Association of Frailty and the Expanded Operative Stress Score with Preoperative Acute Serious Conditions, Complications and Mortality in Males Compared to Females – A Retrospective Observational Study

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Structured Abstract

Objective: Expand Operative Stress Score (OSS) increasing procedural coverage and assessing OSS and frailty association with Preoperative Acute Serious Conditions (PASC), complications and mortality in females versus males.

Summary Background Data: Veterans Affairs male-dominated study showed high mortality in frail veterans even after very low stress surgeries (OSS1).

Methods: Retrospective cohort using NSQIP data (2013–2019) merged with 180-day postoperative mortality from multiple hospitals to evaluate PASC, 30-day complications and 30-, 90- and 180-day mortality.

Results: OSS expansion resulted in 98.2% case coverage versus 87.0% using the original. Of 82,269 patients (43.8% male), 7.9% were frail/very frail. Males had higher odds of PASC (aOR=1.31, 95%CI=1.21–1.41, *P*<.001) and severe/life–threatening Clavien-Dindo IV (CDIV) complications (aOR=1.18, 95%CI=1.09–1.28, *P*<.001). While mortality rates were higher (all time points, P<.001) in males versus females, mortality was similar after adjusting for frailty, OSS, and case status primarily due to increased male frailty scores. Additional adjustments for PASC and CDIV resulted in a lower odds of mortality in males (30-day, aOR=0.81, CI=0.71–0.92, *P*=.002) that was most pronounced for males with PASC compared to females with PASC (30-day, aOR=0.75, CI=0.56–0.99, *P*=.04).

Conclusions: Similar to the male-dominated Veteran population, private sector, frail patients have high likelihood of postoperative mortality, even after low stress surgeries. Preoperative frailty screening should be performed regardless of magnitude of the procedure. Despite males experiencing higher adjusted odds of PASC and CDIV complications, females with PASC had

higher odds of mortality compared to males, suggesting differences in the aggressiveness of care provided to men and women.

Mini-Abstract

Cohort study of 82,269 patients comparing sex differences in Preoperative Acute Serious Conditions (PASC), complications and mortality adjusted for frailty, operative stress and case status. Despite having higher odds of PASC and Clavien-Dindo IV/life-threatening complications, males exhibited a survival advantage compared to females suggesting sex-related differences in care.

INTRODUCTION

Frailty defines the state of decreased physiological reserve contributing to adverse outcomes in the setting of stress, especially in older populations.[1, 2] Frailty more accurately predicts adverse outcomes than age alone.[3] Studies across multiple specialties associated frailty with increased postoperative complications, prolonged hospital stays, discharge to non-home facilities, and mortality.[3–14] Frailty can be used to identify high-risk patients for postoperative complications to improve shared decision making and preoperative optimization.[15]

Surgeries of different complexity place variable amounts of stress on patients. Many surgical outcome studies used groups of high-risk procedures rather than broadly assessing risk across diverse surgeries.[3, 4, 6–8, 11] One study defined high-risk surgeries as procedures having a 30-day mortality rate >1%.[13] However, more surgeries have >1% mortality in patients ≥ 65 years of age compared to younger patients.[16] A recent study by Shinall *et al.* introduced the Operative Stress Score (OSS) assigning a score from minimal (1) to maximal (5) operative stress[17] to evaluate the intersection of frailty and OSS on postoperative mortality in Veterans Health Administration (VHA) patients. Frailty was measured using the Risk Analysis Index (RAI),[18, 19] a validated instrument using variables in the Veterans Affairs Surgical Quality Improvement Program (VASQIP) and American College of Surgeons National Surgical Quality Improvement Program (NSQIP). Mortality increased as OSS increased at 30-, 90-, and 180-day time points after surgery in robust, normal and frail patients. The study found a high 30-day mortality of 10% for very frail patients after even very low stress surgeries. These patterns remained consistent when procedures were grouped by elective or emergent operations.[20]

The VHA study[17] provided an important new method for comparing diverse procedure using a scale of surgical-induced physiologic stress, highlighting the negative impact of frailty, and applicable to control for procedure-related complexity in samples of diverse specialties.[14] However, study generalizability to the overall United States population was limited by VHA patient demographics of 92.8% males, 69.3% White and 5.2% Hispanic.[17] Although the OSS contains 565 *Current Procedural Terminology* (CPT) codes covering 90% of the cases in VASQIP, it may not be representative of the most common surgical procedures in the private sector, especially procedures more commonly performed among women.

NSQIP includes variables for acute conditions present at time of surgery (PATOS) to distinguish preoperative risk factors from postoperative complications. However, most studies using NSQIP data do not include PATOS variables. Urinary tract infection, pneumonia, or septic shock PATOS variables were associated with increased postoperative complications and mortality,[21–24] and other PATOS variables were associated with higher risk of 30-day admissions.[25] However, there is a paucity of data exploring the importance of PATOS variables in postoperative outcomes overall and specific to sex.

Accurate outcome assessment is crucial to informed decision making and guides preoperative health status optimization and multidisciplinary interventions. This study aims to **1)** expand the number of CPT codes assigned an OSS value from the original VHA study,[17] especially for female-specific procedures, **2)** confirm whether the high postoperative mortality in frail Veterans[17] was generalizable to a more diverse, female-majority population, and **3)** assess the association of frailty, operative stress and PATOS conditions with complications and mortality. We hypothesized that the odds of postoperative mortality between males and females would be similar after adjusting for OSS, RAI, case status, preoperative acute conditions/PATOS and complications.

METHODS

Expansion of OSS

The original OSS contained 565 CPT codes assigned scores designating the level of physiological stress induced by each procedure using a modified Delphi consensus method by a panel of surgeons and anesthesiologists across specialty fields.[17] The CPT codes in the original OSS were chosen to include 90% of the procedures in VASQIP that covered a population that was 92.8% male[17] resulting in a predisposition to include male-specific procedures such as prostatectomy with minimal representation of female-specific procedures such as hysterectomy. The VASQIP dataset was originally chosen as long-term mortality was available from the VHA while only 30-day mortality was available in NSQIP. The OSS ranges from 1–5 with 1 and 5 representing surgeries inducing very low and very high physiological stress, respectively. Three surgeons leveraged hierarchies implicit within the Unified Medical Language System (UMLS) to arrange CPT scores according to anatomical location, extending the original OSS ratings to CPT codes located within the same level of UMLS hierarchy (see Supplemental Digital Content (SDC)).

Original and Expanded OSS Case Coverage

Case coverage, defined as the percent of records with an OSS-rated principal CPT code, for the original and expanded OSS was assessed in the NSQIP Participant Use Data File (PUF) from 2015–2018 and the study cohort derived from NSQIP data from multiple hospitals in 4 Academic Medical Centers (AMC).

