913 (21%)	35,580 (16%)	—
Comorbidities			—
Insulin-dependent diabetes mellitus	1,022 (7%)	9,634 (4%)	< 0.001
Stroke	1,209 (9%)	7,491 (3%)	< 0.001
Chronic kidney disease	796 (6%)	6,886 (3%)	< 0.001
Coronary artery disease	3,570 (26%)	20,953 (10%)	< 0.001
Heart failure	1,595 (11%)	7,341 (3%)	< 0.001
Mitral valve pathology	2,530 (18%)	8,075 (4%)	< 0.001
Aortic valve pathology	1,390 (10%)	3,997 (2%)	< 0.001
Other valve pathology	1,110 (8%)	3,262 (2%)	< 0.001
Elixhauser score	6 $\pm$ 9	4 $\pm$ 7	< 0.001
Echocardiogram within 1 yr	1,502 (11%)	24,284 (11%)	0.115
Other cardiac test within 1 yr	1,119 (8%)	18,983 (9%)	0.003
Region			< 0.001
North Central	3,747 (27%)	59,385 (27%)	—
Northeast	2,984 (21%)	30,913 (14%)	—
South	5,375 (39%)	87,369 (40%)	—
West	1,775 (13%)	37,411 (17%)	—
Unknown/missing	55 (< 1%)	1,521 (< 1%)	—
Metropolitan Statistical Area quintile			< 0.001
1	427 (3%)	16,476 (8%)	—
2	1,094 (8%)	29,806 (14%)	—
3	3,891 (28%)	70,686 (33%)	—
4	3,268 (23%)	49,652 (23%)	—
5	5,088 (37%)	46,890 (22%)	—
Unknown/missing	168 (1%)	3,089 (1%)	—

Proportions and SD are reported for categorical and continuous variables, respectively. Significant differences between cohorts were determined via chi-square tests or unpaired *t* tests for categorical and continuous variables, respectively, and significance was set at  $P \leq 0.001$  (Truven Health MarketScan [Truven Health Analytics, USA]).

mean age of 63 yr (SD = 14 yr) as compared to 57 yr (SD = 14 yr) in the untested cohort ( $P < 0.001$ ). Patients who received a preoperative resting echocardiogram had higher frequencies of multiple comorbidities, including insulin-dependent diabetes mellitus, stroke, chronic kidney disease, coronary artery disease, heart failure, and any cardiac valve pathology ( $P < 0.001$ ). We did not identify a difference between the cohorts in frequency of nonpreoperative resting echocardiography (1,502 of 13,936, 11% *vs.* 24,284 of 216,599, 11%;  $P = 0.115$ ) in the year before the procedure. The untested cohort did have a higher frequency of other nonpreoperative cardiac tests performed in the year before surgery (1,119 of 13,936, 8% *vs.* 18,983 of 216,599, 9%;  $P = 0.002$ ); however, this difference is unlikely to be clinically significant.

### Classification According to the Appropriate Use Criteria for Echocardiography

Characteristics of patients who underwent preoperative resting echocardiography for “appropriate,” “rarely appropriate,” and “unclassifiable” indications are presented in table 2. Of all preoperative resting echocardiograms, 12,638 (91%) were classifiable by the Appropriate Use Criteria for Echocardiography, and 1,298 (9%) were unable to be classified. Of classifiable studies, 8,959 (71%) were classified as “appropriate,” and 3,679 (29%) were classified as “rarely appropriate.” There was no change in the frequency of “appropriate” *versus* “rarely appropriate” echocardiograms that were classifiable by the Appropriate Use Criteria or Echocardiography throughout the study period (Supplemental Digital Content table 6, <http://links.lww>).

