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ORIGINAL RESEARCH

AUB-HAS2 Cardiovascular Risk Index: Performance in Surgical Subpopulations and Comparison to the Revised Cardiac Risk Index

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BACKGROUND: The American University of Beirut (AUB)-HAS2 Cardiovascular Risk Index is a newly derived index for preoperative cardiovascular evaluation. It is based on 6 data elements: history of heart disease; symptoms of angina or dyspnea; age ≥75 years; hemoglobin <12 mg/dL; vascular surgery; and emergency surgery. In this study we analyze the performance of this new index and compare it with that of the Revised Cardiac Risk Index in a broad spectrum of surgical subpopulations.

METHODS AND RESULTS: The study population consisted of 1 167 278 noncardiac surgeries registered in the American College of Surgeons National Surgical Quality Improvement Program database. Each patient was given an AUB-HAS2 score of 0, 1, 2, 3, or >3, depending on the number of data elements present. The performance of the AUB-HAS2 index was studied in 9 surgical specialty groups and in 8 commonly performed site-specific surgeries. Receiver operating characteristic curves were constructed for the AUB-HAS2 and Revised Cardiac Risk Index measures, and the areas under the curve were compared. The outcome measure was death, myocardial infarction, or stroke at 30 days after surgery. The AUB-HAS2 score was able to stratify risk in all surgical subgroups (P<0.001). In the majority of surgeries, patients with an AUB-HAS2 score of 0 had an event rate of <0.5%. The performance of the AUB-HAS2 index was superior to that of the Revised Cardiac Risk Index in all surgical subgroups (P<0.001).

CONCLUSIONS: This study extends the validation of the AUB-HAS2 index to a broad spectrum of surgical subpopulations and demonstrates its superior discriminatory power compared with the commonly utilized Revised Cardiac Risk Index.

Key Words: AUB-HAS2 cardiovascular risk index ■ preoperative cardiovascular evaluation ■ revised cardiac risk index

Preoperative cardiovascular risk assessment is an essential step in the initial evaluation and management of patients undergoing noncardiac surgery.[1–6] There are several indices derived for this risk assessment. The Revised Cardiac Risk Index (RCRI) is probably the most commonly used measure because of its relative simplicity.[5] It consists of 6 variables: high-risk surgery; history of ischemic heart disease; history of congestive heart failure; history of cerebrovascular disease; Diabetes mellitus on insulin; and creatinine >2 mg/dL (Table 1). However, recent large cohort studies have suggested that the RCRI may underestimate the risk of cardiovascular events in contemporary surgical practice.[7]

We have recently reported a new risk index: the AUB-HAS2 cardiovascular risk index, which is simple to acquire and has a powerful discriminatory ability to predict cardiovascular events after noncardiac surgery.[8] The index was derived from a prospectively enrolled cohort of 3284 patients undergoing noncardiac surgery at the American University of Beirut (AUB) and it was validated in the large American College

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CLINICAL PERSPECTIVE

What Is New?

- The American University of Beirut (AUB)-HAS2 Cardiovascular Risk Index is a newly derived index for preoperative cardiovascular evaluation that is based on 6 easily acquired data elements: history of heart disease; symptoms of heart disease (angina or dyspnea); age ≥75 years; anemia (hemoglobin <12 mg/dL); vascular surgery; and emergency surgery.
- The AUB-HAS2 index can stratify patients undergoing noncardiac surgery into 3 risk groups: low risk (score 0–1); intermediate risk (score 2–3); and high risk (score >3).
- This study extends the validation of this new index to a broad spectrum of surgical specialties and site-specific surgical procedures, and the performance of the AUB-HAS2 index was shown to be superior to that of the commonly utilized Revised Cardiac Risk Index in all surgical subgroups.

What Are the Clinical Implications?

- The AUB-HAS2 cardiovascular risk index is a simple and comprehensive measure that can be effectively utilized by the busy physician in clinic or the nurse in the preadmission unit to quickly stratify the cardiovascular risk of patients undergoing a wide range of noncardiac surgical procedures.
- The AUB-HAS2 index can identify a large group of low-risk patients with a score of 0 who may not need further cardiovascular evaluation or special monitoring postoperatively.
- This index facilitates optimal use of human and hospital resources in patients undergoing surgery.

Nonstandard Abbreviations and Acronyms

ACS NSQIP	American College of Surgeons National Surgical Quality Improvement Program
AUB	American University of Beirut
AUC	area under the curve
CVRI	cardiovascular risk index
RCRI	revised cardiac risk index
ROC	receiver operating characteristic curve

of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database.[8–10] The AUB-HAS2 index is based on 6 easily acquired data elements: history of **H**eart disease; symptoms of **H**eart disease (angina or dyspnea); **A**ge ≥75 years; **A**nemia (hemoglobin <12 mg/dL); vascular **S**urgery; and emergency **S**urgery (Figure 1). It can stratify patients undergoing noncardiac surgery into 3 risk groups: low risk (score 0–1); intermediate risk (score 2–3); and high risk (score >3). The objective of this study is to analyze the performance of the AUB-HAS2 index in a broad spectrum of surgical subpopulations and compare it to that of the commonly utilized RCRI.

Table 1. Elements of the AUB-HAS2 and Revised Cardiac Risk Indices

AUB-HAS2 Cardiovascular Risk Index	Revised Cardiac Risk Index
• History of heart disease • Symptoms of heart disease (angina or dyspnea) • Age ≥75 years • Anemia (hemoglobin <12 mg/dL) • Vascular surgery • Emergency surgery	• History of ischemic heart disease • History of congestive heart failure • History of cerebrovascular disease • Diabetes mellitus on insulin • Creatinine >2 mg/dL • High-risk surgery

AUB indicates The American University of Beirut.

METHODS

The authors declare that all supporting data are available within the article. According to the guidelines of the AUB institutional review board, review and approval was not needed for our analysis because it involved de-identified data previously collected as part of a quality assurance program.

The study population consisted of 1 167 278 noncardiac surgical procedures registered between 2008 and 2012 in the ACS NSQIP database.[9,10] Data sets after 2012 were not included in our study because they did not capture patients' cardiac history, which is one of the essential elements in the AUB-HAS2 Cardiovascular Risk Index. The ACS NSQIP is a large, multicenter database that collects data on patients undergoing major surgical procedures from >250 participating sites on >150 variables, including preoperative risk factors, intraoperative variables, and 30-day postoperative mortality and morbidity outcomes. The data are collected by trained surgical clinical reviewers at each site using a systematic sampling process and are subject to regular inter-rater reliability audits to assess its quality. Required data variables are entered via web-based data collection to the ACS NSQIP website. Types of surgery are entered in the database using the *International Classification of Diseases* (*ICD*) codes. Patients <18 years of age were excluded from the database as were as minor and transplant surgical procedures.