Study Populations

Retrospective cohort study using patients in the 2013–2019 NSQIP registries at multiple hospitals in four AMC following STROBE reporting guidelines.[26] NSQIP contains detailed data on surgical patients including medical and surgical history, CPT codes, and 30-day

outcomes retrospectively collected by certified surgical clinical reviewers with high inter-rater reliability.[27] The identified NSQIP data were merged with long-term mortality at each site using electronic health record (EHR) data augmented by state mortality and Social Security Death Master File data.[28] De-identified datasets from each institution were merged for analysis with University of Texas Health San Antonio Institutional Review Board (IRB) serving as the single IRB. The University of Pittsburgh IRB determined exempt status for using the deidentified NSQIP PUF.

Frailty was assessed by the recalibrated and validated RAI[18, 19, 29] defining frailty categories as robust (<20), normal (20–29), frail (30–39) and very frail (40). Cases missing any NSQIP variable needed to calculate the RAI were excluded from the analysis (see SDC). Case status determined using NSQIP variables for elective and emergency surgeries, urgent defined as "no" for elective and emergency variables.

OSS Assignment in AMC NSQIP Cohort

NSQIP allows up to 11 CPT codes for each case. After excluding cases without an expanded OSS assigned to the principal CPT code, OSS was assigned using the highest score for all available procedures within each case.

Preoperative Acute Serious Conditions (PASC)

NSQIP contains 8 PATOS variables including 6 serious conditions: on ventilator >48hrs, deep incisional surgical site infection, organ/space surgical site infection, pneumonia, sepsis and septic shock and 2 lower acuity conditions including superficial incisional surgical site infection and urinary tract infection. NSQIP also contains preoperative variables for acute renal failure and dialysis occurring within 24 hours and 2 weeks prior to surgery, respectively. We derived two additional preoperative conditions: **1)** acute renal failure not requiring preoperative dialysis for patients with yes to acute renal failure and no to dialysis and **2)** acute renal failure requiring preoperative dialysis for patients with yes for both acute renal failure and dialysis.

We defined PASC as including the 6 serious PATOS variables and the 2 renal failure variables. The lower acuity PATOS variables were not included in PASC. The distribution of individual PASC variables was assessed and PASC was used as a binary variable.

Study Outcomes

Primary outcomes were 30-, 90- and 180-day mortality grouped by OSS and RAI. Secondary outcomes were **1)** occurrences of PASC, **2)** any 30-day postoperative complication including reoperation using NSQIP variables **3)** 30-day severe/life-threatening Clavien-Dindo level IV (CDIV) complications; CDIV complications included NSQIP variables of postoperative septic shock, postoperative dialysis, pulmonary embolus, myocardial infarction, cardiac arrest, prolonged ventilation, reintubation, coma or stroke[18, 30] and **4)** mortality adjusted odds ratios (aOR).

Statistical Analysis

Data reported as categorical (count and percentage) and continuous (means with standard deviation). Crude mortality rates calculated with 95% confidence interval (CI) for each RAI/OSS group. Chi-square test, Graham-Mengersen-Morton test,[31] and two sample t-test assuming a binomial or normal distribution were used to compare categorical, binary, and continuous variables between males and females. Logistic regression analyses assessed PASC, complications, and mortality adjusting for sex, RAI, OSS, case status, PASC, and complications. Interaction terms of sex with CDIV and PASC were used to assess effect of sex on the associations of CDIV or PASC with mortality. Sensitivity analyses performed using PASC subgroups. Analyses performed using RStudio version 1.3.1056 (RStudio, Inc., Boston, MA).

RESULTS

Expansion of OSS and NSQIP Case Coverage of Original Versus Expanded OSS

The 565 CPT codes in the original OSS[17] were increased to 2,343 CPT codes in the expanded OSS (SDCTable1). NSQIP 2015–2018 PUF contained 3,935,119 cases (43.2% male). Coverage of original versus expanded OSS increased from 87.0% to 98.2% of cases, and improvement was most pronounced in females, increasing by 13.6% in females (84.9% to 98.5%) compared to 8.2% in males (89.7% to 97.9%).

The AMC study population included 90,819 non-cardiac NSQIP cases from 2013–2019. The expanded OSS covered 98.6% of cases compared to 83.4 % using the original OSS (SDCTable2). Coverage varied across centers, ranging from 71.0%–91.5% for the original OSS and 96.5%–99.4% for the expanded OSS.

Cases were excluded due to missing **1)** variables used to calculate the RAI (n=527), **2)** expanded OSS assignment of principal CPT code (n=1,290) and **3)** case status variables (n=667), resulting in 88,335 cases in 82,269 patients. Random selection of a single case/patient was used for patients with multiple cases to assess the mortality endpoint (SDCFigure1) resulting in 82,269 cases for analysis.

Population Demographics

The 82,269 unique patients were 43.8% male, 76.6% Caucasian, 13.8% Black and 17.7% Hispanic ethnicity (Table 1). The cohort was mostly robust (63.6%) and normal (28.5%), while 7.1% were frail and 0.8% were very frail. Most patients underwent OSS2 (37.3%) and OSS3 (47.2%) procedures. The principal CPT code had the highest OSS in 78,680 cases, while 3,589 cases (4.4%) were categorized to a higher OSS by additional procedures included in the case. For these 3,589 cases, using the highest OSS CPT code increased OSS by 1 point for 3,486 cases (97.1%), by 2 points for 97 cases (2.7%) and by 3 points for 6 cases (0.2%).

Males had higher rates of PASC ($P<.001$), any complication ($P<.001$), CDIV complications ($P<.001$), urgent/emergent cases ($P<.001$), and mortality at all 3 time points ($P<.001$) compared to females (Table 1). Frailty ($P<.001$) and OSS distribution ($P<.001$) differed

between males and females. A higher percentage of females were robust while more males were normal, frail, or very frail. Males underwent higher percents of OSS1, 2, 4 and 5 procedures while the majority of females (50.8%) underwent OSS3 procedures. The five most common procedure types per OSS level represented 62.7%, 47.9%, 41.8%, 74.2% and 92.6% of OSS1 to 5 categories, respectively (SDCTable3).

Mortality Grouped by Frailty and Expanded OSS

Mortality at 30, 90 and 180 days grouped by RAI generally increased with increasing expanded OSS (Table 2 and Figure 1A–C). Case numbers in each group were >100 except for the very frail patients undergoing OSS1 and OSS5 procedures which only contained 18 and 17 cases, respectively. Mortality patterns were similar comparing the expanded and original OSS (n=69,677 cases) groups (SDCFigure2). Mortality patterns across expanded OSS/frailty groups were also similar for male compared to female patients (Figure 1D–I).

Increased PASC and 30-day Complication Rates in Males Compared to Females

PASC was present in 4.2% of patients and higher in males ($P<.001$) compared to females (Table1). PASC variable distribution was similar between males and females except males had increased preoperative acute renal failure ($P=.005$) and requiring acute dialysis ($P=.03$) with lower rates of septic shock ($P=.04$) compared to female patients (Table 3). The composite distribution of patients with multiple occurrences of PASC variables was similar between males and females. Patients with PASC predominately (87.9%) underwent urgent/emergent surgeries.