**Table 2.** Characteristics of Patients Who Received Preoperative Echocardiography (within 60 Days of Procedure) for Appropriate, Rarely Appropriate, or Unclassifiable Indications in Subjects Undergoing Elective Intra-abdominal Surgeries from MarketScan Commercial and Medicare Supplemental Databases 2005 to 2017

Characteristics	Appropriate (No. [%] or Mean $\pm$ SD)	Rarely Appropriate (No. [%] or Mean $\pm$ SD)	Unclassifiable (No. [%] or Mean $\pm$ SD)	P Value
Patients, No.	8,959	3,679	1,298	
Age, yr	63 $\pm$ 14	64 $\pm$ 14	62 $\pm$ 14	< 0.001
Sex				< 0.001
Male	4,277 (48%)	2,031 (55%)	704 (54%)	—
Female	4,682 (52%)	1,648 (45%)	594 (46%)	—
Procedure type				< 0.001
Small bowel resection	319 (4%)	108 (3%)	58 (4%)	—
Large bowel resection	4,075 (45%)	1,534 (42%)	553 (43%)	—
Pancreatic resection	272 (3%)	141 (4%)	64 (5%)	—
Gastrectomy	2,078 (23%)	850 (23%)	258 (20%)	—
Cystectomy	430 (5%)	212 (6%)	71 (5%)	—
Nephrectomy	1,785 (20%)	834 (23%)	294 (23%)	—
Comorbidities				
Insulin-dependent diabetes mellitus	591 (7%)	335 (9%)	96 (7%)	< 0.001
Stroke	766 (9%)	347 (9%)	96 (7%)	0.063
Chronic kidney disease	460 (5%)	268 (7%)	68 (5%)	< 0.001
Coronary artery disease	1,823 (20%)	1,458 (40%)	289 (22%)	< 0.001
Heart failure	1,066 (12%)	382 (10%)	147 (9%)	0.052
Mitral valve pathology	1,894 (21%)	475 (13%)	161 (12%)	< 0.001
Aortic valve pathology	967 (11%)	350 (10%)	73 (6%)	< 0.001
Other valve pathology	830 (9%)	206 (6%)	74 (6%)	< 0.001
Elixhauser score	6 $\pm$ 9	6 $\pm$ 9	8 $\pm$ 10	< 0.001
Repeat echocardiogram within 1 yr	537 (6%)	785 (21%)	180 (14%)	< 0.001
Region				< 0.001
North Central	2,319 (26%)	1,027 (28%)	401 (31%)	—
Northeast	2,051 (23%)	731 (20%)	202 (16%)	—
South	3,533 (39%)	1,346 (37%)	496 (38%)	—
West	1,025 (11%)	557 (15%)	193 (14%)	—
Unknown/missing	31 (< 1%)	18 (< 1%)	6 (< 1%)	—

Proportions and SD are reported for categorical and continuous variables, respectively. Significant differences between cohorts were determined via chi-square tests or one-way ANOVA tests for categorical and continuous variables, respectively, and significance was set at  $P \leq 0.01$  (Truven Health MarketScan [Truven Health Analytics, USA]).

com/ALN/C688). Repeat echocardiograms (*i.e.*, a preoperative resting echocardiogram when another resting echocardiogram was done within the year before the procedure) accounted for 11% (1,502 of 13,936) of all perioperative resting echocardiograms, and 52% (785 of 1,502) were classified as “rarely appropriate,” 36% (537 of 1,502) as “appropriate,” and 12% (180 of 1,502) as “unclassifiable.” Men had a higher proportion of “rarely appropriate” echocardiograms (2,031 of 6,308, 32% *vs.* 1,648 of 6,330, 26%;  $P < 0.001$ ) as compared to women. Patients with coronary artery disease had the highest frequency (44%, 1,458 of 3,281) of “rarely appropriate” echocardiograms among all the cardiac comorbidities. The most common “rarely appropriate” echocardiogram indications in our study were surveillance of chronic ischemic heart disease (954 of 3,679, 26%), general preoperative examination (767 of 3,679, 21%), and hypertension (634 of 3,679, 17%).

