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# Association of metabolic syndrome with morbidity and mortality in emergency general surgery

Samer Elsamna, Omar Elkattawy, Aziz M. Merchant*

*Department of General Surgery, Rutgers New Jersey Medical School, Newark, NJ, USA*

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ABSTRACT

*Background:* Metabolic syndrome (MetS) is defined by numerous comorbidities. We sought to assess MetS's effect on the 7 main emergency general surgery (EGS) procedures that constitute 80% of EGS procedures, mortalities, complications, and costs.
*Methods:* Data were acquired from the ACS-NSQIP database from 2005 to 2017. Current procedural terminology (CPT) codes were utilized to identify cases. Patients with obesity, diabetes, and hypertension were defined as having MetS. MetS and non-MetS cohorts were propensity score matched, compared by outcomes, and assessed with multivariate logistic regression to attain odds ratios (OR).
*Results:* Of 752,023 cases, 41,788 (5.6%) MetS cases were identified. Significant outcomes included superficial infection (OR: 1.51), pulmonary complications (OR: 1.17), renal complications (OR: 1.82), cumulative morbidity (OR: 1.22), and hospital readmission (OR: 1.41).
*Conclusions:* For patients undergoing these procedures, MetS increased risk for comorbidities and hospital readmission. MetS had a significant impact on mortality only for appendectomy.


## Introduction

Metabolic syndrome (MetS) is defined by a group of cardiovascular disease (CVD) risk-factors and comorbidities such as hypertension, insulin resistance, obesity, and dyslipidemia.[1] An estimated 75 to 100 million Americans are believed to have MetS and due to increasing obesity rates, this number continues to rise.[2,3] The total cost attributed to this syndrome due to healthcare costs and loss of economic activity is believed to be in the trillions.[4] Obesity has previously been shown to have a negative impact on the field of emergency general surgery (EGS)—a discipline with exceedingly high patient complication and readmission rates, postoperative mortality, and costs.[5–8] Though MetS encompasses obesity, it is also marked by a chronic state of inflammation.[9] MetS is already known to be associated with worse outcomes in a variety of different surgical settings, but its effect on EGS remains unexplored.[9–14]

Over 3 million patients are admitted into US hospitals per year for EGS diagnoses.[6,7] Despite comprising 11% of surgical admissions, EGS is accountable for about 50% of all surgical mortality.[5] Of the total 35 EGS procedure groups, just 7 of these account for approximately 80% of EGS operative volume, deaths, complications, and inpatient costs.[5] Nearly half-a-million of these select seven EGS procedures are performed annually in the US for a total economic burden of about $5 billion US dollars.[5] These seven procedures include the following: partial colectomy, small-bowel resection, cholecystectomy, operative management of peptic ulcer disease, lysis of peritoneal adhesions, appendectomy, and laparotomy.

Given the increasing prevalence of MetS and EGS patients' high-risk status, we believed it to be imperative to determine the extent of MetS's impact on EGS. Our objective was to discern whether or not the presence of MetS was associated with increased morbidity and worse outcomes. We hypothesized that MetS would be associated with increased morbidity and mortality. We sought to determine this using data from the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database that records data on 30-day outcome measures.[15,16]

## Materials & methods

### *Data source*

A propensity-score matched retrospective analysis of the ACS-NSQIP database from the years 2005–2017 was performed. The

* Corresponding author. Divisional Chief, Department of Surgery, Rutgers New Jersey Medical School, 140 Bergen Street Room E-Level, Newark, NJ 07103, USA.
*E-mail address:* aziz.merchant@rutgers.edu (A.M. Merchant).

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NSQIP database, funded by the ACS, is a nationwide, multicenter database that collects preoperative, intraoperative, and postoperative (30-day) data on randomly selected patients. NSQIP also carries out randomized audits at all participating sites in order to ensure that the highest quality of data is collected. Institutional review board (IRB) approval was obtained from the Rutgers IRB of Rutgers New Jersey Medical School (Newark, New Jersey).

### Patient selection

Patients that had undergone any one of the seven EGS procedure between the years 2005–2017 were identified and included into the study using respective procedures' current procedural terminology (CPT) codes and included both open and laparoscopic variants. Utilized CPT codes can be located in Table 1.