Any complication and CDIV complications occurred in 15.9% and 3.3% of patients, respectively (Table 1) with males exhibiting higher rates than females. The types of CDIV complications were similar between males and females except males had increased postoperative acute renal failure requiring dialysis ($P=.006$, Table 3). Distribution of multiple occurrences of CDIV complications showed that males were more likely than females to have higher numbers of CDIV complications ($P=.03$). Patients experiencing CDIV complications predominately (64.7%) underwent urgent/emergent surgeries. Patients having both PASC and CDIV complications (1.0% of AMC cohort) predominately (94.6%) underwent urgent/emergent surgeries.

PASC and 30-Day Complication Logistic Regression Models; Males had Increased Odds of PASC and CDIV Complications Compared to Females

Males were more likely to have PASC (aOR=1.31, CI=1.21–1.41, $P<.001$, Table 4). Increasing RAI categories and urgent/emergent cases were associated with higher odds of PASC. Patients undergoing OSS4 procedures were the most likely to have PASC.

Increasing OSS or RAI categories and urgent/emergent cases were associated with increased aOR for complications (Table 4). Males had lower odds of experiencing any complication (aOR=0.94, CI=0.90–0.98, $P=.003$) compared to females. However, males had higher odds of experiencing CDIV complications (aOR=1.18, CI=1.09–1.28, $P<.001$).

Mortality Logistic Regression Models; Similar aOR between Males and Females after Adjusting for RAI, OSS and Case Status

Increasing RAI and OSS categories were associated with increased mortality rates (Table 2). Males had higher percent mortality (Table 1) at all 3 time points compared to females. Unadjusted mortality for males was higher at all time points (30-day: OR=1.51, CI=1.35–1.69, 90-day: OR=1.55, CI=1.41–1.70, 180-day: OR=1.56, CI=1.44–1.69). However, mortality aOR were similar between males and females after RAI adjustment (30-day: aOR=0.90, CI=0.80–1.01, 90-day: aOR=0.92, CI=0.83–1.01, 180-day: aOR=0.93, CI=0.85–1.01) and remained similar after additional OSS and case status adjustment (30-day: aOR=0.95, CI=0.84–1.06, 90-day: aOR=0.96, CI=0.87–1.06, 180-day: aOR=0.96, CI=0.88–1.05), suggesting that the increased, unadjusted mortality rates in males were primarily due to higher RAI scores (Table 1).

Males with PASC Exhibit Lower Odds of Mortality Compared to Females with PASC

PASC was associated with higher odds of mortality after adjustment for sex, RAI, OSS and case status (Table 5). Subgroup analyses suggested that males with PASC had lower odds of mortality/survival advantage compared to females at all time points. Interaction term analysis examining sex and PASC showed that the increased odds of mortality associated with PASC at 90 (P=.02) and 180 days (P=.004) were more pronounced for women than men.

Males Exhibit Lower Odds of Mortality in Logistic Regression Models Adjusted for CDIV Complications

Addition of any complication to mortality logistic regression models showed similar aOR for mortality between males and females (SDCTable4). Adjusting for CDIV complications resulted in lower odds of mortality for males at all time points (SDCTable5). However, the sex-CDIV interaction term was not statistically significant.

Males with PASC Exhibit Lower Odds of Mortality in Logistic Regression Models after adjusting for CDIV

PASC and CDIV were associated with higher odds of mortality after adjustment for sex, RAI, OSS, and case status (Table 6). Adjusting for PASC and CDIV complications resulted in lower odds of mortality for males at all time points (30-day aOR=0.81, CI=0.71–0.92, P=.002, SDCTable6). Subgroup analyses suggested that males with PASC had a survival advantage compared to females at all time points (Table 6). The sex-PASC interaction term again demonstrated the increased odds of mortality associated with PASC were more pronounced for women than men (Table 6).

DISCUSSION

OSS scores reflect the estimated physiologic stress induced by a procedure. We expanded the original OSS from 565 to 2,343 CPT codes. Expanded OSS improved procedural coverage at four AMC and within the NSQIP PUF. Importantly, coverage in females improved, compensating for the original OSS using a male-dominated veteran population. Our private sector cohort with a more racially and ethnically diverse, female-majority

population demonstrated similar patterns as the VHA study with high mortality in frail patients across the OSS spectrum.[17] We confirmed the VHA study's findings in longer-term outcomes, an analysis that is not possible using NSQIP PUF limited to 30-day outcomes. Importantly, our findings of 14.6%, 18.4%, 27.2% 30-day mortality in the very frail group were similar to the VHA study of 10.1%, 18.7%, 22.3% for OSS2, 3 and 4 procedures, respectively.

Studies on frailty and postoperative outcomes have focused heavily on emergent and major elective procedures that are considered either intermediate or high risk.[3, 32, 33] Our data in a female-majority, private-sector population confirmed the VHA study[17] finding that even low risk procedures carry elevated mortality risk for frail patients. High-risk procedures have been defined as those with 30-day mortality exceeding 1%.[13] However, even for the low stress, OSS2 procedures, the VHA study demonstrated a 30-day mortality of 10.1% in very frail patients compared to 14.6% in our study, well exceeding the preset level for high-risk procedures.[17] A recent study using VASQIP and NSQIP demonstrated that the association of frailty and postoperative mortality was consistent across non-cardiac surgical specialties regardless of case-mix.[14] A study using Medicare inpatient data also found high mortality even after low risk emergency surgeries emphasizing the importance of preoperative frailty screening for all.[34] Frailty screening used by a multidisciplinary team in preoperative planning reduced 30-day mortality in frail patients from 12.2% to 3.8%; possibly due to better preoperative planning, intraoperative management and postoperative rescue.[35] Additionally, rehabilitation through exercise and nutrition supplementation are promising interventions to improve function and decrease perioperative complications and mortality.[36–40] These observations suggest that frailty screening is important even for surgeries associated with low physiologic stress and may improve risk assessment accuracy for shared decision making in elective and emergency settings.

Although a variety of tools exist for measuring frailty, none has emerged as a gold standard.[41] Frailty indices based on deficit accumulation are widely available,[42] but typically deployed for post-hoc applications in registries. Measures of physical frailty are often used in research settings[9] but are often too intensive for routine screening of robust populations. A recent consensus panel emphasized the need for a pragmatic approach to frailty screening that emphasizes feasible tests that can be implemented systematically.[41] One such feasible tool is the Edmonton Frail Scale that measures frailty in 10 domains with mostly patient reported items and two performance-based items.[43, 44] Alternatively, the RAI can be calculated from registry variables as done in this study or can be implemented as a 14-item survey taking less than a minute for patients to complete. Both versions of the RAI have been thoroughly validated in surgical patients,[19, 45, 46] and the survey version is the only screening tool proven feasible for system-wide implementation in both the VHA[35] and private sector[45–47] and was associated with improved postoperative survival.[47] Based on these data, the RAI survey will soon be released as a "clinical program" embedded in the Epic electronic record system, and work is also under way to make the RAI survey available within the VHA's electronic record, both Computerized Patient Record System (CPRS) and Cerner.