### Major Adverse Cardiac Events

The overall frequency of major adverse cardiac events that included myocardial infarction, cardiac arrest, and heart

failure was 0.6% (1,317 of 230,535). The frequency among patients that did not have a preoperative echocardiogram was 0.5% (1,116 of 216,599) as compared to 1.4% (201 of 13,936) in patients who did receive a preoperative echocardiogram ( $P < 0.001$ ). There was no difference in the frequency of major adverse cardiac events in patients with a “rarely appropriate” (1.8%, 66 of 3,679), “appropriate” (1.3%, 116 of 8,959), or “unclassifiable” resting echocardiogram (1.5%, 19 of 1,298;  $P = 0.086$ ).

### Sensitivity Analysis

In our cohort, 11.2% (25,786 of 230,535) of patient records contained a claim for a resting echocardiogram performed before the preoperative period. Of those echocardiograms, 23,160 (90%) were classifiable by the Appropriate Use Criteria for Echocardiography, 17,213 (74%) were “appropriate,” and 5,947 (26%) were “rarely appropriate.” The proportion of resting echocardiograms that were classified as “rarely appropriate” in the preoperative setting was higher than those outside of the preoperative period in our cohort. Additionally, the frequency for all resting echocardiograms

done in the year before surgery can be seen in Supplemental Digital Content figure 1 (<http://links.lww.com/ALN/C688>) and Supplemental Digital Content table 7 (<http://links.lww.com/ALN/C688>). Resting echocardiograms in the 2 months before surgery accounted for 47% (28,122 of 59,788) of the total volume of resting echocardiograms. We observed a sharp increase in the frequency of resting echocardiograms in the 2 months before major abdominal surgery, as illustrated by Supplemental Digital Content figure 1 (<http://links.lww.com/ALN/C688>).

Among records of patients that included a resting echocardiogram in the preoperative period and also an echocardiogram in the previous year, mean Elixhauser comorbidity scores were greater for patients who had an “unclassifiable” 13 (SD = 11) and “appropriate” 12 (SD = 10) resting echocardiogram as compared to a “rarely appropriate” 10 (SD = 10) resting echocardiogram ( $P < 0.001$ ). The frequency of myocardial infarction, cardiac arrest, and heart failure associated with repeat echocardiograms overall was 2.7% (39 of 1,502). There was no difference in the frequency of complications in patients with a “rarely appropriate” (3.3%, 26 of 785), “appropriate” (1.9%, 10 of 537), or “unclassifiable” resting echocardiogram (1.5%, 3 of 180;  $P = 0.187$ ).

## Discussion

In our retrospective cohort study, we found that while preoperative resting echocardiography was uncommon overall (6%), more than one in four echocardiograms (29%) that were classifiable by the Appropriate Use Criteria for Echocardiography were considered “rarely appropriate.” The American College of Cardiology and American Heart Association perioperative practice guidelines recommend a narrow set of conditions for preoperative resting echocardiography known to be associated with increased perioperative complications.<sup>2</sup> An important and consistent theme throughout the practice guidelines is that cardiac testing should be rarely pursued in the absence of a clear indication independent of the impending surgery. The Appropriate Use Criteria for Echocardiography provide guidance to clinicians in the optimal use of resting echocardiography for all clinical settings and provide guidance to perioperative clinicians in appropriate use of resting echocardiography for conditions that may not directly apply to the perioperative period. The most frequent reason for “rarely appropriate” preoperative resting echocardiograms in our study was routine surveillance of known cardiovascular disease, such as chronic ischemic heart disease. Further, there was no difference in frequency of major adverse cardiac events among patients undergoing “rarely appropriate” as compared to “appropriate” or “unclassifiable” echocardiograms. These findings suggest that while overall preoperative resting echocardiography utilization is low, there still exists an opportunity to reduce testing that has not been shown to impact perioperative cardiac morbidity.