Each patient was assigned an AUB-HAS2 score of 0, 1, 2, 3, and >3, based on the number of data elements present. The AUB-HAS2 elements are: history of heart

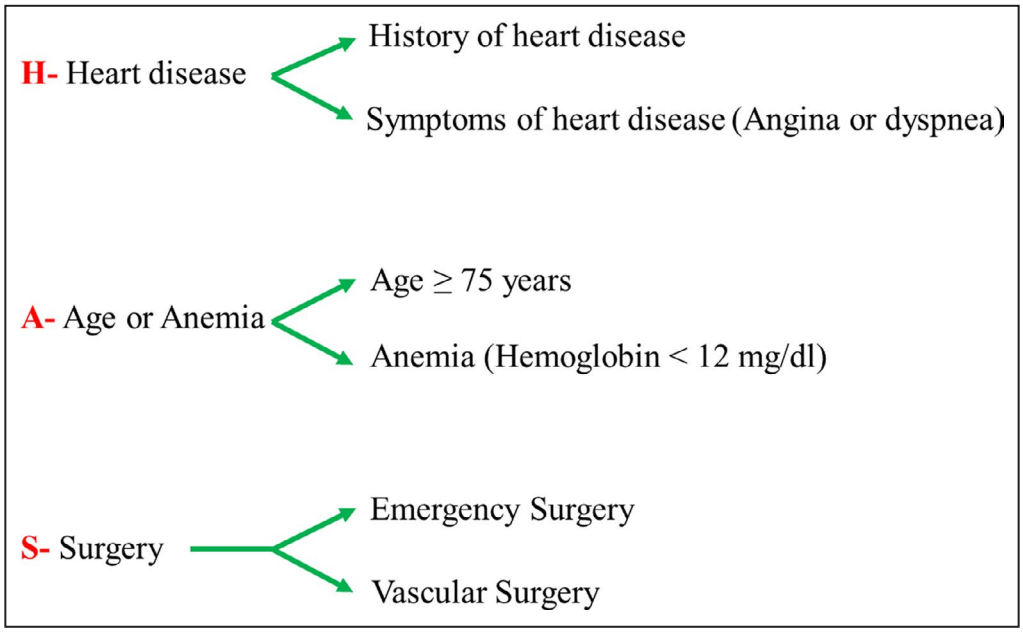

Figure 1. The AUB-HAS2 index.
AUB indicates American University of Beirut. The HAS2 is an acronym of the data elements as illustrated in the figure.

disease; symptoms of heart disease (angina or dyspnea); age ≥75 years; anemia (hemoglobin <12 mg/dL); vascular surgery; and emergency surgery. Patients were designated as having a history of heart disease if they had a history of previous myocardial infarction, coronary angioplasty, cardiac surgery, heart failure, atrial fibrillation, or moderate/severe valvular disease confirmed by echocardiography. The primary outcome measure was death, myocardial infarction, or stroke at 30 days after surgery.[8–10] Death was defined as mortality secondary to any cause occurring during the intraoperative period or at any point within 30 days after the principal operative procedure. Myocardial infarction was defined by electrocardiographic changes indicative of an acute myocardial infarction (at least 1 of the following factors: ST elevation >1 mm in 2 or more contiguous leads; new left bundle branch; or new Q waves in 2 of more contiguous leads), or new elevation in troponin >3-fold the upper level of the reference range in the setting of suspected myocardial ischemia. Stroke was defined as the new occurrence of a motor, sensory, or cognitive dysfunction that persists for >24 hours. The performance of the AUB-HAS2 index was studied in the 9 surgical specialty groups coded in the NSQIP database (general, vascular, orthopedics, gynecology, urology, neurosurgery, ear-nose-throat, plastic surgery, and thoracic surgery) and in 8 site-specific surgeries that are commonly performed in routine clinical practice (cholecystectomy, breast [mastectomy], colon [colectomy], hip, hysterectomy, prostate [prostatectomy], abdominal aortic aneurysm [AAA]–open surgical repair, and spine surgery).

Statistical Analysis

Descriptive analysis of the surgical specialty groups and site-specific surgical procedures was performed and presented in the respective tables. Categorical variables are presented as number and percentage and continuous variables as mean±standard deviation. Comparison of baseline clinical characteristics among the different surgical groups was performed using the Pearson's chi-square test for categorical variables. The performance of the AUB-HAS2 index was assessed by comparing the event rates among the different score groups (0, 1, 2, 3, and >3) in each of the surgical subgroups. The Cochran-Armitage test for trend was used to evaluate the trend in the proportions of the outcome across the levels of the AUB-HAS2 score. Comparison of areas under the curve (AUCs) of the AUB-HAS2 Cardiovascular Risk Index and RCRI was performed using the nonparametric *Z* test.[11] SAS version 9.4 was used for data management and analyses. Statistical significance was set at the 0.05 alpha level.

RESULTS

Surgical Specialties

Table 2 shows the baseline clinical characteristics of the patients enrolled in the different surgical specialty groups. The largest groups of patients were those undergoing general, vascular, and orthopedic surgeries (amounting to 85% of the overall population). Vascular,