The most common procedures within the OSS categories that differed in the VHA study versus our cohort were most notably sex-specific procedures.[17] Overlap between the VHA and our study in the 5 most common procedure types was 20%, 60%, 60%, 40%, and 60% for OSS1 to OSS5, respectively. In the VHA study, male-specific procedures of hydrocele, transurethral prostate procedures, and prostatectomy ranked 2nd, 4th, and 2nd in terms of frequency for OSS1, OSS2 and OSS4 categories, respectively. Our most common procedures included mastectomy and hysterectomy ranking 4th in OSS2 and OSS3 categories, respectively, but no male-specific procedures were present. As such, expanded OSS provides improved CPT code coverage and is more appropriate than original OSS for use in NSQIP and non-male-majority populations.

Males had lower odds of any 30-day complications than females after adjusting for RAI, OSS, and case status but higher odds of CDIV complications. Other studies adjusting for frailty showed that males had complication risks compared to females that were higher after pancreatectomy,[6] lower after ambulatory general surgeries[48] and similar after paraoesophageal hernia repair[49]. Complication risk may be different for males versus females in surgeries of different stress levels and needs further evaluation.

While males had higher unadjusted mortality compared to females, adjustment for only frailty and in conjunction with OSS and case status resulted in similar odds of postoperative mortality for males and females at all time points. OSS did not exhibit a substantial effect for sex on mortality possibly related to the bimodal distribution of OSS with males having more OSS1, 2, 4, and 5 procedures while females had a higher percentage of OSS3 procedures. Two studies found similar mortality rates between both sexes after adjusting for frailty, other patient characteristics and surgery types.[3, 6] However, female sex was associated with higher mortality after vascular procedures[8, 50] but lower mortality after emergency general surgery.[34] Sex-related mortality differences may be related to different procedure types and requires further investigation.

NSQIP PATOS variables were associated with increased complications and mortality.[21–24] However, the literature on preoperative acute conditions is limited with only select conditions studied for targeted surgeries. We found that while males had higher rates and aOR of PASC, males with PASC had lower odds of mortality compared to females with PASC using both subgroup and interaction term analyses across a broad array of surgical types. We speculate that the lower mortality odds in males could be related to differences in aggressiveness of treatment and intensive care unit (ICU) admission.[51, 52] Studies have shown sex differences in hospitalization and mortality for acute diverticulitis[53] and coronary artery disease[54] where females were less likely to receive surgery or cardiac protective medication. Additionally, females had lower ICU admission rates and shorter ICU stays after adjusting for diagnosis and disease severity.[51, 52] Surveys of physicians found that sex did not affect their willingness to admit patients to the ICU.[55, 56] However, surveying elderly outpatients found females less frequently desired life-supporting medical therapies, suggesting male predominance in ICU admissions could be related to patient preference.[57] These differences could affect other management decisions possibly leading to mortality differences in severely ill patients. Further investigation is needed to determine whether disparities in female patient care contribute to the survival advantage for males with PASC.

This was a retrospective observational study that did not allow for determination of causal relationships. Due to the small number of very frail patients that underwent OSS1 and OSS5 procedures, we also cannot draw conclusions for these two subgroups. There are other important outcome measures that were not evaluated in our study such as length of stay, discharge location, disability, and quality of life that are may be more meaningful, especially for frail patients. NSQIP does not distinguish deaths directly related to surgical procedures from all-cause mortality, nor does NSQIP specifically identify procedures that may have been performed with a goal of palliation rather than extending life. It is also likely that the RAI survey was assessed preoperatively for some of the patients included in our sample, but only from one of the participating AMC and only on cases after July 1, 2016. Although such RAI screening was associated with increased survival at 1year after surgery,[47] this benefit was not apparent before 1 year (unpublished data), and thus not likely to impact the findings here limited to survival up to 180 days after surgery. Furthermore, the response to frailty identified by the RAI was left to the discretion of the treating surgeon without formal prehabilitation or decision support interventions beyond the identification of frailty.

In conclusion, frailty is associated with high mortality even after low-stress surgeries in both sexes and OSS expansion improved procedural coverage in a female-majority population. Our study provides further support[14, 17] that preoperative frailty screening should be performed regardless of the magnitude of the planned procedure to improve shared decision making and preoperative optimization. Importantly, including PASC variables in analyses showed sex-specific differences in mortality. While males have higher rates and adjusted odds of PASC and CDIV complications, females with PASC had higher odds of mortality. The extent to which more aggressive treatment for males, patient care preferences and/or disparities in the care of female patients account for the survival differences is unknown and deserves further study.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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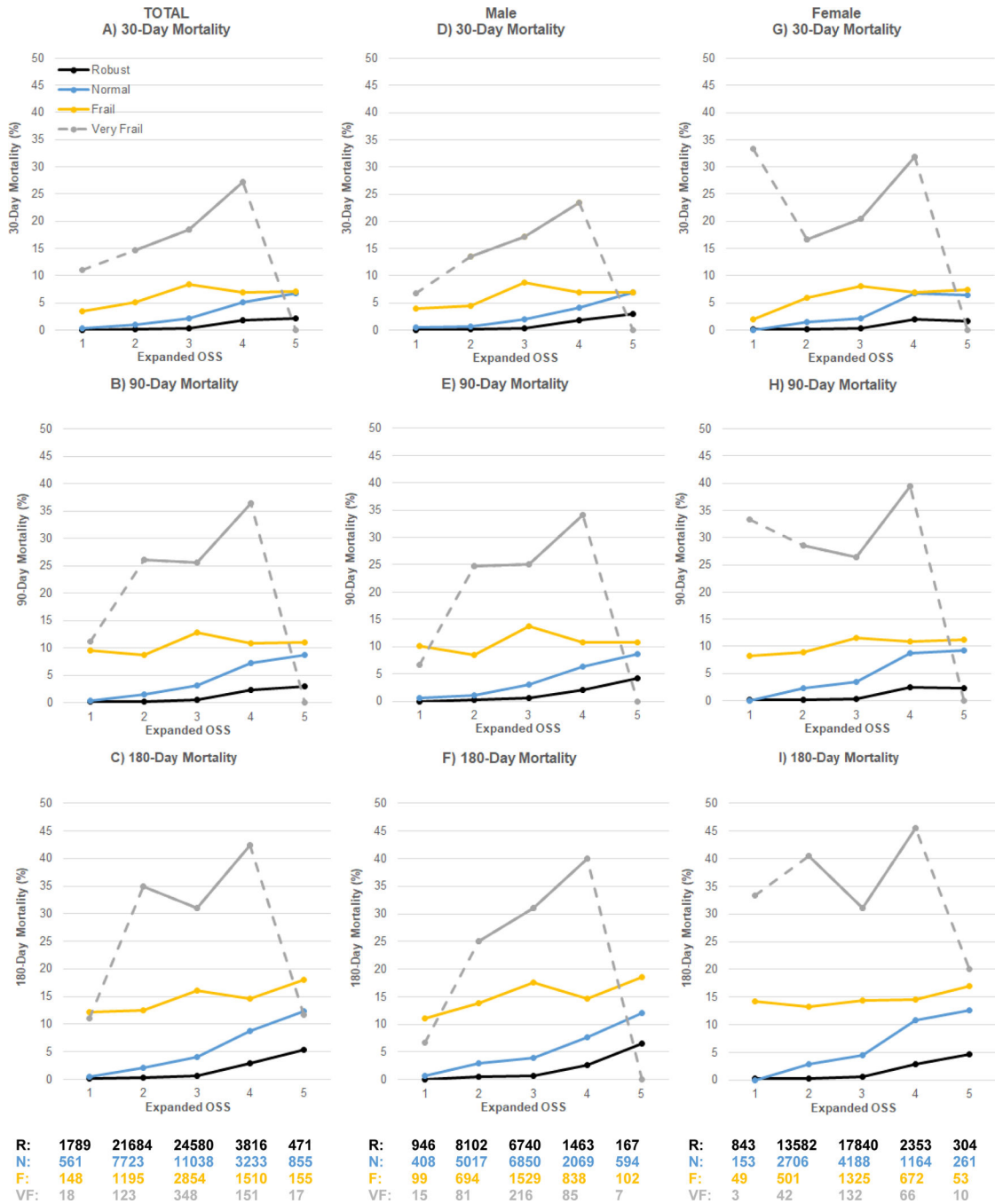
Figure 1. Mortality Grouped by Expanded Operative Stress Score (OSS) and Frailty.
Total cases (n=82,269) **A–C**, cases performed in males (n=36,022) **D–F** and females (n=46,247) **G–I**. Expanded OSS defined physiologic stress induced by surgery as 1 (very low), 2 (low), 3 (moderate), 4 (high) and 5 (very high). Frailty assessed by Risk Analysis Index scores of ≤20 robust (R), 21–29 normal (N), 30–39 frail (F), and ≥40 very frail (VF). Small sample size for very frail patients undergoing OSS1 and OSS5 procedures shown with dashed gray line.