The high proportion of “rarely appropriate” echocardiograms may be secondary to the outpatient nature of the echocardiograms assessed in this study as well as ordering clinician characteristics. Outpatient studies are less likely to be associated with a change in clinical status and are known to have a higher frequency of “rarely appropriate” echocardiograms compared to inpatient exams. The frequency of “rarely appropriate” echocardiograms in other practice settings has been reported as high as 30%, which is similar to our findings.<sup>13–15</sup> In our sensitivity analysis of nonperioperative echocardiograms, we identified a high percentage of “rarely appropriate” echocardiograms in the outpatient setting, which suggests that potential overuse of cardiac imaging in the outpatient setting is not limited to the preoperative period. Ordering clinician characteristics may lead to a higher frequency of “rarely appropriate” echocardiograms in the preoperative setting. In a single academic center retrospective cohort of patients referred for outpatient transthoracic echocardiography, we demonstrated that anesthesia and surgical clinicians had the highest frequency of “rarely appropriate” echocardiograms (21% and 19%, respectively) as compared to cardiologists (3%) or internal medicine clinicians (10%).<sup>16</sup> This may be due to a lack of familiarity with the Appropriate Use Criteria for Echocardiography among anesthesia and surgical clinicians.<sup>16</sup> Anesthesiologists are required to address medical concerns during perioperative visits that extend beyond the upcoming procedure. As such, our specialty should consider incorporating the Appropriate Use Criteria for Echocardiography to guide preoperative cardiovascular imaging and develop interventions to reduce potential overuse. Our finding that a small number of diagnoses (*e.g.*, surveillance of chronic ischemic heart disease) are associated with a large proportion of “rarely appropriate” echocardiograms may help to guide interventions that may be effective to decrease potential overuse of preoperative resting echocardiography.<sup>13,17,18</sup>

Chronic ischemic heart disease without change in clinical status accounted for just over a quarter of all the “rarely appropriate” echocardiograms in our study and may be an easy target to reduce overuse. In the only prospective trial across eight hospital systems to reduce “rarely appropriate” echocardiograms, the second most common reason for a “rarely appropriate” echocardiogram was routine surveillance of ventricular function with known coronary artery disease and no change in clinical status or cardiac examination.<sup>17</sup> The intervention for the trial comprised an initial video lecture, a mobile application-based decision support tool, and monthly clinician feedback reports for cardiologists and primary care providers that summarized individual ordering behavior. The proportion of rarely appropriate echocardiograms decreased in the intervention group as compared to the control (8.8% *vs.* 10.1%; odds ratio, 0.75; 95% CI, 0.57 to 0.99;  $P = 0.039$ ), and the decrease was sustained throughout the study period.

Sex bias may have played a role in the higher frequency of men receiving a “rarely appropriate” echocardiogram as men may be more likely to receive cardiovascular testing. Previous population-based studies that evaluated utilization of perioperative resting echocardiograms similarly identified a higher frequency of testing in men as compared to women.<sup>6</sup> In a study of sex bias among cardiologists evaluating a simulated patient with suspected coronary artery disease, male patients were more consistently rated as likely to benefit from angiography as compared to female patients.<sup>19</sup> Given the known bias toward men and cardiovascular disease, it appears highly plausible that sex bias played a role with the increased frequency of “rarely appropriate” preoperative resting echocardiograms in our analysis.

Our study is timely in light of the Centers for Medicare and Medicaid Services mandate starting in 2022 that will require appropriateness determinations according to the Appropriate Use Criteria for Echocardiography to be submitted at the time of study order for all “advanced imaging procedures” for Medicare beneficiaries.<sup>20</sup> Clinicians will be tracked through the program, and those considered outliers with a high frequency of “rarely appropriate” studies will be subject to more rigorous authorizing procedures and potential reimbursement denials. Initially, perioperative physicians will experience this program in relation to preoperative nuclear stress testing as resting echocardiography is not included in the first phase of the mandate. However, as the highest volume cardiac imaging test performed, resting echocardiography is expected to be included as the program expands.<sup>21</sup> Further, perioperative testing is likely to be a particular focus and may be disproportionately affected by these programs. Our study addresses the knowledge gap of appropriate use criteria for resting echocardiography on a national level, and our finding of a high frequency of rarely appropriate studies suggests significant potential overuse. However, a full understanding of appropriate utilization of perioperative resting echocardiography also requires consideration of potential underuse when “appropriate” indications are present. In a study that used the National Inpatient Sample to identify “appropriate” use of inpatient resting echocardiography for certain conditions (*e.g.*, acute myocardial infarction), only 8% of inpatient admissions received a resting echocardiogram.<sup>22</sup> Patients who received a resting echocardiogram had a lower inpatient mortality as compared to patients who did not when adjusting for patient and hospital characteristics. Given that there are a variety of appropriate indications unrelated to surgery that may first come to clinical attention in the perioperative setting (*e.g.*, heart murmur), the potential for underuse of resting echocardiography is real. While our study did not address underuse, further study of this issue in the perioperative setting, and its association with patient outcomes, deserves study.