Patients were then marked as having MetS if NSQIP reported them as having a body mass index (BMI) $\geq$30 kg/$m^2$, diabetes requiring medical intervention, and hypertension requiring medical intervention.[16,17] As dyslipidemia is not recorded by NSQIP, this factor was left out of our MetS definition as commonly done in other MetS NSQIP studies.[10,11] A diagnosis with diabetes requiring medication was used as a proxy for insulin resistance. All cases included were then divided into MetS and non-MetS groups for variable and outcome comparison.

### Variable selection

General patient characteristics were acquired from NSQIP and included sex, age, race, and BMI. Clinicopathological characteristics and comorbidities recorded included hypertension, diabetes, smoking status (within 1-year of operation), dyspnea, chronic obstructive pulmonary disease (COPD), history of congestive heart failure (CHF), ascites, metastatic cancer, use of dialysis, sepsis, weight loss (defined as a loss greater than 10% of body weight over the previous 6 months), and steroid use for chronic conditions.

Numerous 30-day postoperative outcomes were also obtained from NSQIP and subdivided into 3 complication types: wound, pulmonary, and medical. Wound complications included superficial infection, deep infection, and wound dehiscence. Pulmonary complications included pneumonia, ventilator use (defined as >48 h use), pulmonary embolism, and unplanned intubation. Medical complications included myocardial infarction, acute renal failure, progressive renal insufficiency, stroke, deep vein thrombosis, sepsis, and septic shock. These were deemed as secondary outcomes. Primary outcomes included cumulative outcomes for renal complications, pulmonary complications, and overall morbidity. Additional primary outcomes included whether a transfusion was received, extended hospital stay (defined as 1-week, 2-week, and 1-month), hospital readmission, return to the operating room (OpR), and overall mortality. The interquartile range (IQR) and medians were also obtained for both non-MetS and Met cohorts. Precise definitions of variables and complications are located in the NSQIP Participant Use File Guide.[17]

### Statistical analyses

Data gathered from the NSQIP database was exported and analyzed in SPSS 24.0 (IBM Corp, Armonk NY). Statistical significance was set at $\alpha < 0.05$ for all analyses performed in this study. Prior to controlling for confounding variables with a propensity score match (PSM) algorithm, differences in patient characteristics, comorbidities, and outcomes were assessed for the MetS and non-MetS cohorts using Chi-square analysis for categorical variables and independent *t*-test for continuous variables.

To control for confounding factors in the form of patient characteristics and comorbidities, a predetermined 1:1 PSM was carried out to match similar cases of those with MetS to those without. Patients were matched by the following variables: age, gender, race, smoking status, dyspnea, COPD, history of CHF, ascites, metastatic cancer, dialysis, weight loss, sepsis, and steroid use. All cases with unknown values for matched covariates were excluded from the analysis. Diabetes, hypertension, and BMI were excluded from the match due to inclusion in the MetS definition used. Procedure type was also excluded in order to assess outcomes by individual procedure. Similar to the pre-matched data, differences between the two cohorts were assessed by Chi-square and independent *t*-test analyses. Multivariate logistic regression was then carried out for the different outcomes to determine odds ratios (OR). The continuity correction factor employed by SPSS statistical software was utilized for measure of model fit. The Bonferroni correction was subsequently applied and a new p-value of significance of 0.002 was established for our multivariate analysis. This was done to circumvent the issue that as the number of tests and variables increase, the chance of a type I error also increases.[18] This process was then repeated but split by the seven procedures to assess the effect of MetS on each of the 7 procedures by looking at five primary outcomes: cumulative morbidity, >1-week hospital stay, hospital readmission, return to OpR, and 30-day mortality.

## Results

### Patient characteristics

A total 1,310,456 number of patients were identified prior to the removal of any cases with missing data. 1,168,130 cases with pertinent data on MetS were identified (Tables 2 and 3). 752,023 cases remained after all cases with unknown information for either any of the defining variables for MetS or the covariates matched on propensity score. Of these, 5.6% (n = 41,788) were deemed as having MetS. Greater than 95% (95.7%) of the MetS cases were