Table 1.

Demographic Characteristics of Patients from 4 Academic Medical Centers

	Total	Male	Female	*P* Value
No. (%)	**82,269**	**36,022 (43.8)**	**46,247 (56.2)**	
Age, mean (SD), years	54.4 (16.7)	55.5 (16.6)	53.6 (16.7)	<.001
Race				<.001
Caucasian, No. (%)	62,990 (76.6)	28,162 (78.2)	34,828 (75.3)	
African American, No. (%)	11,345 (13.8)	4,361 (12.1)	6,984 (15.1)	
Other, No. (%)[a]	1,379 (1.7)	554 (1.5)	825 (1.8)	
Unknown, No. (%)	6,555 (8.0)	2,945 (8.2)	3,610 (7.8)	
Ethnicity				<.001
Non-Hispanic or Latino, No. (%)	57,496 (69.9)	25,471 (70.7)	32,025 (69.2)	
Hispanic or Latino, No. (%)	14,583 (17.7)	5,943 (16.5)	8,640 (18.7)	
Unknown, No. (%)	10,190 (12.4)	4,608 (12.8)	5,582 (12.1)	
Expanded Operative Stress Score (OSS)				<.001
OSS1, No. (%)	2,516 (3.1)	1,468 (4.1)	1,048 (2.3)	
OSS2, No. (%)	30,725 (37.3)	13,894 (38.6)	16,831 (36.4)	
OSS3, No. (%)	38,820 (47.2)	15,335 (42.6)	23,485 (50.8)	
OSS4, No. (%)	8,710 (10.6)	4,455 (12.4)	4,255 (9.2)	
OSS5, No. (%)	1,498 (1.8)	870 (2.4)	628 (1.4)	
Risk Analysis Index				<.001
Robust (20), No. (%)	52,340 (63.6)	17,418 (48.4)	34,922 (75.5)	
Normal (21–29), No. (%)	23,410 (28.5)	14,938 (41.5)	8,472 (18.3)	
Frail (30–39), No. (%)	5,862 (7.1)	3,262 (9.1)	2,600 (5.6)	
Very Frail (40), No. (%)	657 (0.8)	404 (1.1)	253 (0.5)	
PASC present, No. (%)	3,492 (4.2)	1,970 (5.5)	1,522 (3.3)	<.001
30-day Complications				
No Complications, No. (%)	69,213 (84.1)	29,773 (82.7)	39,440 (85.3)	<.001
Any Complication, No. (%)	13,056 (15.9)	6,249 (17.3)	6,807 (14.7)	<.001
CDIV Complications, No. (%)	2,689 (3.3)	1,497 (4.2)	1,192 (2.6)	<.001
Case status				
Elective, No. (%)	58,319 (70.9)	24,355 (67.6)	33,964 (73.4)	<.001
Urgent/Emergent, No. (%)	23,950 (29.1)	11,667 (32.4)	12,283 (26.6)	<.001
Mortality				
30-day Mortality, No. (%)	1,267 (1.5)	683 (1.9)	584 (1.3)	<.001
90-day Mortality, No. (%)	1,884 (2.3)	1,026 (2.8)	858 (1.9)	<.001
180-day Mortality, No. (%)	2,483 (3.0)	1,355 (3.8)	1,128 (2.4)	<.001

Abbreviations: CDIV, Clavien-Dindo Level IV; SD, Standard deviation

Pearson's Chi-square tests were used to calculate *P* values.

[a]Other includes American Indian, Asian and Pacific Islander

Table 2.

30-, 90-, and 180-day Mortality Grouped by Frailty and Expanded Operative Stress Score

Mortality	OSS1	OSS2	OSS3	OSS4	OSS5
	n=2,516	n=30,725	n= 38,820	n=8,710	n=1,498
30-day Deaths, No.	10	183	614	381	79
30-day Mortality by RAI % (95% CI)					
Robust (20)	0.06 (0.00–0.31)	0.14 (0.09–0.20)	0.32 (0.25–0.40)	1.83 (1.43–2.31)	2.12 (1.02–3.87)
Normal (21–29)	0.36 (0.04–1.28)	0.96 (0.75–1.20)	2.09 (1.83–2.38)	5.10 (4.37–5.92)	6.78 (5.19–8.68)
Frail (30–39)	3.38 (1.11–7.71)	5.10 (3.93–6.51)	8.44 (7.45–9.53)	6.95 (5.72–8.36)	7.10 (3.60–12.34)
Very Frail (40)	11.11 (1.38–34.71)	14.63 (8.91–22.14)	18.39 (14.46–22.87)	27.15 (20.24–34.98)	0.00 (0.00–19.51)
Overall Mortality	0.40 (0.19–0.73)	0.60 (0.51–0.69)	1.58 (1.46–1.71)	4.37 (3.95–4.83)	5.27 (4.20–6.53)
90-day Deaths, No.	20	300	917	541	106
Mortality by RAI, % (95% CI)					
Robust (20)	0.11 (0.01–0.40)	0.23 (0.17–0.30)	0.48 (0.40–0.58)	2.36 (1.90–2.89)	2.97 (1.63–4.94)
Normal (21–29)	0.36 (0.04–1.28)	1.50 (1.24–1.80)	3.12 (2.80–3.46)	7.21 (6.34–8.15)	8.77 (6.96–10.87)
Frail (30–39)	9.46 (5.27–15.36)	8.62 (7.09–10.36)	12.79 (11.58–14.07)	10.79 (9.27–12.47)	10.97 (6.52–16.98)
Very Frail (40)	11.11 (1.38–34.71)	26.02 (18.52–34.70)	25.57 (21.07–30.50)	36.42 (28.75–44.64)	0.00(0.00–19.51)
Overall Mortality	0.79 (0.49–1.23)	0.98 (0.87–1.09)	2.36 (2.21–2.52)	6.21 (5.71–6.74)	7.08 (5.83–8.49)
180-day Deaths, No.	26	434	1186	677	160
Mortality by RAI, % (95% CI)					
Robust (20)	0.17 (0.03–0.49)	0.35 (0.27–0.43)	0.67 (0.57–0.78)	2.83 (2.33–3.41)	5.31 (3.46–7.74)
Normal (21–29)	0.53 (0.11–1.55)	2.15 (1.84–2.50)	4.12 (3.76–4.51)	8.78 (7.83–9.81)	12.28 (10.16–14.67)
Frail (30–39)	12.16 (7.37–18.54)	12.55 (10.73–14.57)	16.08 (14.75–17.48)	14.64 (12.89–16.52)	18.06 (12.35–25.04)
Very Frail (40)	11.11 (1.38–34.71)	34.96 (26.58–44.08)	31.03 (26.21–36.19)	42.38 (34.39–50.68)	11.76 (1.46–36.44)
Overall Mortality	1.03 (0.68–1.51)	1.41 (1.28–1.55)	3.06 (2.89–3.23)	7.77 (7.22–8.35)	10.68 (9.16–12.36)