Table 2. Clinical Characteristics of Surgical Specialty Groups

	Total (N=1 167 278)	Surgical Specialty								
		General (n=751 927)	Vascular (n=136 201)	Orthopedics (n=101 529)	Gynecology (n=56 096)	Urology (n=43 018)	Neurosurgery (n=30 186)	ENT (n=20 360)	Plastics (n=16 077)	Thoracic (n=11 884)
Demographics										
Age, y	57±17	55±17	67±13	63±15	49±14	65±14	57±15	52±18	51±15	61±15
Male gender	42	40	59	43	0.0	78	51	46	19	54
BMI, kg/m^2	30±8.4	31±9.0	28±6.6	31±7.4	30±7.6	29±6.2	29±6.6	29±7.5	29±7.2	28±7.0
CVD risk factors										
Diabetes mellitus	16.2	14.7	29.6	15.9	7.9	17.5	14.8	11.6	9.8	15.6
Hypertension	48.7	44.2	76.8	56.0	29.1	56.7	48.0	38.3	31.3	51.8
Current smoker	20.0	18.7	31.8	15.2	17.9	15.8	24.7	21.6	15.9	26.4
Cardiac history										
MI	0.6	0.4	2.3	0.3	0.0	0.3	0.3	0.2	0.4	1.5
CHF	0.9	0.7	2.6	0.6	0.1	0.5	0.4	0.4	0.4	2.5
h/o PCI	5.8	4.2	16.3	6.0	1.1	8.3	5.2	3.5	2.4	8.1
h/o cardiac surgery	5.8	4.0	19.2	4.7	0.9	7.3	4.1	3.1	2.9	7.6
Any h/o heart disease	10.9	7.9	32.2	10.0	1.9	13.9	8.6	6.2	4.8	15.8
Symptoms										
Angina or dyspnea	10.4	9.8	18.8	7.7	4.6	7.9	6.8	7.8	4.0	39.4
Comorbidities										
Cr >1.5 mg/dL	7.1	5.8	18.5	4.6	1.2	9.6	2.9	3.6	3.0	6.4
Dialysis	2.0	1.4	7.6	0.7	0.1	1.0	0.5	0.6	0.8	1.5
COPD	5.3	4.2	12.8	4.6	1.5	5.5	4.3	4.0	2.1	18.3
Stroke	4.5	3.1	14.7	3.9	1.2	4.2	6.2	2.5	2.1	4.1
Blood tests										
Hemoglobin, g/dL	13.0±1.8	13.0±1.8	12.6±2.0	13.2±1.7	12.8±1.4	13.5±1.7	13.4±1.6	13.4±1.5	12.9±1.5	12.9±1.9
Creatinine, mg/dL	1.1±0.9	1.0±0.9	1.5±1.6	0.9±0.6	0.8±0.4	1.1±0.8	0.9±0.5	0.9±0.6	0.9±0.6	1.0±0.8
Surgery characteristics										
Anesthesia										
General	92.0	95.0	84.7	73.4	95.6	90.0	98.8	98.6	94.0	99.1
Spinal/epidural	3.1	0.6	3.8	21.0	3.2	7.6	0.2	0.1	0.8	0.4
Regional	0.8	0.2	3.0	3.9	0.2	0.5	0.1	0.0	1.4	0.0
Local	0.3	0.3	0.7	0.1	0.0	0.1	0.1	0.2	0.7	0.1
Other	3.8	3.9	7.8	1.6	1.0	1.8	0.9	1.2	3.2	0.4

(*Continued*)

Table 2. Continued

	Total (N=1 167 278)	General (n=751 927)	Vascular (n=136 201)	Orthopedics (n=101 529)	Gynecology (n=56 096)	Urology (n=43 018)	Neurosurgery (n=30 186)	ENT (n=20 360)	Plastics (n=16 077)	Thoracic (n=11 884)
		Surgical Specialty								
ASA class										
1	7.8	8.8	2.2	6.2	15.2	4.7	4.2	11.4	12.9	1.3
2	44.1	47.6	12.4	48.5	63.6	46.4	42.6	48.8	56.6	20.9
3	41.0	38.1	63.2	41.3	20.3	44.7	45.7	36.4	27.5	60.0
>3	7.2	5.6	22.2	4.0	0.9	4.2	7.6	3.5	2.9	17.7
Emergency case	13.2	16.8	11.0	5.4	3.5	2.0	6.8	3.9	2.7	4.9
Operation time, minutes	114±94	108±90	140±100	95±68	112±75	118±104	165±114	137±151	151±127	138±104
Hospital stay, days	4.4±9.8	4.6±10.1	6.3±11.5	3.4±7.0	2.0±5.7	2.6±6.8	4.7±9.5	2.4±8.6	2.8±10.0	7.8±12.0

Values are expressed as percent or mean±standard deviation. Comparisons of the clinical characteristics variables between the different surgical specialty groups were all statistically significant with a $P<0.001$. ASA indicates American Society of Anesthesiology; BMI, body mass index; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; Cr, creatinine; CVD, cardiovascular disease; ENT, ear-nose-throat; h/o, history of ; MI, myocardial infarction; and PCI, percutaneous coronary intervention.

orthopedic, urology, and thoracic patients were older, with a mean age >60 years. Vascular patients had a higher prevalence of cardiovascular risk factors, previous cardiac disease, and comorbidities (creatinine >1.5 mg/dL, dialysis, and stroke). Vascular and thoracic patients had a higher prevalence of symptoms of angina or dyspnea, chronic obstructive pulmonary disease, advanced American Society of Anesthesiology class (>3), and a longer duration of hospital stay.

Table 3 and Figure 2A show the incidence of the primary outcome in each of the specialties and compares the event rates among the different AUB-HAS2 score groups within each specialty. Fifty percent or more of the patients had a score of 0 in the overall population and within each subspecialty (except for vascular surgery patients who had a minimum score of 1). On the other hand, 1.4% of patients in the overall population had a score >3 and this percentage was low in all of the specialties as well (except for vascular surgery patients in which it was 9.5%). The highest event rate was in the vascular (5.1%) followed by thoracic (4.0%) surgeries. General and neurosurgery procedures had event rates of 2.0% and 2.6%, respectively. The remaining specialties had an event rate of around 1% or less. The event rate in patients with a score of 0 was <0.5% in all specialties except neurosurgery (1.0%) and thoracic (1.5%) surgeries. The event rate in patients with a score >3 was at least 10% in all specialties. Gynecology, ear-nose-throat, and plastic surgeries did not have a significant number of patients in this subgroup to make any clinically relevant interpretation (absolute number <10). In all specialties, there was a significant trend to higher event rates at higher AUB-HAS2 scores (*P* value for trend <0.001).

Site-Specific Surgical Procedures

The performance of the AUB-HAS2 index was further analyzed in 8 commonly performed site-specific surgeries that were selected from the various specialties. These included cholecystectomy, breast (mastectomy), colon (colectomy), hip surgery, hysterectomy, prostate (prostatectomy), AAA–open surgical repair, and spine surgery. The baseline clinical characteristics of these patients are shown in Table 4. Similar to the data in Table 1, AAA patients were the oldest and had the highest prevalence of cardiovascular risk factors, previous cardiac disease, comorbidities, and advanced American Society of Anesthesiology class (>3). AAA repair and colectomy had the longest hospital stay (mean >9 days).