**Table 1**
Emergency General Surgery (EGS) procedure.

| Procedure | Non-MetS | | MetS | | CPT Codes |
|---|---|---|---|---|---|
| | n | % | n | % | |
| Peritoneal Adhesion Lysis | 37,174 | 3.4 | 2039 | 3.3 | 44005 and 44180 |
| Appendectomy | 269,873 | 24.4 | 5868 | 9.5 | 44950, 44955, 44960, and 44970 |
| Bowel Resection | 49,401 | 4.5 | 3206 | 5.2 | 44202, 44203, 44110, 44111, 44120, 44121, and 44125 |
| Colectomy | 334,810 | 30.3 | 24,321 | 39.2 | 44139, 44140, 44141, 44143, 44144, 44145, 44146,44147, 44155, 44156, 44160, 44205, 44207, 44208, 45395, 45397, 44204, 44206, 44212, and 44213 |
| Cholecystectomy | 374,658 | 33.9 | 23,706 | 38.2 | 47600, 47605, 47610, 47612, 47562, 47563, and 47564 |
| Peptic Ulcer Disease (Operative Management) | 12,010 | 1.1 | 726 | 1.2 | 43840, 44602, 44603, 53501, and 43502 |
| Laparotomy | 28,162 | 2.5 | 2176 | 3.5 | 35840, 47015, 49000, 49002, 49020, 49040, 49060, 49220, and 49412 |

**Table 2**
Patient characteristics before and after propensity score match.

| Categories | No MetS N = 1,106,088 | | MetS N = 62,042 | | P-value (before and after propensity score match) | |
|---|---|---|---|---|---|---|
| | n | % | n | % | Before | After |
| **Age Categories** | | | | | | |
| <41 | 296,145 | 26.8 | 2318 | 3.7 | <0.001 | 0.172 |
| 41–60 | 335,083 | 30.3 | 19,441 | 31.3 | | |
| 61+ | 349,305 | 31.6 | 33,001 | 53.2 | | |
| Unknown | – | 11.4 | – | 11.7 | | |
| **Gender** | | | | | | |
| Male | 462,518 | 41.8 | 27,818 | 44.8 | <0.001 | 0.657 |
| Female | 642,651 | 58.1 | 34,191 | 55.1 | | |
| Unknown | – | 0.1 | – | 0.1 | | |
| **Race** | | | | | | |
| Asian | 38,228 | 3.5 | 1246 | 2.0 | <0.001 | 0.076 |
| Black | 91,536 | 8.3 | 9015 | 14.5 | | |
| Native American | 7199 | 0.7 | 488 | 0.8 | | |
| White | 751,035 | 67.9 | 41,531 | 66.9 | | |
| Unknown | – | 19.7 | – | 15.7 | | |
| **BMI Category**[b] | | | | | | |
| Normal (18.5–24.99) | 316,216 | 28.6 | – | 0 | – | – |
| Underweight (<18.5) | 51,050 | 4.6 | – | 0 | | |
| Overweight (25–29.99) | 362,621 | 32.8 | – | 0 | | |
| Obese (30+) | 374,500 | 33.9 | 62,042 | 100 | | |
| Mean | 28.39 | | 37.56 | | | |

[b] Patients not matched with these factors.

41 + years old (vs 69.8% in non-MetS group). The male:female (M:F) ratio was less than 1.00 in both cohorts (0.813 in MetS vs 0.719 for non-MetS), indicative of a female dominance.

Prior to performing the PSM, the proportion of blacks was nearly double in the MetS group (14.5% vs 8.3% in non-MetS). The two most commonly performed procedures assessed among the two cohorts were colectomy and cholecystectomy (Table 1). These two procedures accounted for more than half of all cases in both groups. The third most common procedure performed for both groups was appendectomy, but a greater proportion was present in the non-MetS cohort (24.4% vs 9.5% in MetS). About a third of patients in the non-MetS group were classified as obese (33.9%). Pre-PSM p-values for differences between MetS and non-MetS in regard to patient characteristics were all below the set cut-off (0.05) and therefore significant. Post-PSM p-values for the differences of the same variables were all insignificant ($p > 0.05$).

### *Patient comorbidities*

Among the non-MetS cohort, the diabetes proportion was 7.2% and hypertension was 34.0%. Higher rates of dyspnea, COPD, CHF, ascites, dialysis use, chronic steroid use, and sepsis were seen among MetS patients. A greater proportion of non-MetS patients reported smoking within a year prior to the procedure (19.1% vs 13.6% in MetS). More non-MetS patients reported a history of weight loss. No difference was observed between rates of metastatic cancer.