Abbreviations: CI, Confidence Interval; OSS, Operative Stress Score; RAI, Risk Analysis Index

Graham-Mengersen-Morton tests were used to calculate 95% confidence intervals.

Table 3.

Distribution of Preoperative Acute Serious Conditions (PASC) and Clavien-Dindo IV (CDIV) Complications

	Total	Male	Female	*P* value
PASC [a]	3,492	1,970	1,522	
Deep incision surgical site infection (DSSIPATOS), No. (%)	128 (3.7)	71 (3.6)	57 (3.7)	.90
Organ/space surgical site infection (OSSIPATOS), No. (%)	447 (12.8)	254 (12.9)	193 (12.7)	.89
Pneumonia (PNAPATOS), No. (%)	298 (8.5)	178 (9.0)	120 (7.9)	.25
On ventilator >48hrs (VENTPATOS), No. (%)	406 (11.6)	216 (11.0)	190 (12.5)	.18
Sepsis (SEPSISPATOS), No. (%)	1551 (44.4)	876 (44.5)	675 (44.3)	.97
Septic shock (SEPSHOCKPATOS), No. (%)	849 (24.3)	453 (23.0)	396 (26.0)	.04
Acute renal failure not requiring dialysis [b], No. (%)	334 (9.6)	213 (10.8)	121 (8.0)	.005
Acute renal failure requiring dialysis [c], No. (%)	247 (7.1)	156 (7.9)	91 (6.0)	.03
Composite Distribution of PASC				.59
Patients with 1 PASC, No. (%)	2,857 (81.8)	1,603 (81.4)	1,254 (82.4)	
Patients with 2 PASC, No. (%)	524 (15.0)	302 (15.3)	222 (14.6)	
Patients with 3 PASC, No. (%)	91 (2.6)	51 (2.6)	40 (2.6)	
Patients with 4–5 PASC, No. (%)	20 (0.6)	14 (0.7)	6 (0.4)	
Urgent/Emergent case status	3069 (87.9)	1729 (87.8)	1340 (88.0)	.85
CDIV complications	2689	1497	1192	
Reintubation (REINTUB), No. (%)	1,014 (37.7)	583 (38.9)	431 (36.2)	.15
Pulmonary embolism (PULEMBOL), No. (%)	348 (12.9)	192 (12.8)	156 (13.1)	.89
Failure to wean (ventilator >48hrs) (FAILWEAN), No. (%)	1,120 (41.7)	622 (41.5)	498 (41.8)	.94
Acute renal failure (require dialysis) (OPRENAFL), No. (%)	355 (13.2)	222 (14.8)	133 (11.2)	.006
Cerebral vascular event/stroke (CNSCVA), No. (%)	210 (7.8)	103 (6.9)	107 (9.0)	.052
Cardiac arrest (CDARREST), No. (%)	343 (12.8)	208 (13.9)	135 (11.3)	.054
Myocardial infarction (CDMI), No. (%)	324 (12.0)	196 (13.1)	128 (10.7)	.07
Septic shock (OTHSESHOCK), No. (%)	450 (16.7)	256 (17.1)	194 (16.3)	.61
Composite Distribution of CDIV complications				.03
Patients with 1 CDIV	1,700 (63.2)	915 (61.1)	785 (65.9)	
Patients with 2 CDIV	629 (23.4)	359 (24.0)	270 (22.7)	
Patients with 3 CDIV	265 (9.9)	163 (10.9)	102 (8.6)	
Patients with ≥4 CDIV	95 (3.5)	60 (4.0)	35 (2.9)	
Urgent/Emergent case status	1739 (64.7)	990 (66.1)	749 (62.8)	.08
Patients with PASC and CDIV	848	475	373	
Urgent/Emergent case status, No. (%)	802 (94.6)	448 (94.3)	354 (94.9)	.82

Abbreviations: NSQIP, National Surgical Quality Improvement Program, NSQIP variable names included in parentheses

Pearson's Chi-square test was used to calculate *P* values.

[a] 144 patients with only preoperative urinary tract infection or superficial surgical site infection were not included in PASC.

[b] defined as a positive response to RENAFAIL and negative response to DIALYSIS NSQIP variables

[c] defined as a positive response to both RENAFAIL and DIALYSIS NSQIP variables

Table 4.

PASC and 30-day Complications Odds Ratios Adjusted for Sex, RAI, OSS and Case Status

	Adjusted OR (95% CI)	*P* value
PASC		
Male (Ref = Female)	1.31 (1.21–1.41)	<.001
RAI (Ref = Normal 21–29)		
Robust (20)	0.60 (0.55–0.66)	<.001
Frail (30–39)	1.46 (1.31–1.63)	<.001
Very frail (40)	2.41 (1.97–2.95)	<.001
Expanded OSS (Ref = OSS1)		
OSS2	0.71 (0.59–0.87)	.001
OSS3	0.71 (0.58–0.86)	.001
OSS4	2.24 (1.83–2.74)	<.001
OSS5	0.57 (0.39–0.85)	.005
Urgent/Emergent (Ref = elective)	19.08 (17.19–21.16)	<.001
Model C-Statistic	0.87	
No complications		
Male (Ref = Female)	1.07 (1.02–1.11)	.003
RAI (Ref = Normal 21–29)		
Robust (20)	1.75 (1.68–1.84)	<.001
Frail (30–39)	0.64 (0.60–0.68)	<.001
Very frail (40)	0.39 (0.33–0.46)	<.001
Expanded OSS (Ref = OSS1)		
OSS2	0.87 (0.74–1.03)	.11
OSS3	0.37 (0.32–0.43)	<.001
OSS4	0.12 (0.11–0.15)	<.001
OSS5	0.06 (0.05–0.07)	<.001
Urgent/Emergent (Ref = elective)	0.40 (0.38–0.42)	<.001
Model C-Statistic	0.75	
Any complication		
Male (Ref = Female)	0.94 (0.90–0.98)	.003
RAI (Ref = Normal 21–29)		
Robust (20)	0.57 (0.54–0.60)	<.001
Frail (30–39)	1.56 (1.46–1.67)	<.001
Very frail (40)	2.56 (2.16–3.02)	<.001
Expanded OSS (Ref = OSS1)		
OSS2	1.14 (0.97–1.35)	.11
OSS3	2.71 (2.31–3.18)	<.001
OSS4	8.10 (6.88–9.55)	<.001
OSS5	16.70 (13.82–20.19)	<.001