Our study has several limitations. First, the MarketScan databases only include patients with employer-sponsored

health insurance or Medicare supplemental plans and may not be a representative sample of the U.S. population. This may explain why our frequency of preoperative echocardiograms was lower than other population-based studies that had higher mean ages for their cohorts. Thus, it remains unclear if our results are generalizable to a traditional Medicare population. MarketScan provides diagnosis and procedure codes for billing purposes, and these codes do not fully represent the scope of disease and may not capture clinical changes over time for each patient. Other unmeasured variables may have impacted the decision for preoperative echocardiography that we were unable to account for, and it is possible that the billing codes utilized did not appropriately reflect the clinical status of the patient. However, we used a robust approach to classify echocardiograms based on principal and secondary diagnoses that were directly matched to criteria found within the Appropriate Use Criteria for Echocardiography. Further, we did not identify any change in the frequency of “appropriate” echocardiograms across the transition from International Classification of Diseases, Ninth Revision–Clinical Modification to International Classification of Diseases, Tenth Revision–Clinical Modification coding that took place in 2015. In addition, our data collection focused on comorbidities that were documented in the year before surgery, which may not capture the full burden of comorbid disease for each patient. The Appropriate Use Criteria for Echocardiography rely much more heavily on consensus and expert opinion as compared to practice guidelines that rely heavily on a more evidence-based format.<sup>23</sup> However, the Appropriate Use Criteria for Echocardiography incorporate the preoperative cardiac evaluation practice guidelines with regards to their recommendations. Finally, the later years of the study cohort contained fewer patients as compared to earlier in the cohort, and this may have led to decreased precision in some of the later estimates of the frequency of “rarely appropriate” studies.

In conclusion, more than one in four classifiable resting preoperative echocardiograms before major abdominal surgical procedures may be considered “rarely appropriate” according to the Appropriate Use Criteria for Echocardiography. It is important to focus continued efforts on mitigating potential overuse of preoperative echocardiography, as unnecessary testing contributes to increased costs to patients and to the healthcare system.

## Research Support

Dr. Rubin and Dr. Nagele were supported by funding from the National Institutes of Health/National Heart, Lung, and Blood Institute (Bethesda, Maryland; R01 HL126892).

## Competing Interests

Dr. Rubin is the president of DRDR Mobile Health (Chicago, Illinois), a company that creates mobile



applications for health care, including functional capacity assessment applications. He has engaged in consulting for mobile applications as well. He has not taken any salary or money from the company. Dr. Rubin has also consulted as an expert witness. The research in this article had no relationship to any of that work. The other authors declare no competing interests.

## Correspondence

Address correspondence to Dr. Rubin: 5841 S. Maryland Avenue, MC-4028, Chicago, Illinois 60637. drubin@dacc.uchicago.edu ANESTHESIOLOGY's articles are made freely accessible to all readers on [www.anesthesiology.org](http://www.anesthesiology.org), for personal use only, 6 months from the cover date of the issue.