### *Patient outcomes*

Prior to PSM, differences between the two groups for the different selected outcomes were assessed. The p-values for all outcomes were below the set cut-off and therefore significant (Table 4). Mean length of hospital stay was 4.96 days for non-MetS and 7.07 days for MetS. The interquartile range for length of stay for non-MetS was 1 day (25%), 4 days (50% - median), and 8 days (75%). The interquartile range for length of stay for MetS was 2 days (25%), 4 days (50% - median), and 8 days (75%). After PSM, significance of differences in outcomes remained for ten of the measures. ORs were then acquired for these outcomes that retained significance even after the PSM (Table 4) and included: superficial infection (OR: 1.51), cumulative pulmonary complications (OR: 1.17), >48 h of ventilator use, unplanned intubation, acute renal failure, progressive renal insufficiency, cumulative renal complications (OR: 1.82), cumulative morbidity (OR: 1.22), >30-day hospital stay (OR: 1.78), and hospital readmission (OR: 1.41). For all these outcomes, the rates were higher among the MetS group and henceforth ORs greater than 1.00 indicate associated risk with MetS.

For cumulative morbidity, a significant OR was attained for all seven procedures except peritoneal adhesion lysis (Table 6). The values for the significant ORs ranged from 1.23 (bowel resection) to 2.25 (appendectomy). For >1-week hospital stay, a significant OR was obtained for all 7 procedures except for laparotomy and bowel resection. Of the five procedures with a significant OR, one was less than 1.00—peritoneal adhesion lysis (OR: 0.75). For hospital readmission, four procedures had significant ORs: appendectomy (OR: 1.26), cholecystectomy (OR: 1.29), colectomy (OR: 1.39), and laparotomy (OR: 1.40). Four procedures were significant for return to

**Table 3**
Patient comorbidities before and after propensity score match.

| Categories | No MetS N = 1,106,088 | | MetS N = 62,042 | | P-value (before and after propensity score match) | |
|---|---|---|---|---|---|---|
| | n | % | n | % | Before | After |
| **Diabetes**[b] | 79,528 | 7.2 | 62,042 | 100 | – | – |
| **Hypertension**[b] | 376,488 | 34.0 | 62,042 | 100 | – | – |
| **Smoked within 1-Year** (of procedure) | 211,557 | 19.1 | 8459 | 13.6 | <0.001 | 0.858 |
| **Dyspnea*** | 58,360 | 5.3 | 8966 | 14.5 | <0.001 | 0.661 |
| **COPD**[c]* | 36,746 | 3.7 | 4885 | 8.9 | <0.001 | 0.972 |
| **History of CHF**[d]* (30 days prior) | 8079 | 0.8 | 1688 | 3.1 | <0.001 | 0.358 |
| **Ascites*** | 11,250 | 1.1 | 771 | 1.4 | <0.001 | 0.597 |
| **Metastatic Cancer*** | 27,582 | 2.8 | 1505 | 2.7 | 0.373 | 0.489 |
| **Dialysis*** | 8212 | 0.8 | 1651 | 3.0 | <0.001 | 0.061 |
| **Weight Loss**[e]* | 24,924 | 2.5 | 888 | 1.6 | <0.001 | 0.258 |
| **Steroid Use*** (for chronic conditions) | 38,471 | 3.9 | 2501 | 4.6 | <0.001 | 0.096 |
| **Sepsis** | 156,586 | 17.3 | 9495 | 18.8 | <0.001 | 0.776 |

* Unknown values excluded from percent totals.
[b] Patients not matched with these factors due to inclusion into metabolic syndrome criteria.
[c] COPD = chronic obstructive pulmonary disease.
[d] CHF = chronic heart failure.
[e] Weight loss greater than 10% of body weight over course of 6 months.