	Adjusted OR (95% CI)	*P* value
Urgent/Emergent (Ref = elective)	2.51 (2.41–2.62)	<.001
Model C-Statistic	0.75	
Clavien-Dindo IV complications		
Male (Ref = Female)	1.18 (1.09–1.28)	<.001
RAI (Ref = Normal 21–29)		
Robust (20)	0.40 (0.36–0.44)	<.001
Frail (30–39)	1.44 (1.29–1.61)	<.001
Very frail (40)	2.00 (1.61–2.50)	<.001
Expanded OSS (Ref = OSS1)		
OSS2	1.21 (0.81–1.80)	0.35
OSS3	3.17 (2.16–4.67)	<.001
OSS4	7.26 (4.92–10.72)	<.001
OSS5	13.78 (9.10–20.86)	<.001
Urgent/Emergent (Ref = elective)	4.50 (4.14–4.89)	<.001
Model C-Statistic	0.81	

Abbreviations: OR, Odds Ratio; RAI, Risk Analysis Index; OSS, Operative Stress Score; PASC, Preoperative Acute Serious Conditions; Ref, reference

Logistic regression analyses

Table 5.

Mortality Odds Ratios Adjusted for Sex, RAI, OSS, Case Status, and PASC with Sex*PASC Interaction Term or PASC Subgroup Analyses

	30-day		90-day		180-day	
	Adjusted OR (95% CI)	P value	Adjusted OR (95% CI)	P value	Adjusted OR (95% CI)	P value
Sex*PASC Interaction Term Analysis (n=82,269)						
Male (Ref = Female)	0.98 (0.85–1.14)	.82	1.00 (0.89–1.13)	.99	1.00 (0.90–1.11)	.997
RAI (Ref = Normal 21–29)						
Robust (20)	0.20 (0.17–0.24)	<.001	0.19 (0.17–0.22)	<.001	0.19 (0.17–0.22)	<.001
Frail (30–39)	2.39 (2.08–2.75)	<.001	2.80 (2.50–3.15)	<.001	3.05 (2.75–3.37)	<.001
Very frail (40)	4.02 (3.17–5.10)	<.001	4.88 (3.96–6.01)	<.001	5.52 (4.55–6.69)	<.001
Expanded OSS (Ref = OSS1)						
OSS2	1.90 (0.99–3.64)	.053	1.55 (0.97–2.47)	.07	1.72 (1.14–2.60)	.009
OSS3	3.53 (1.87–6.69)	<.001	2.64 (1.67–4.18)	<.001	2.67 (1.78–4.00)	<.001
OSS4	5.48 (2.88–10.43)	<.001	4.18 (2.63–6.65)	<.001	4.27 (2.83–6.42)	<.001
OSS5	15.11 (7.65–29.81)	<.001	9.57 (5.79–15.83)	<.001	11.16 (7.20–17.31)	<.001
Urgent/Emergent (Ref = elective)	5.56 (4.78–6.48)	<.001	4.80 (4.27–5.41)	<.001	3.90 (3.54–4.30)	<.001
PASC	6.31 (5.19–7.67)	<.001	5.42 (4.56–6.45)	<.001	4.80 (4.08–5.65)	<.001
Males*PASC	0.78 (0.61–1.01)	.055	0.76 (0.60–0.95)	.02	0.73 (0.59–0.91)	.004
Model C-Statistic	0.91		0.90		0.88	
Subgroup Analyses						
PASC subgroup (n=3,492)						
Male (Ref = Female)	0.80 (0.65–0.98)	.03	0.80 (0.66–0.96)	.02	0.78 (0.65–0.94)	.007
RAI (Ref = Normal 21–29)						
Robust (20)	0.28 (0.21–0.36)	<.001	0.27 (0.21–0.34)	<.001	0.27 (0.22–0.35)	<.001
Frail (30–39)	1.87 (1.47–2.38)	<.001	2.29 (1.83–2.87)	<.001	2.32 (1.87–2.89)	<.001
Very frail (40)	2.69 (1.88–3.85)	<.001	3.06 (2.16–4.33)	<.001	3.38 (2.39–4.77)	<.001
Expanded OSS (Ref = OSS1)						
OSS2	2.89 (0.88–9.44)	.08	2.38 (0.93–6.09)	.07	2.98 (1.17–7.58)	.02
OSS3	5.90 (1.84–18.94)	.003	4.51 (1.80–11.34)	.001	5.36 (2.14–13.45)	<.001
OSS4	7.85 (2.44–25.26)	.001	6.73 (2.67–16.95)	<.001	7.76 (3.08–19.53)	<.001
OSS5	7.70 (1.75–33.84)	.007	11.11 (3.38–36.57)	<.001	12.62 (3.89–40.99)	<.001
Urgent/Emergent (Ref = elective)	4.02 (2.48–6.50)	<.001	3.21 (2.18–4.74)	<.001	2.64 (1.87–3.73)	<.001
Model C-Statistic	0.76		0.77		0.77	
No PASC subgroup (n=78,777)						
Male (Ref = Female)	0.95 (0.82–1.11)	.53	0.98 (0.87–1.10)	.72	0.98 (0.89–1.09)	.69
RAI (Ref = Normal 21–29)						
Robust (20)	0.17 (0.14–0.22)	<.001	0.17 (0.14–0.20)	<.001	0.17 (0.15–0.20)	<.001

	30-day		90-day		180-day	
	Adjusted OR (95% CI)	***P* value**	**Adjusted OR (95% CI)**	***P* value**	**Adjusted OR (95% CI)**	***P* value**
Frail (30–39)	2.67 (2.24–3.17)	<.001	2.99 (2.61–3.43)	<.001	3.26 (2.90–3.66)	<.001
Very frail (40)	5.37 (3.99–7.24)	<.001	6.17 (4.83–7.88)	<.001	6.71 (5.38–8.37)	<.001
Expanded OSS (Ref = OSS1)						
OSS2	1.54 (0.72–3.33)	.27	1.31 (0.77–2.24)	.32	1.46 (0.93–2.30)	.10
OSS3	2.70 (1.27–5.74)	.01	2.14 (1.27–3.60)	.004	2.15 (1.40–3.35)	.001
OSS4	4.52 (2.10–9.70)	<.001	3.39 (1.99–5.77)	<.001	3.47 (2.21–5.46)	<.001
OSS5	13.22 (6.01–29.10)	<.001	8.01 (4.57–14.06)	<.001	9.39 (5.83–15.11)	<.001
Urgent/Emergent (Ref = elective)	5.61 (4.77–6.59)	<.001	4.86 (4.29–5.51)	<.001	3.95 (3.56–4.37)	<.001
Model C-Statistic	0.88		0.87		0.86	

Abbreviations: OR, Odds Ratio; OSS, Operative Stress Score; PASC, Preoperative Acute Serious Conditions; RAI, Risk Analysis Index; Ref, reference

Logistic regression analyses

Table 6.