Table 5 and Figure 2B show the incidence of the primary outcome and compares the event rates among the different AUB-HAS2 score groups within each type of surgery. Again, here, more than half of the patients

Table 3. Comparison of Outcomes Among the AUB-HAS2 Score Groups Within Each Surgical Specialty

	Total (N=1 167 278)	AUB-HAS2 Score				
		0 (N=583 161)	1 (N=361 973)	2 (N=149 057)	3 (N=56 622)	>3 (N=16 465)
General, n	751 927	407 062	245 432	76 991	19 443	2999
Death, MI, or stroke	14 931 (2.0%)	1346 (0.3%)	4025 (1.6%)	5438 (7.1%)	3265 (17%)	857 (29%)
Death	12 265 (1.6%)	891 (0.2%)	3116 (1.3%)	4584 (6.0%)	2894 (15%)	780 (26%)
MI	2361 (0.3%)	305 (0.1%)	738 (0.3%)	779 (1.0%)	435 (2.2%)	104 (3.5%)
Stroke	1212 (0.2%)	230 (0.1%)	398 (0.2%)	381 (0.5%)	172 (0.9%)	31 (1.0%)
Vascular, n	136 201	0	42 546	48 860	31 859	12 936
Death, MI, or stroke	6881 (5.1%)	0 (0.0%)	614 (1.4%)	1850 (3.8%)	2463 (7.7%)	1954 (15%)
Death	4514 (3.3%)	0 (0.0%)	232 (1.0%)	1024 (2.1%)	1711 (5.4%)	1547 (12%)
MI	1749 (1.3%)	0 (0.0%)	194 (0.5%)	574 (1.2%)	603 (1.9%)	378 (2.9%)
Stroke	1285 (0.9%)	0 (0.0%)	238 (0.6%)	439 (0.9%)	388 (1.2%)	220 (1.7%)
Orthopedics, n	101 529	59 344	27 981	10 883	2988	333
Death, MI, or stroke	1218 (1.2%)	131 (0.2%)	335 (1.2%)	471 (4.3%)	248 (8.3%)	33 (9.9%)
Death	812 (0.8%)	57 (0.1%)	201 (0.7%)	346 (3.2%)	182 (6.1%)	26 (7.8%)
MI	352 (0.4%)	47 (0.1%)	106 (0.4%)	118 (1.1%)	72 (2.4%)	9 (2.7%)
Stroke	152 (0.2%)	31 (0.1%)	54 (0.2%)	45 (0.4%)	20 (0.7%)	2 (0.6%)
Gynecology, n	56 096	39 583	14 332	2060	118	3
Death, MI, or stroke	133 (0.2%)	27 (0.1%)	71 (0.5%)	27 (1.3%)	8 (6.8%)	0 (0.0%)
Death	82 (0.2%)	17 (0.0%)	39 (0.3%)	21 (1.0%)	5 (4.2%)	0 (0.0%)
MI	40 (0.1%)	8 (0.0%)	22 (0.2%)	7 (0.3%)	3 (2.5%)	0 (0.0%)
Stroke	16 (0.0%)	2 (0.0%)	12 (0.1%)	1 (0.1%)	1 (0.9%)	0 (0.0%)
Urology, n	43 018	25 417	11 913	4618	1013	57
Death, MI, or stroke	420 (1.0%)	91 (0.4%)	142 (1.2%)	119 (2.6%)	60 (5.9%)	8 (14%)
Death	244 (0.6%)	36 (0.1%)	84 (0.7%)	74 (1.6%)	44 (4.3%)	6 (11%)
MI	131 (0.3%)	34 (0.1%)	44 (0.4%)	39 (0.8%)	11 (1.1%)	3 (5.3%)
Stroke	70 (0.2%)	25 (0.1%)	22 (0.2%)	15 (0.3%)	8 (0.8%)	0 (0.0%)
Neurosurgery, n	30 186	20 086	7318	2231	485	66
Death, MI, or stroke	775 (2.6%)	195 (1.0%)	280 (3.8%)	198 (8.9%)	82 (17%)	20 (30%)
Death	546 (1.8%)	81 (0.4%)	204 (2.8%)	170 (7.6%)	72 (15%)	19 (29%)
MI	66 (0.2%)	22 (0.1%)	24 (0.3%)	11 (0.5%)	8 (1.7%)	1 (1.5%)
Stroke	234 (0.8%)	111 (1.0%)	78 (1.1%)	35 (1.6%)	10 (2.1%)	0 (0.0%)
ENT, n	20 360	14 500	4569	1127	156	8
Death, MI, or stroke	115 (0.6%)	28 (0.2%)	48 (1.1%)	29 (2.6%)	10 (6.4%)	0 (0.0%)
Death	65 (0.3%)	15 (0.1%)	25 (1.0%)	17 (1.5%)	8 (5.1%)	0 (0.0%)
MI	32 (0.2%)	8 (0.1%)	15 (0.3%)	8 (0.7%)	1 (0.6%)	0 (0.0%)
Stroke	23 (0.1%)	6 (0.0%)	10 (0.2%)	5 (0.4%)	2 (1.3%)	0 (0.0%)
Plastics, n	16 077	11 372	3779	760	160	6
Death, MI, or stroke	82 (0.5%)	6 (0.1%)	28 (0.7%)	32 (4.2%)	16 (10%)	0 (0.0%)
Death	61 (0.4%)	3 (0.0%)	20 (0.5%)	25 (3.3%)	13 (8.1%)	0 (0.0%)
MI	20 (0.1%)	1 (0.0%)	6 (0.2%)	9 (1.2%)	4 (2.5%)	0 (0.0%)
Stroke	9 (0.1%)	2 (0.0%)	6 (0.2%)	1 (0.1%)	0 (0.0%)	0 (0.0%)
Thoracic, n	11 884	5797	4103	1527	400	57
Death, MI, or stroke	479 (4.0%)	85 (1.5%)	184 (4.5%)	134 (8.8%)	68 (17%)	8 (14%)
Death	409 (3.4%)	66 (1.1%)	164 (4.0%)	109 (7.1%)	62 (16%)	8 (14%)
MI	46 (0.4%)	13 (0.2%)	15 (0.4%)	15 (1.0%)	2 (0.5%)	1 (1.8%)
Stroke	43 (0.4%)	11 (0.2%)	12 (0.3%)	15 (1.0%)	5 (1.3%)	0 (0.0%)

Values expressed as number (%). Comparisons of the event rates between the different AUB-HAS2 score groups within each specialty were all statistically significant with a $P<0.001$. AUB indicates American University of Beirut; ENT, ear-nose-throat; and MI, myocardial infarction.