**Table 4**
Outcomes after propensity score match.

| Outcome | No MetS N = 41,788 | | MetS N = 41,788 | | P-value (before and after propensity score match) | |
|---|---|---|---|---|---|---|
| | n | % | n | % | Before | After |
| **Wound Complications** | | | | | | |
| Superficial Infection[s] | 1379 | 3.3 | 2006 | 4.8 | <0.001 | <0.05 |
| Deep Infection | 334 | 0.8 | 418 | 1.0 | <0.001 | 0.239 |
| Wound Disruption (Dehiscence) | 376 | 0.9 | 501 | 1.2 | <0.001 | 0.113 |
| **Pulmonary Complications** | | | | | | |
| Cumulative[s] | 2967 | 7.1 | 3428 | 8.2 | <0.001 | <0.05 |
| Pneumonia | 1421 | 3.4 | 1295 | 3.1 | <0.001 | 0.399 |
| >48 Hours on Ventilator[s] | 1630 | 3.9 | 2340 | 5.6 | <0.001 | <0.05 |
| Pulmonary Embolism | 251 | 0.6 | 209 | 0.5 | <0.001 | 0.595 |
| Unplanned Intubation[s] | 836 | 2.0 | 1170 | 2.8 | <0.001 | <0.05 |
| **Medical Complications** | | | | | | |
| MI | 373 | 0.9 | 377 | 0.9 | <0.001 | 0.673 |
| Acute Renal Failure[s] | 376 | 0.9 | 627 | 1.5 | <0.001 | <0.05 |
| Renal Insufficiency (Progressive)[s] | 251 | 0.6 | 501 | 1.2 | <0.001 | <0.05 |
| Cumulative Renal Disease[s] | 627 | 1.5 | 1087 | 2.6 | <0.001 | <0.05 |
| Stroke | 167 | 0.4 | 251 | 0.6 | <0.001 | 0.242 |
| DVT | 459 | 1.1 | 503 | 1.2 | <0.001 | 0.780 |
| Transfusion | 2881 | 6.9 | 2886 | 6.9 | <0.001 | 1.000 |
| Sepsis | 37,141 | 3.4 | 2818 | 4.5 | <0.001 | 0.632 |
| Septic Shock[s] | 1880 | 4.5 | 1964 | 4.7 | <0.001 | <0.05 |
| **Cumulative Morbidity**[s] | 8230 | 19.7 | 9653 | 23.1 | <0.001 | <0.05 |
| **>1 Week Hospital Stay** | 11,198 | 26.8 | 11,695 | 28.0 | <0.001 | 0.208 |
| **>2 Week Hospital Stay** | 4471 | 10.7 | 4514 | 10.8 | <0.001 | 0.846 |
| **>30-Day Hospital Stay**[s] | 420 | 1.0 | 709 | 1.7 | <0.001 | <0.05 |
| **Mean Hospital Stay (in Days, post-match)** | Pre: 4.96<br>Post: 6.65 | | Pre: 7.0<br>Post: 6.94 | | <0.001 | 0.190 |
| **Hospital Stay (Interquartile range, Median)** | 25%: 1<br>50%: 4<br>75%: 8 | | 25%: 2<br>50%: 4<br>75%:8 | | 1.000 | 0.945 |
| **Hospital Readmission**[s] | 3220 | 7.7 | 4387 | 10.5 | <0.001 | <0.05 |
| **Return to OR** | 1839 | 4.4 | 2089 | 5.0 | <0.001 | 0.118 |
| **Mortality** | 1464 | 3.5 | 1715 | 4.1 | <0.001 | 0.174 |

[s] Indicates signifiance

OpR and these had ORs that ranged from 1.13 (colectomy) to 1.66 (peptic ulcer disease). The three procedures that lacked significance for return to OpR were peritoneal adhesion lysis, bowel resection, and appendectomy. Lastly, only one procedure (appendectomy, OR: 1.76) was significantly associated with increased 30-day mortality.

## Discussion

MetS is believed to affect 25–30% of the global population.[1,19,20] Its inflammatory nature brings with it risk for numerous chronic conditions and comorbidities. MetS has also been known to increase the rate of postoperative complications in other surgical fields. Because the select seven procedures are the core of EGS not just by procedure volume but also by morbidity, mortality, and cost, we sought to quantify the effects MetS has on this set of procedures.[5]

Of all cases, 5.6% were identified as having MetS, a value less than what has previously been reported to be the incidence of MetS.[21] This low number may be a reflection of our choice of using diabetes requiring medicine as a surrogate for uncontrolled blood sugar levels. While a patient taking medicine for diabetes does indeed have insulin resistance, this method might exclude patients who do have this metabolic dysfunction.