Mortality Odds Ratios Adjusted for Sex, RAI, OSS, Case Status, CDIV and PASC with Sex*PASC Interaction Term or PASC Subgroup Analyses

	30-day		90-day		180-day	
	Adjusted OR (95% CI)	*P* value	Adjusted OR (95% CI)	*P* value	Adjusted OR (95% CI)	*P* value
Sex*PASC Interaction Term Analysis (n=82,269)						
Male (Ref = Female)	0.88 (0.75–1.04)	.13	0.92 (0.81–1.05)	.21	0.94 (0.85–1.05)	.27
RAI (Ref = Normal 21–29)						
Robust (20)	0.25 (0.21–0.30)	<.001	0.22 (0.19–0.26)	<.001	0.21 (0.19–0.24)	<.001
Frail (30–39)	2.45 (2.10–2.86)	<.001	2.96 (2.61–3.36)	<.001	3.20 (2.87–3.57)	<.001
Very frail (40)	4.60 (3.51–6.03)	<.001	5.64 (4.50–7.09)	<.001	6.17 (5.03–7.57)	<.001
Expanded OSS (Ref = OSS1)						
OSS2	1.74 (0.89–3.40)	.11	1.43 (0.89–2.32)	.14	1.63 (1.07–2.48)	.02
OSS3	2.52 (1.30–4.86)	.006	2.01 (1.26–3.23)	.004	2.16 (1.43–3.26)	<.001
OSS4	3.18 (1.64–6.18)	.001	2.70 (1.67–4.35)	<.001	3.03 (1.99–4.59)	<.001
OSS5	6.51 (3.21–13.21)	<.001	4.75 (2.82–8.01)	<.001	6.57 (4.19–10.31)	<.001
Urgent/Emergent (Ref = elective)	4.08 (3.48–4.79)	<.001	3.79 (3.35–4.29)	<.001	3.22 (2.90–3.56)	<.001
CDIV	15.50 (13.49–17.81)	<.001	12.13 (10.74–13.69)	<.001	9.30 (8.31–10.41)	<.001
PASC	3.50 (2.82–4.35)	<.001	3.28 (2.71–3.96)	<.001	3.08 (2.58–3.67)	<.001
Males*PASC	0.75 (0.56–0.989)	.04	0.73 (0.57–0.93)	.01	0.71 (0.56–0.89)	.003
Model C-statistic	0.95		0.93		0.95	
Subgroup Analyses						
PASC subgroup (n=3,492)						
Male (Ref = Female)	0.76 (0.61–0.93)	.009	0.76 (0.62–0.92)	.006	0.74 (0.62–0.90)	.002
RAI (Ref = Normal 21–29)						
Robust (20)	0.31 (0.23–0.41)	<.001	0.30 (0.23–0.39)	<.001	0.30 (0.24–0.39)	<.001
Frail (30–39)	1.89 (1.47–2.44)	<.001	2.40 (1.89–3.05)	<.001	2.42 (1.92–3.05)	<.001
Very frail (40)	2.64 (1.80–3.88)	<.001	3.10 (2.14–4.50)	<.001	3.46 (2.39–4.99)	<.001
Expanded OSS (Ref = OSS1)						
OSS2	2.75 (0.83–9.12)	.10	2.27 (0.87–5.88)	.09	2.87 (1.11–7.39)	.03
OSS3	4.45 (1.37–14.47)	.01	3.43 (1.34–8.74)	.01	4.18 (1.65–10.63)	.003
OSS4	5.43 (1.66–17.72)	.005	4.78 (1.87–12.24)	.001	5.69 (2.23–14.50)	<.001
OSS5	3.56 (0.79–15.97)	.10	5.26 (1.55–17.79)	.008	6.19 (1.86–20.60)	.003
Urgent/Emergent (Ref = elective)	3.07 (1.88–5.01)	<.001	2.49 (1.67–3.71)	<.001	2.07 (1.45–2.95)	<.001
CDIV	4.73 (3.82–5.84)	<.001	4.66 (3.82–5.70)	<.001	4.37 (3.60–5.31)	<.001
Model C-Statistic	0.82		0.82		0.82	
No PASC subgroup (n=78,777)						
Male (Ref = Female)	0.82 (0.70–0.97)	.02	0.88 (0.78–1.01)	.06	0.91 (0.82–1.02)	.10

	30-day		90-day		180-day	
	Adjusted OR (95% CI)	**_P_ value**	**Adjusted OR (95% CI)**	**_P_ value**	**Adjusted OR (95% CI)**	**_P_ value**
RAI (Ref = Normal 21–29)						
Robust (20)	0.24 (0.19–0.30)	<.001	0.21 (0.17–0.25)	<.001	0.20 (0.17–0.23)	<.001
Frail (30–39)	2.61 (2.15–3.16)	<.001	3.08 (2.65–3.57)	<.001	3.37 (2.98–3.81)	<.001
Very frail (40)	6.56 (4.63–9.29)	<.001	7.38 (5.63–9.68)	<.001	7.56 (5.97–9.57)	<.001
Expanded OSS (Ref = OSS1)						
OSS2	1.38 (0.62–3.05)	.43	1.22 (0.71–2.11)	.48	1.40 (0.88–2.21)	.15
OSS3	1.88 (0.86–4.10)	.11	1.66 (0.97–2.84)	.06	1.80 (1.15–2.83)	.01
OSS4	2.26 (1.02–5.00)	.04	2.09 (1.21–3.62)	.008	2.47 (1.56–3.92)	<.001
OSS5	4.98 (2.18–11.36)	<.001	3.75 (2.09–6.75)	<.001	5.51 (3.38–9.00)	<.001
Urgent/Emergent (Ref = elective)	3.87 (3.25–4.59)	<.001	3.76 (3.29–4.29)	<.001	3.22 (2.89–3.59)	<.001
CDIV	29.54 (24.90–35.04)	<.001	18.73 (16.22–21.63)	<.001	12.64 (11.07–14.43)	<.001
Model C-Statistic	0.94		0.92		0.89	

Abbreviations: CDIV, Clavien-Dindo IV complications; OR, Odds Ratio; OSS, Operative Stress Score; PASC, Preoperative Acute Serious Conditions; RAI, Risk Analysis Index; Ref, reference.

Logistic regression analyses