## References

- Smilowitz NR, Gupta N, Ramakrishna H, Guo Y, Berger JS, Bangalore S: Perioperative major adverse cardiovascular and cerebrovascular events associated with noncardiac surgery. *JAMA Cardiol* 2017; 2:181–7
- Fleisher LA, Fleischmann KE, Auerbach AD, Barnason SA, Beckman JA, Bozkurt B, Davila-Roman VG, Gerhard-Herman MD, Holly TA, Kane GC, Marine JE, Nelson MT, Spencer CC, Thompson A, Ting HH, Uretsky BF, Wijeyesundera DN; American College of Cardiology; American Heart Association: 2014 ACC/AHA guideline on perioperative cardiovascular evaluation and management of patients undergoing noncardiac surgery: A report of the American College of Cardiology/American Heart Association Task Force on practice guidelines. *J Am Coll Cardiol* 2014; 64:e77–137
- Douglas PS, Khandheria B, Stainback RF, Weissman NJ, Brindis RG, Patel MR, Khandheria B, Alpert JS, Fitzgerald D, Heidenreich P, Martin ET, Messer JV, Miller AB, Picard MH, Raggi P, Reed KD, Rumsfeld JS, Steimle AE, Tonkovic R, Vijayaraghavan K, Weissman NJ, Yeon SB, Brindis RG, Douglas PS, Hendel RC, Patel MR, Peterson E, Wolk MJ, Allen JM: ACCF/AHA/ACEP/ASNC/SCAI/SCCT/SCMR 2007 appropriateness criteria for transthoracic and transesophageal echocardiography. *J Am Soc Echocardiogr* 2007; 20:787–805
- American College of Cardiology Foundation Appropriate Use Criteria Task Force, American Society of Echocardiography, American Heart Association, American Society of Nuclear Cardiology, Heart Failure Society of America, Heart Rhythm Society, Society for Cardiovascular Angiography and Interventions, Society of Critical Care Medicine, Society of Cardiovascular Computed Tomography, Society for Cardiovascular Magnetic Resonance, Douglas PS, Garcia MJ, Haines DE, Lai WW, Manning WJ, Patel AR, Picard MH, Polk DM, Ragosta M, Ward RP, Weiner RB: ACCF/AHA/ASE/ASNC/HFSA/HRS/SCAI/SCCM/SCCT/SCMR 2011 appropriate use criteria for echocardiography. A report of the American College of Cardiology Foundation Appropriate Use Criteria Task Force, American Society of Echocardiography, American Heart Association, American Society of Nuclear Cardiology, Heart Failure Society of America, Heart Rhythm Society, Society for Cardiovascular Angiography and Interventions, Society of Critical Care Medicine, Society of Cardiovascular Computed Tomography, and Society for Cardiovascular Magnetic Resonance Endorsed by the American College of Chest Physicians. *J Am Coll Cardiol* 2011; 57:1126–66
- Hendel RC, Patel MR, Allen JM, Min JK, Shaw LJ, Wolk MJ, Douglas PS, Kramer CM, Stainback RF, Bailey SR, Doherty JU, Brindis RG: Appropriate use of cardiovascular technology: 2013 ACCF appropriate use criteria methodology update: A report of the American College of Cardiology Foundation appropriate use criteria task force. *J Am Coll Cardiol* 2013; 61:1305–17
- Wijeyesundera DN, Beattie WS, Karkouti K, Neuman MD, Austin PC, Laupacis A: Association of echocardiography before major elective non-cardiac surgery with postoperative survival and length of hospital stay: Population based cohort study. *BMJ* 2011; 342:d3695
- Levitan EB, Graham LA, Valle JA, Richman JS, Hollis R, Holcomb CN, Maddox TM, Hawn MT: Preoperative echocardiography among patients with coronary artery disease in the United States Veterans Affairs healthcare system: A retrospective cohort study. *BMC Cardiovasc Disord* 2016; 16:173
- Appropriate Use Criteria Program | CMS. Available at: <https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/Appropriate-Use-Criteria-Program>. Accessed July 15, 2021.
- Sheffield KM, McAdams PS, Benarroch-Gampel J, Goodwin JS, Boyd CA, Zhang D, Riall TS: Overuse of preoperative cardiac stress testing in Medicare patients undergoing elective noncardiac surgery. *Ann Surg* 2013; 257:73–80
- Sun LY, Gershon AS, Ko DT, Thilen SR, Yun L, Beattie WS, Wijeyesundera DN: Trends in pulmonary function testing before noncardiothoracic surgery. *JAMA Intern Med* 2015; 175:1410–2
- Rubin DS, Hughey R, Gerlach RM, Ham SA, Ward RP, Nagele P: Frequency and outcomes of preoperative stress testing in total hip and knee arthroplasty from 2004 to 2017. *JAMA Cardiol* 2021; 6:13–20
- Walraven C van, Austin PC, Jennings A, Quan H, Forster AJ: A modification of the Elixhauser comorbidity measures into a point system for hospital death using administrative data. *Med Care* 2009; 47:626–33