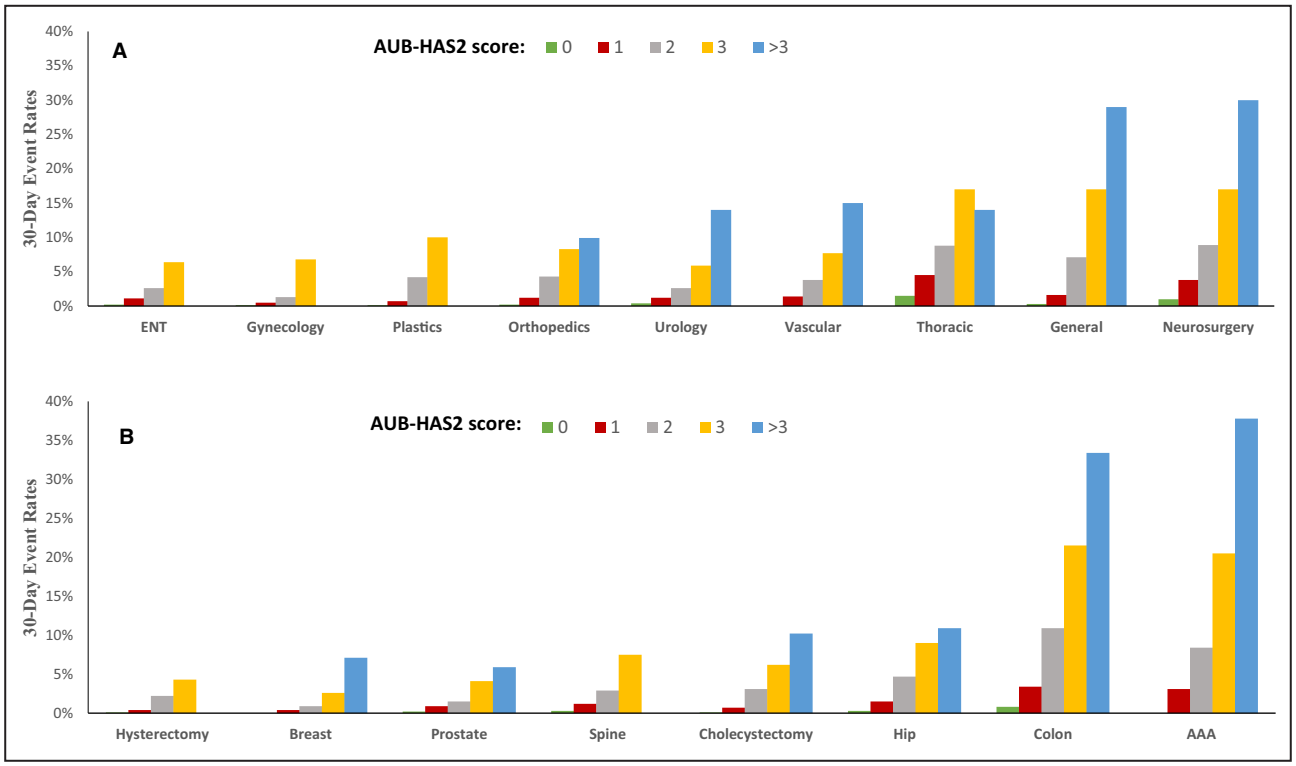

Figure 2. Bar graph comparing the 30-day event rates (death, myocardial infarction, or stroke) among the different AUB-HAS2 score groups within each specialty (A) and each site-specific surgery (B) (*P* value for trend <0.001 in all subgroups). AUB indicates American University of Beirut.

had a score of 0 in all types of surgical procedures, except for colectomy (41%) and AAA (who have a minimum score of 1). The highest event rate was in AAA (13.1%), followed by colectomy (5.2%) and hip (1.5%) surgeries. The remainder of procedures had an event rate at <1%. The event rate in patients with a score of 0 was <0.5% in all procedures except for colectomy (0.8%). There was a significant trend to higher event rates at higher AUB-HAS2 scores in all types of surgery (*P* value for trend <0.001).

Comparison of AUB-HAS2 and RCRI Performance

Comparison of the AUB-HAS2 index performance with that of the RCRI was done by constructing receiver operating characteristic (ROC) curves for the 2 indices and comparing the areas under the curve (AUCs) in the overall study population and in each of the surgical subgroups. The performance of the AUB-HAS2 index was superior to that of the RCRI in the overall study population (AUCs of 0.818 vs 0.716, *P*<0.001) (Figure 3). ROC curves were also constructed and AUCs measured for the 2 indices in the various specialties and site-specific surgeries (Table 6). The AUCs for the AUB-HAS2 index in the surgical specialties ranged from 0.71 in vascular and thoracic surgery to >0.80 in orthopedic, general, and plastic surgery. In the site-specific surgical procedures, AUCs of the AUB-HAS2 index ranged from 0.73 in spine surgery to 0.83 in cholecystectomy. The AUCs of the AUB-HAS2 index were higher than those of the RCRI in all of the surgical specialties and site-specific procedures (*P*<0.001).

DISCUSSION

The AUB-HAS2 Cardiovascular Risk Index is a newly derived measure that can quickly stratify the risk of patients undergoing noncardiac surgery.[8] It was validated in a large population of >1 million patients registered in the ACS NSQIP database. Different types of surgery carry different risks depending on their location, hemodynamic stress, duration, and other factors.[12–14] It is therefore important to study the performance of a new preoperative risk index in different surgical subpopulations as part of its ongoing validation. In this study, the performance of the AUB-HAS2 index was analyzed and compared with that of the RCRI in a wide spectrum of surgical specialties and site-specific surgeries. Several important observations are noted.

