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Impact of Chronic Immunosuppression on Emergency General Surgery Outcomes

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Introduction: While patients on immunosuppressive agents are at increased risk for complications after surgery, the impact of immunosuppressive medications on surgical outcomes in the emergency setting remains unclear. As the number of people on chronic immunosuppression rises, this cohort may disproportionately contribute to outcomes associated with emergency general surgery (EGS).

Study Design: We evaluated patients from a statewide EGS collaborative undergoing the following operations: cholecystectomy, appendectomy, operation for small bowel obstruction, or emergent exploratory laparotomy. The exposure was pre-existing chronic usage of corticosteroid or immunosuppressive agents. Risk-adjusted outcomes were evaluated using entropy balancing, a technique that reweights control covariates to ensure reproducible balance between the exposure and control populations without losing data. The primary outcome was mortality, and secondary outcomes included complications, readmission, and discharge disposition. We performed a sensitivity analysis with propensity score matching.

Results: We identified 30,073 adult patients, of whom 1,538 (5.1%) were on chronic immunosuppression. In the overall cohort, immunosuppression medication use was associated with higher rates of mortality (marginal effect 2.3, 95% CI 1.0 – 3.6, $p<0.001$), complications, infection, sepsis, and readmission. Sensitivity analysis yielded similar results. On subgroup analysis by operation, only emergent exploratory laparotomy had a higher rate of mortality associated with immunosuppression use. No association between immunosuppressive mediation use and mortality was found following appendectomy, cholecystectomy, or surgery for small bowel obstruction.

Conclusions: Patients on chronic immunosuppression medication constitute a substantial portion of the EGS population. Mortality rates are worse for larger operations such as exploratory laparotomy in this population. Less complicated operations such as cholecystectomy and appendectomy can be performed safely without increased risk of mortality in this population, despite a modest increase in non-fatal complications.

Keywords: emergency general surgery; immunosuppression; entropy balancing

BACKGROUND

Approximately 20 million people in the United States are currently on immunosuppressive medications, which has more than doubled since 2013.[1,2] It is known that the usage of immunosuppressive medications can negatively affect patients across a spectrum of disease processes resulting in worse outcomes such as higher mortality, poorer wound healing, and increased risk of infection.[3–5] These adverse outcomes could be heightened in the context of emergency general surgery (EGS), as unplanned surgery does not allow for temporary discontinuation or modification of medication regimens to mitigate peri-operative risk. Furthermore, immunosuppressive medications may be associated with atypical disease presentations that result in delays in diagnosis.[6] Hence, it is possible that EGS patients may be at the highest risk for immunosuppression-related harm in addition to the previously described higher level of risk associated with surgery performed in the emergency setting.[7]

However, the impact of immunosuppressive medications on EGS outcomes is not well characterized. The effect of concurrent corticosteroid use on operative outcomes has been investigated in many surgical subspecialties, mostly in the elective setting, and these results are varied, with some suggesting higher mortality and complications while others found no such association.[8–14] Beyond corticosteroids, the literature on other immunosuppressive medication use prior to surgery is also largely limited to elective procedures and the reported outcomes are similarly varied.[15–17] Studies that have included EGS operations in their analysis are either limited to single hospital or patient populations, include surgeries across multiple subspecialities or are only descriptive in nature without significant statistical analysis, making clinical association difficult.[18–21] Improving clinical decision-making and prognostication for EGS

patients requires novel evidence specific to the emergency setting on how these medications impact clinical outcomes.

In this context, we performed an observational study using data from the Michigan Acute Care Surgery (MACS) collaborative quality initiative (CQI). Patients were included from four common admission categories that encapsulate the severity of disease and treatment intensity faced in the emergency operative setting: acute appendicitis, acute gallbladder disease, small bowel obstruction, and patients undergoing emergent exploratory laparotomy. We utilized entropy balancing, a powerful reproducible reweighting technique to ensure equilibrium between the exposure and control populations with the goal of assessing the impact of chronic corticosteroid or other immunosuppression medication use on the outcomes of patients receiving emergency general surgery. We hypothesized that patients on chronic immunosuppressive agents would have higher rates of operative mortality.