The difference between MetS and non-MetS gender proportions was significant prior to PSM, in agreement with what has already been reported. This may partially be explained by the higher mean BMI found among females both in our cohort and according to the literature.[21] The prevalence of MetS among women is greater at older ages as well.[22] Another demographic feature identified from our data was that the proportion of blacks in the MetS group was double the proportion in the non-MetS group. Moore JX et al. have shown that though black men are less likely to develop MetS when compared to white men, black women are more likely to develop it when compared to white women.[21] This discrepancy may then be due to the less-than-1.00 M:F ratio for the MetS cohort.

Differences between the two groups in respect to diabetes and hypertension were not assessed due to the two variables' inclusion into our established definition of MetS. The proportions of diabetes (7.2%) and hypertension (34.0%) among the non-MetS group resembled prevalence rates previously mentioned in the literature for these two comorbidities.[23–25] The higher rates of the other

**Table 5**
Odds ratios of metabolic syndrome with outcomes (propensity score adjusted, cumulative).

| Outcome | Odds Ratio | 95% Confidence Interval | | p-value |
|---|---|---|---|---|
| | | Lower | Upper | |
| Cumulative Morbidity[s] | **1.22** | 1.10 | 1.35 | <0.002 |
| >1 Week Hospital Stay | 1.06 | 0.97 | 1.16 | 0.126 |
| >30-Day Hospital Stay[s] | **1.78** | 1.18 | 2.70 | <0.002 |
| Hospital Readmission[s] | **1.41** | 1.20 | 1.65 | <0.002 |
| Return to OR | 1.16 | 0.96 | 1.40 | 0.118 |
| Mortality | 1.16 | 0.94 | 1.42 | 0.170 |
| Cumulative Pulmonary Complications[s] | **1.17** | 1.01 | 1.36 | <0.002 |
| Cumulative Renal Complications[s] | **1.82** | 1.37 | 2.43 | <0.002 |
| Superficial Infection[s] | **1.51** | 1.23 | 1.85 | <0.002 |
| Septic Shock | 1.40 | 1.14 | 1.72 | 0.009 |

[s] Indicates significance.

**Table 6**
Odds ratios of metabolic syndrome with major outcomes (propensity score adjusted, by procedure type).

| Procedure | Cumulative Morbidity[a] | >1 Week Hospital Stay[a] | Hospital Readmission[a] | Return to OR[a] | Mortality[a] |
|---|---|---|---|---|---|
| Peritoneal Adhesion Lysis | – | 0.75 | – | – | – |
| Appendectomy | 2.25 | 1.74 | 1.26 | – | 1.76 |
| Bowel Resection | 1.23 | – | – | – | – |
| Colectomy | 1.32 | 1.08 | 1.39 | 1.13 | – |
| Cholecystectomy | 1.61 | 1.46 | 1.29 | 1.47 | – |
| Peptic Ulcer Disease (Operative Management) | 1.60 | 1.47 | – | 1.66 | – |
| Laparotomy | 1.26 | – | 1.40 | 1.27 | – |

[a] Only Hazard Ratios with significance below p-value threshold 0.002 reported.

comorbidities seen in the MetS group corresponds with what is reported.[20] O'Neill S. et al. have posed that MetS increases the risk of developing CVD 3x fold.[26] An increased chance of developing CVD may account for the difference in cardiopulmonary comorbidities seen between MetS and non-MetS groups.

Though Oh SW et al. have shown that MetS and smoking are positively correlated, our data suggests they are inversely linked as a greater proportion of non-MetS patients reported smoking within the past year.[27] Physicians counseling patients toward tobacco cessation may explain such a finding as MetS and smoking are two commonly known CVD risk factors.

After we performed the PSM, eleven of the outcomes retained their significance. These outcomes demonstrate the extent of MetS's real effect on the seven procedures (Tables 4 and 5). Patients with MetS who underwent one of these seven procedures had higher rates of pulmonary complications, renal complications, superficial infection, overall morbidity, and hospital readmission.

In their study on MetS and coronary artery bypass grafting surgery, Ozkan S et al. reported increased rates of infection and pulmonary complications.[28] They too reported no observable difference in overall mortality. Another study looking at MetS and hip fracture surgeries reported increased rates of renal involvement, infection, and hospital readmission.[29] Other studies that span different specialties also claim similar results: MetS is associated with increased ORs for numerous comorbidities.[10,12,30] While risk for extended hospital stay greater than one month for all procedures was significant, such a lengthy stay is rare and therefore impact on hospital stay was not clinically relevant.