The RCRI (reported in 1999) was derived and validated in a study of 4315 patients undergoing noncardiac surgery in 1 tertiary-care teaching hospital.[5] Its primary outcome measure was a combination of

Table 4. Clinical Characteristics of the Site-Specific Surgical Groups

	Surgical Procedure							
	Cholecystectomy (n=86 956)	Breast (n=73 673)	Colon (n=83 368)	Hip (n=17 828)	Hysterectomy (n=35 766)	Prostate (n=16 851)	AAA (n=5202)	Spine (n=28 036)
Demographics								
Age, y	51±18	58±14	63±16	67±13	49±12	67±10	71±9	57±15
Male gender	31	0.0	47	43	0.0	100	74	51
BMI, kg/m^2	31±7.8	29±7.4	28±6.9	29±6.7	30±7.8	29±5.1	28±5.9	30±6.6
CVD risk factors								
Diabetes mellitus	12.6	11.5	15.5	12.4	7.9	15.5	12.7	15.5
Hypertension	38.0	42.4	52.5	59.0	29.1	56.9	79.8	50.2
Current smoker	19.4	13.9	18.6	13.4	18.7	11.7	43.0	25.1
Cardiac history								
MI	0.3	0.1	1.0	0.3	0.0	0.3	1.2	0.1
CHF	0.6	0.2	1.6	0.6	0.1	0.4	1.1	0.2
h/o PCI	3.9	2.1	6.0	6.1	0.8	8.3	16.7	5.6
h/o cardiac surgery	4.2	1.6	5.8	5.3	0.7	7.8	18.8	4.0
Any h/o heart disease	7.4	3.5	11.7	10.7	1.5	14.3	32.4	8.6
Symptoms								
Angina or dyspnea	6.9	6.7	12.1	7.9	4.6	6.6	21.9	7.0
Comorbidities								
Cr >1.5 mg/dL	3.8	2.1	8.1	4.5	1.0	7.3	16.3	2.7
Dialysis	0.8	0.3	1.5	0.4	0.1	0.4	1.2	0.3
COPD	3.2	2.6	6.9	5.2	1.3	4.6	19.5	4.1
Stroke	2.7	2.4	4.8	4.3	1.1	3.9	9.5	2.6
Blood tests								
Hemoglobin, g/dL	12.9±1.6	13.0±1.3	12.5±2.0	13.2±1.6	12.8±1.4	13.9±1.5	13.0±2.0	13.6±1.5
Creatinine, mg/dL	0.9±0.7	0.8±0.5	1.0±0.8	1.0±0.6	0.8±0.4	1.1±0.6	1.2±0.8	0.9±0.5
Surgery characteristics								
Anesthesia								
General	99.9	83.8	99.7	61.0	97.1	86.4	99.2	99.1
Spinal/epidural	0.1	0.1	0.2	33.8	2.6	12.3	0.6	0.8
Regional	0.0	0.4	0.0	4.5	0.2	0.8	0.0	0.0
Local	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0
Other	0.0	14.6	0.1	0.7	0.1	0.5	0.2	0.1
ASA class								
1	11.3	9.0	2.8	3.8	13.8	3.7	0.2	5.3
2	57.3	60.8	42.8	47.7	65.4	53.1	4.9	51.9
3	28.5	29.0	43.7	44.3	20.0	40.4	54.7	40.0
>3	2.8	1.2	10.7	4.2	0.8	2.7	40.2	2.8
Emergency case	11.4	0.3	18.0	3.3	0.7	0.8	21.5	2.2
Operation time, minutes	76±47	106±99	160±85	101±53	127±72	131±92	235±104	153±100
Hospital stay, days	2.6±6.3	0.9±4.8	9.7±11.9	4.2±6.2	2.2±5.8	1.9±5.1	10.4±12.2	3.4±6.7

Values are expressed as percent or as mean±standard deviation. Comparisons of the clinical characteristic variables between the different surgical procedures were all statistically significant with a $P<0.001$. AAA indicates abdominal aortic aneurysm; ASA, American Society of Anesthesiology; BMI, body mass index; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; Cr, creatinine; CVD, cardiovascular disease; h/o, history of; MI, myocardial infarction; and PCI, percutaneous coronary intervention.

myocardial infarction, pulmonary edema, ventricular fibrillation, primary cardiac arrest, and complete heart block. Recent large-cohort studies have suggested that the RCRI may underestimate the risk of cardiovascular events in contemporary surgical practice.[7] Our findings show that the AUB-HAS2 index has a

Table 5. Comparison of Outcomes Among the AUB-HAS2 Score Groups Within Each of the Site-Specific Surgeries