METHODS

Data Collection

Data were obtained from the Michigan Acute Care Surgery (MACS) collaborative. The collaborative consists of 12 hospitals throughout the state of Michigan that provide emergency general surgery care using an acute care surgery model.[22] Participation in MACS is voluntary, and Blue Cross Blue Shield of Michigan/Blue Care Network supports administrative conduct of the program via an independent coordinating center and reimburses hospitals for 85% of their data abstraction costs. MACS provides risk-adjusted benchmark reporting to participants, organizes in-person collaborative meetings, and conducts quality improvement efforts using agreed upon clinical objectives. MACS collects data on four clinical domains within EGS: acute appendicitis, acute gallbladder disease, small bowel obstruction, and emergent exploratory

laparotomy. Data are collected on all patients meeting standardized inclusion and exclusion criteria and data is extracted using guidance from a published and annually updated data definitions manual.[23] The data set includes information on both operative and non-operative patients. Annual abstractor training and data validation visits are conducted to ensure accurate data entry.

Study Population

The analysis cohort included patients in the MACS database from April 1, 2020, to June 30, 2025. We included all patients receiving an operation within at least one of the four clinical domains: acute appendicitis, acute gallbladder disease, small bowel obstruction, and emergent exploratory laparotomy. Study cohorts were created from patients who were taking chronic immunosuppression medications and those who were not. MACS defines the exposure of a patient on "chronic immunosuppressive medications" as a patient who regularly received corticosteroids (oral or parenteral) for a chronic condition or immunosuppressive medications for one of the following: chemotherapy, autoimmune disease, non-autoimmune inflammatory disease, or to prevent organ transplant rejection within 30 days before surgery. Immune checkpoint inhibitors are not included in this definition and data on whether patients were taking these medications were not collected.[23] The MACS database does not differentiate between corticosteroids or other immunosuppressive medications when this data is abstracted and, therefore, are collected as a single datapoint. This does not allow for us to sub-categorize patients on corticosteroids versus other immunosuppressive medications. Patients using topical steroid medications were not included in the immunosuppression cohort. If patients received corticosteroid medication for 10 days or less in the 30 days prior to admission, they were not included in the exposure cohort. Interferons are not included as an immunosuppressive

medication in the MACS database. We did exclude patients who had a previous solid organ transplant, as prior studies have suggested that this patient population may have distinct processes of care and disease-specific confounding impacting clinical outcomes.[18]

Outcome Variables

The intent of our study was to characterize the differences in outcomes for EGS patients who were on chronic immunosuppressive medications versus those who were not. The primary outcome was 30-day mortality. Secondary clinical outcomes were any complication, any infectious complication, sepsis, surgical site infection, venous thromboembolism, readmission, unexpected emergency department visit after hospital discharge and hospital discharge disposition. These outcome variables are collected prospectively and stored in the MACS database. The variables have been validated and evaluated in prior studies that have utilized this database and the MACS data definitions for these outcomes remained consistent throughout the study period.

Statistical Analysis

We used logistic regression to identify associations between the use of chronic immunosuppressive medications and the clinical outcomes following emergency general surgery. To match treated observations as closely as possible to controls, we used an entropy balance analysis, an emerging approach in the health services research literature.[24,25] Entropy balance reweights the control group such that the weighted means and variances of the control group exactly match those of the treatment group (see Table 1).[26,27] This mimics the desirable property of balance between treatment and control observations found in a perfect randomized controlled trial. Furthermore, the entropy balance weights are as close to equal as possible. In our study, the covariates used for entropy balancing and covariate adjustment included all variables listed in

Table 1, as well as insurance type. After calculating the entropy weights, these were applied to our control cohort and, to assess our outcomes of interest, we ran logistic regression models for mortality (primary outcome), any complication, any infectious complication, sepsis, surgical site infection, venous thromboembolism (VTE), readmission, unexpected emergency department visit after discharge, and discharge disposition.

The outcomes were analyzed using four separate models: 1) unadjusted logistic regression estimating crude associations between immunosuppression medication use and the outcome of interest, 2) an adjusted model using all baseline covariates, 3) an entropy-balanced model that applied entropy weights to adjust for confounding, and 4) an entropy-balanced model combining the entropy weights with covariate adjustment. We utilized the entropy-balanced model combining the entropy weights with covariate adjustment to report the effect of immunosuppression medication use on outcomes as adjusted odds ratios (aOR) and absolute risk difference was estimated using marginal effects.[28–30] Clustering at the hospital level was accounted for.

To account for the known increase in mortality associated with anastomotic leak after surgery, we completed a secondary analysis of the exploratory laparotomy group.[31] We calculated a separate set of entropy weights for just the exploratory laparotomy group using the same covariates as were used for the entire population. We used logistic regression to analyze 1) the effect of chronic immunosuppression use on mortality for patients who did and did not undergo bowel resection with anastomosis and 2) the effect of anastomotic leak on morality, independent of chronic immunosuppression use.