For both MetS and non-MetS, the three most commonly performed procedures were colectomy, cholecystectomy, and appendectomy. Cholecystectomy was the most-commonly performed procedure for the non-MetS group (33.9%) and second-most common for the MetS group (38.2%). Researchers have recently demonstrated an association between cholecystectomies and MetS.[31] This is thought to occur due to the disruption of bile acid's role as a factor that modulates the expression of genes involved in glucolipid homeostasis and energy expenditure.[32,33] This complex relationship may help us understand our data and why patients with MetS who undergo cholecystectomies are at increased risk for lengthened stay, overall morbidity, reoperation, and readmission. The association between MetS and cholecystectomy may also account for the procedure's greater proportion among MetS patients.

Colectomy was the most-commonly performed procedure among the MetS group (39.2%) and the second-most common among non-MetS (30.3%). Choi BJ et al. have previously looked at the effect of obesity on laparoscopic colectomy for colorectal cancer.[34] While different from MetS, obesity is also associated with numerous other comorbidities and is one of the mainstay criteria used in defining MetS.[35] Their study found no discernable effects on outcomes following colectomy. However, this may be attributable to the nature of the colectomies they assessed; as they treated colorectal cancers the nonemergent colectomies were adequately planned, unlike the colectomy of EGS.

Appendectomies made up nearly a quarter of the non-MetS procedures (24.4%) but only a tenth of MetS (9.5%), the largest discrepancy between the two groups in terms of procedure frequencies. Another defining feature of appendectomy in our results was that it was the sole procedure with a significant OR for mortality (Table 5). Appendectomy also had the greatest OR value for cumulative morbidity and >1-week hospital stay measures. A potential explanation for these findings is due to the large discrepancy of the number of patients undergoing appendectomy between MetS and non-MetS. The large number of healthy patients (non-MetS group) undergo appendectomy are expected to have better outcomes, when compared to unhealthier patients (MetS group).[3,9] This is also is applicable to the mortality finding. Appendectomies are known to be associated with low rates of complications, and this is likely because healthy members of population may also undergo this procedure.[36,37] These healthy patients may then cause the difference between MetS and non-Mets to be further pronounced. Lastly, the small number of patient cases relative to the total cohort who experienced mortality may also contribute to this.

Bowel resection, laparotomy, and peptic ulcer disease (surgical management) all had significant ORs for varying outcomes (Table 5). Together, these three procedures amounted to just under 10% of procedures performed for both MetS and non-MetS groups. Peptic ulcer disease had the highest OR values for >1-week hospital stay and return to OpR, suggesting that MetS often complicates this procedure. Laparotomy had the highest value OR for hospital readmission—MetS patients undergoing this procedure were 40% more likely to be re-hospitalized when compared to patients without MetS.

### *Limitations*

Several of the limitations of our study include all those factors that naturally confine both retrospective analysis and large-population studies. The NSQIP database was missing data for approximately a third of all cases. As NSQIP does not report on dyslipidemia, there was no way to include it into the definition of MetS. There are varying definitions of MetS, some of which are not as rigid as the criteria we had used and may therefore be a potential drawback. It is also possible that patients with forms of insulin resistance outside diabetes mellitus were not included in our MetS cohort if they had not been diagnosed with diabetes mellitus; this may also explain the low incidence we obtained. Although statistical significance was achieved, the small differences in percentage between the MetS and non-MetS cohorts suggests that not all statistical findings may necessarily translate into clinical significance. Despite the limitations present in this study, the NSQIP database offered us the ability to assess how MetS affects these seven EGS procedures by outcome and amount of impact.

## Conclusion

MetS is an increasingly common metabolic disorder associated with numerous comorbidities and increased postoperative risks. For patients undergoing any of the seven select procedures, clear cases of MetS increased risk for cumulative morbidity, cumulative pulmonary and renal complications, superficial infection, and hospital readmission but had no effect on overall 30-day mortality. When split by procedure, MetS had a significant impact on mortality for appendectomy. Future studies should attempt to discern whether or not the effect MetS has on EGS differs if the procedure is open or laparoscopic. They should also attempt to utilize more traditional definitions of MetS, and if possible, assess the independent effects of each component MetS has on outcomes.

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## Declaration of competing interest

None.

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