	Total	AUB-HAS2 Score				
		0	1	2	3	>3
Cholecystectomy, n	86 956	50 636	26 414	7739	1901	266
Death, MI, or stroke	637 (0.7%)	61 (0.1%)	191 (0.7%)	241 (3.1%)	117 (6.2%)	27 (10.2%)
Death	465 (0.5%)	42 (0.1%)	134 (0.5%)	183 (2.4%)	82 (4.3%)	24 (9.0%)
MI	148 (0.2%)	14 (0.0%)	46 (0.2%)	56 (0.7%)	28 (1.5%)	4 (1.5%)
Stroke	72 (0.1%)	9 (0.0%)	22 (0.1%)	24 (0.3%)	16 (0.8%)	1 (0.4%)
Breast, n	73 673	50 823	19 406	3117	313	14
Death, MI, or stroke	120 (0.2%)	17 (0.0%)	67 (0.4%)	27 (0.9%)	8 (2.6%)	1 (7.1%)
Death	66 (0.1%)	4 (0.0%)	44 (0.2%)	14 (0.5%)	3 (1.0%)	1 (7.1%)
MI	30 (0.0%)	5 (0.0%)	14 (0.1%)	6 (0.2%)	5 (1.6%)	0 (0.0%)
Stroke	35 (0.1%)	9 (0.0%)	16 (0.1%)	9 (0.3%)	1 (0.3%)	0 (0.0%)
Colon, n	83 368	34 517	27 423	15 080	5409	939
Death, MI, or stroke	4306 (5.2%)	265 (0.8%)	926 (3.4%)	1641 (10.9%)	1160 (21.5%)	314 (33.4%)
Death	3528 (4.2%)	163 (0.5%)	709 (2.6%)	1344 (8.9%)	1031 (19.1%)	281 (29.9%)
MI	697 (0.8%)	68 (0.2%)	182 (0.7%)	249 (1.7%)	159 (2.9%)	39 (4.2%)
Stroke	389 (0.5%)	49 (0.1%)	95 (0.4%)	160 (1.1%)	71 (1.3%)	14 (1.5%)
Hip, n	17 828	9776	5311	2129	557	55
Death, MI, or stroke	268 (1.5%)	31 (0.3%)	82 (1.5%)	99 (4.7%)	50 (9.0%)	6 (10.9%)
Death	163 (0.9%)	10 (0.1%)	41 (0.8%)	70 (3.3%)	38 (6.8%)	4 (7.3%)
MI	80 (0.5%)	11 (0.1%)	30 (0.6%)	24 (1.1%)	12 (2.2%)	3 (5.5%)
Stroke	46 (0.3%)	12 (0.1%)	19 (0.4%)	10 (0.5%)	5 (0.9%)	0 (0.0%)
Hysterectomy, n	35 766	25 971	9099	648	47	1
Death, MI, or stroke	67 (0.2%)	16 (0.1%)	35 (0.4%)	14 (2.2%)	2 (4.3%)	0 (0.0%)
Death	39 (0.1%)	10 (0.0%)	16 (0.2%)	13 (2.0%)	0 (0.0%)	0 (0.0%)
MI	21 (0.1%)	4 (0.0%)	12 (0.1%)	4 (0.6%)	1 (2.1%)	0 (0.0%)
Stroke	11 (0.0%)	2 (0.0%)	8 (0.1%)	0 (0.0%)	1 (2.1%)	0 (0.0%)
Prostate, n	16 851	11 089	3862	1541	342	17
Death, MI, or stroke	95 (0.6%)	23 (0.2%)	34 (0.9%)	23 (1.5%)	14 (4.1%)	1 (5.9%)
Death	44 (0.3%)	7 (0.1%)	13 (0.3%)	14 (0.9%)	9 (2.6%)	1 (5.9%)
MI	31 (0.2%)	8 (0.1%)	14 (0.4%)	6 (0.4%)	3 (0.9%)	0 (0.0%)
Stroke	24 (0.1%)	9 (0.1%)	8 (0.2%)	5 (0.3%)	2 (0.6%)	0 (0.0%)
AAA, n	5202	0	1496	1900	1187	619
Death, MI, or stroke	683 (13.1%)	0 (0.0%)	46 (3.1%)	160 (8.4%)	243 (20.5%)	234 (37.8%)
Death	533 (10.3%)	0 (0.0%)	19 (1.3%)	103 (5.4%)	198 (16.7%)	213 (34.4%)
MI	150 (2.9%)	0 (0.0%)	22 (1.5%)	53 (2.8%)	44 (3.7%)	31 (5.0%)
Stroke	55 (1.1%)	0 (0.0%)	8 (0.5%)	19 (1.0%)	19 (1.6%)	9 (1.5%)
Spine, n	28 036	19 919	6289	1578	241	9
Death, MI, or stroke	199 (0.7%)	60 (0.3%)	76 (1.2%)	45 (2.9%)	18 (7.5%)	0 (0.0%)
Death	114 (0.4%)	23 (0.1%)	45 (0.7%)	31 (2.0%)	15 (6.2%)	0 (0.0%)
MI	61 (0.2%)	23 (0.1%)	24 (0.4%)	10 (0.6%)	4 (1.7%)	0 (0.0%)
Stroke	38 (0.1%)	19 (0.1%)	12 (0.2%)	6 (0.4%)	1 (0.4%)	0 (0.0%)

Values are expressed as number (%). Comparisons of the event rates between the different AUB-HAS2 groups within each type of surgery were all statistically significant with a $P<0.001$. AAA indicates abdominal aortic aneurysm; AUB, American University of Beirut; and MI, myocardial infarction.

superior discriminatory power compared with the RCRI in the overall study population and in all surgical subgroups as well. There are several factors that may explain this superiority. The AUB-HAS2 index is more comprehensive in both its data elements as well as in its outcome measure. Two of the primary data elements in the RCRI (history of ischemic heart disease and history of congestive heart failure) are included in the history of heart disease element in the AUB-HAS2 index. The AUB-HAS2 index includes an additional

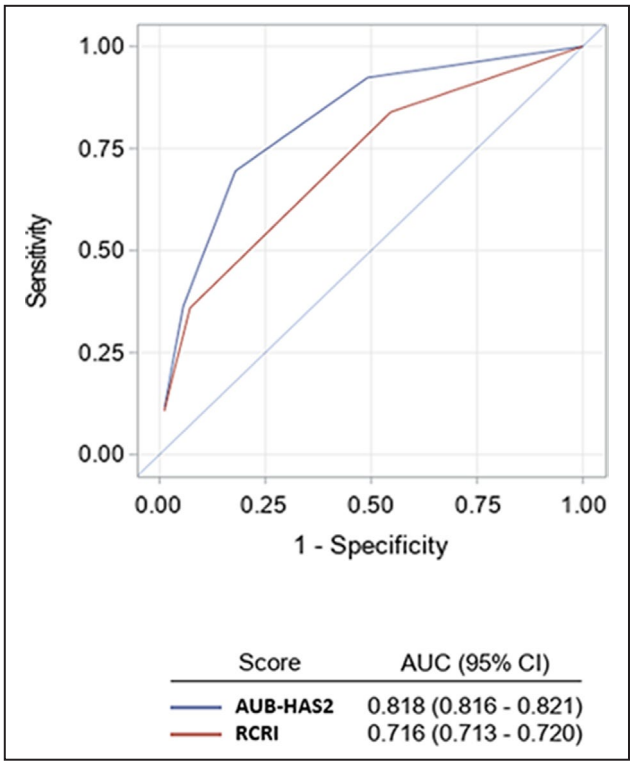

Figure 3. Comparison of the receiver operating characteristic (ROC) curves of the AUB-HAS2 index and the Revised Cardiac Risk Index (RCRI) in the overall study population.
AUB indicates American University of Beirut; AUC, area under the curve (P<0.001 for AUB-HAS2 vs RCRI).