13. Mansour IN, Razi RR, Bhavé NM, Ward RP: Comparison of the updated 2011 appropriate use criteria for echocardiography to the original criteria for transthoracic, transesophageal, and stress echocardiography. *J Am Soc Echocardiogr* 2012; 25:1153–61
14. Kirkpatrick JN, Ky B, Rahmouni HW, Chirinos JA, Farmer SA, Fields AV, Ogbara J, Eberman KM, Ferrari VA, Silvestry FE, Keane MG, Opatowsky AR, Sutton MS, Wiegers SE: Application of appropriateness criteria in outpatient transthoracic echocardiography. *J Am Soc Echocardiogr* 2009; 22:53–9
15. Rao G, Sajjani N, Kusnetzky LL, Main ML: Appropriate use of transthoracic echocardiography. *Am J Cardiol* 2010; 105:1640–2
16. McClelland I, Mor-Avi V, Lang RM, Ward RP: Prevalence of clinically important abnormalities found on transthoracic echocardiography ordered for indication of heart murmur found on physical examination. *J Am Soc Echocardiogr* 2020; 33:900–1
17. Bhatia RS, Ivers NM, Yin XC, Myers D, Nesbitt GC, Edwards J, Yared K, Wadhwa RK, Wu JC, Kithcart AP, Wong BM, Hansen MS, Weinerman AS, Shadowitz S, Elman D, Farkouh ME, Thavendiranathan P, Udell JA, Johri AM, Chow CM, Hall J, Bouck Z, Cohen A, Thorpe KE, Rakowski H, Picard MH, Weiner RB: Improving the appropriate use of transthoracic echocardiography: The Echo WISELY Trial. *J Am Coll Cardiol* 2017; 70:1135–44
18. Dudzinski DM, Bhatia RS, Mi MY, Isselbacher EM, Picard MH, Weiner RB: Effect of educational intervention on the rate of rarely appropriate outpatient echocardiograms ordered by attending academic cardiologists: A randomized clinical trial. *JAMA Cardiol* 2016; 1:805–12
19. Daugherty SL, Blair IV, Havranek EP, Furniss A, Dickinson LM, Karimkhani E, Main DS, Masoudi FA: Implicit gender bias and the use of cardiovascular tests among cardiologists. *J Am Heart Assoc* 2017; 6:e006872
20. Protecting Access to Medicare Act of 2014, Pub L No. 113–93. Available at: <https://www.congress.gov/113/plaws/publ93/PLAW-113publ93.pdf>. Accessed July 15, 2021.
21. Hackett I, Ward RP: Appropriate use criteria for echocardiography in the era of value-based care: Mission accomplished or future mandates? *Curr Cardiol Rep* 2020; 22:69
22. Papolos A, Narula J, Bavishi C, Chaudhry FA, Sengupta PP: U.S. hospital use of echocardiography: Insights from the Nationwide Inpatient Sample. *J Am Coll Cardiol* 2016; 67:502–11
23. Singh A, Ward RP: Appropriate use criteria for echocardiography: Evolving applications in the era of value-based healthcare. *Curr Cardiol Rep* 2016; 18:93