Table 6. Comparison of AUCs for RCRI and AUB-HAS2 Index Among the Different Specialties and Site-Specific Surgical Groups

	RCRI	AUB-HAS2
Surgical specialty		
General surgery	0.743 (0.739–0.746)	0.828 (0.825–0.831)
Vascular	0.659 (0.652–0.665)	0.709 (0.703–0.715)
Orthopedics	0.648 (0.633–0.662)	0.814 (0.803–0.826)
Gynecology	0.638 (0.594–0.681)	0.776 (0.738–0.814)
Urology	0.634 (0.608–0.661)	0.734 (0.710–0.758)
Neurosurgery	0.664 (0.643–0.684)	0.746 (0.729–0.764)
ENT	0.626 (0.573–0.678)	0.762 (0.718–0.806)
Plastics	0.792 (0.724–0.859)	0.881 (0.845–0.916)
Thoracic	0.589 (0.565–0.614)	0.712 (0.690–0.735)
Site-specific surgery		
Cholecystectomy	0.690 (0.670–0.710)	0.826 (0.810–0.842)
Breast	0.637 (0.594–0.680)	0.802 (0.767–0.838)
Colon	0.673 (0.665–0.681)	0.800 (0.794–0.807)
Hip	0.636 (0.607–0.666)	0.790 (0.764–0.815)
Hysterectomy	0.645 (0.588–0.702)	0.770 (0.713–0.826)
Prostate	0.583 (0.538–0.629)	0.740 (0.690–0.789)
AAA	0.571 (0.552–0.589)	0.747 (0.729–0.766)
Spine	0.580 (0.549–0.612)	0.731 (0.695–0.766)

Data are expressed as area under the curve (95% CI). P<0.001 for AUB-HAS2 vs RCRI in all surgical subgroups. AAA indicates abdominal aortic aneurysm; AUB, American University of Beirut; AUC, area under the curve; ENT, ear-nose-throat; NSQIP, National Surgical Quality Improvement Program Index; and RCRI, Revised Cardiac Risk Index.

element related to the symptoms of active heart disease (angina or dyspnea on exertion). It is very well known that the presence of symptoms significantly increases the risk profile of patients across the spectrum of ischemic, heart failure, and valvular diseases. The AUB-HAS2 index also includes 2 additional elements of age ≥75 years and anemia. The RCRI included all adult patients ≥50 years old, but did not stratify them by age any further. The cardiac risk increases across the age strata and a 75-year-old patient is expected to have a higher risk profile than someone 55 years old. Anemia has been recently shown to be a major predictor of postoperative events in multiple studies.[1–3] The AUB-HAS2 index had a wider representation of patient groups in its derivation cohort, enrolling both low-risk and emergency surgery patients who were not enrolled in the RCRI cohort. Finally, the outcome measures in the AUB-HAS2 index are more comprehensive and include both death and stroke, which were not included in the RCRI. Thus, the AUB-HAS2 index is more comprehensive in its data elements, derivation population, and outcome measures.

This study reconfirms the very low risk of patients with an AUB-HAS2 score of 0 in a broad range of surgical procedures. In most, the 30-day risk of death, myocardial infarction, or stroke was <1.0% and in many it was <0.5%. The only exception was thoracic surgery, where the risk was 1.5%. This has major implications because the group of patients with an AUB-HAS2 score of 0 constitutes more than half of the patients undergoing noncardiac surgery. The availablity of a simple index that the physician can acquire in the clinic or a nurse can measure in the preadmission unit can facilitate the quick triage of this large population of patients who, in the large majority of cases, would probably not require any further cardiac evaluation/testing or special monitoring postoperatively. On the other hand, the AUB-HAS2 index was also able to identify a small but high-risk group of patients (score >3) with a postoperative event rate of >10% in most procedures and reaching >30% in AAA and colon surgeries. This small patient group would therefore require more extensive cardiovascular evaluation and optimization before surgery and would probably need closer postoperative monitoring. These clinical care strategies based on the AUB-HAS2 score constitute major targets for prospective validation in future studies.

Our findings also reconfirm the ability of the AUB-HAS2 index to stratify risk in different surgical subpopulations. The 30-day event rates increased gradually

with the AUB-HAS2 score in all subgroups, with some variation in the AUCs between them. The performance of the index, in terms of the ROC analysis, was best in general and orthopedic surgeries, which constituted 73% of the overall population. In those specialties, the AUC was 0.83 and 0.81, respectively. Similarly, the AUC in the respective site-specific surgeries in these specialties (cholecystectomy, mastectomy, colectomy, and hip) ranged from 0.79 to 0.83. The AUC was lower in vascular surgeries such as AAA (0.75), but still there was a steady increase in risk, with an increase in score (from 3.1% in those with a score of 1 up to 37.8% in those with a score >3). Furthermore, even in traditionally "low-risk surgeries," such as mastectomy, the AUB-HAS2 index was able to further stratify risk into different levels from 0% in those with a score of 0 up to 7.1% in those with a score of >3.

The original study describing the derivation and validation of the AUB-HAS2 Cardiovascular Risk Index recommended use of low-, intermediate-, and high-risk categories, depending on the score (low risk for score of 0–1, intermediate risk for score of 2–3, and high risk for score >3).[8] Conventionally, low-risk surgeries are those with a risk of <1%, with a >10% risk considered high, and intermediate risk anything in between. For the majority of the specialties and site-specific surgeries, there was a correlation between the AUB-HAS2 risk categories and these percent definitions. However, in a few specific situations, there was some overlap in these categories. In both AAA repair and colectomy, there was an upward shift of risk in all AUB-HAS2 risk groups. In both types of surgery, a score of 1 had a low/intermediate risk of around 3% and a score of 3 had a high risk of around 20%. This is probably due to the fact that the overall risk of these 2 surgeries is relatively high (13.1% and 5.2%, respectively) similar to what has been reported in the literature.[15–17] This should be taken into consideration in the evaluation of patients undergoing these types of surgery.

Limitations

In this study we have described the performance of the newly derived AUB-HAS2 Cardiovascular Risk Index and compared it to that of the commonly utilized RCRI in a wide spectrum of surgical specialties and site-specific surgeries. Although our study population is derived from a large multicenter database, it still primarily represents North America. The findings will need to be further validated in other patient populations in different countries with a wider geographic representation. Furthermore, because the ACS NSQIP database consisted of surgeries rather than patients, it is possible that the same patient may have been included more than once in the study population, which may have impacted variability. Because data in the NSQIP database are de-identified, it would not be possible to verify whether the same patient was included more than once for another surgery. However, because the database is multicenter (with >250 participating sites), with only a sample of patients included from each site, the expected percentage of patients with multiple entries would be very small and thus would have no significant impact on the overall findings.

CONCLUSIONS

This study extends the validation of the newly derived AUB-HAS2 Cardiovascular Risk Index to a broad range of surgical specialties and site-specific surgeries. The AUB-HAS2 index performed better than the commonly used RCRI in all surgery groups. Moreover, for all surgical subpopulations, the AUB-HAS2 index was able to identify a large group of low-risk patients (score = 0) who, in general, may not require any special preoperative cardiovascular evaluation or postoperative monitoring.

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