We performed a sensitivity analysis using propensity score matching to compare the results and validate our findings from entropy balancing. We have described the specifics of the propensity score matching method utilized in previously published work.[32] Briefly, we used the same covariates as we used for entropy balancing and matching was conducted using a nearest-neighbor approach without replacement. Patients who fell outside the common support region were excluded.

All statistical tests were two-sided, with a significance level set at a *p*-value less than 0.05. All analyses were performed using Stata (Version 18.0, StataCorp). Institutional Review Board approval was obtained, and the study was deemed exempt as it relied on secondary use of previously collected data for quality improvement efforts. This study was designed and is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[33]

RESULTS

We identified 30,073 adult patients in the MACS database between April 1, 2020, to June 30, 2025, who met inclusion criteria for our study (Figure 1). 1,538 (5.1%) were on chronic immunosuppression medications. Prior to applying any weighting, the baseline characteristics of the chronic immunosuppression cohort differed significantly from the control group (Table 1). After entropy balancing, all the baseline patient characteristics were identical between the two groups. With propensity score matching, 1,533 matches were found between the exposure and control group, thus dropping 27,018 observations. After propensity score matching, the patient characteristics of the two cohorts were statistically equivalent. The results of the propensity matched population can be found in Supplemental Table 1, http://links.lww.com/JACS/A633.

Adjusted outcomes using entropy balancing

Using entropy balancing we found that chronic immunosuppression medication use was associated with a higher rate of mortality (Table 2). When examining secondary outcomes, the rates of any complication, any infection, and sepsis were also significantly higher in the immunosuppression medication use cohort (Table 2). When stratifying based on type of operation, the impact of immunosuppression on outcomes were most pronounced in the exploratory laparotomy group. These patients had a higher mortality rate as well as higher rates of any complication, any infection, and sepsis. However, patients undergoing appendectomy, cholecystectomy, and surgery for small bowel obstruction did not have a statistically significant higher rate of mortality. These findings are summarized in Table 3.

Upon analysis of the sub-group who received an exploratory laparotomy and underwent bowel resection with anastomosis, chronic immunosuppressive use was not associated with increased rates of mortality. Independent of chronic immunosuppressive use, the development of an anastomotic leak was associated with a higher rate of mortality. When analyzing the patients who did not receive a bowel resection with anastomosis, chronic immunosuppressive use was associated with a higher mortality rate. These results are included in Table 4 and 5.

Adjusted outcomes using propensity score matching

In our sensitivity analysis, using propensity score matching to compare chronic immunosuppression medication use to the control group, we found similar results as we did when using entropy balancing. Specifically, patients on chronic immunosuppression were found to have higher rates of mortality, any complication, and sepsis. Chronic immunosuppression use was not associated with higher rates of any infection. In this analysis, readmission was also

higher in the chronic immunosuppression use cohort. (Supplemental Table 2, http://links.lww.com/JACS/A633).

DISCUSSION

This observational study using data from a multicenter state collaborative has two principal findings. First, we demonstrate that chronic immunosuppressive medication use is associated with significantly worse outcomes across a variety of EGS operations. Second, while this association is strongest in severe disease processes requiring an exploratory laparotomy, less critical operations such as appendectomy and cholecystectomy can be performed safely with only a modest increase in aggregate complications. These findings add specificity to the prior body of work investigating the effects of chronic immunosuppression medication use primarily in the elective operative setting. To our knowledge this is the largest study evaluating the effects of chronic immunosuppression medication use on surgical outcomes consisting entirely of patients undergoing EGS operations. Overall, our findings have important implications for clinical decision-making and prognostication for patients in the EGS setting who are on chronic immunosuppression.

Examination of the effect of chronic immunosuppression on the outcomes of surgical patients has been previously evaluated but has often not been specific to EGS patients. For example, a recent study of more than 70,000 patients taking corticosteroids demonstrated higher rates of mortality and complications in patients on higher doses of corticosteroids. This study lacked a rigorous statistical analysis, reporting only univariate, unadjusted results; but, more importantly, the study included patients across a wide range of surgical specialties with most of the operations being performed on an elective basis.[20] Another group, using the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database,

identified over 180,000 patients on corticosteroids prior to surgery and compared their outcomes to a control group using double-adjustment propensity matching and double-adjusted logistic regression. While the statistical analysis method was strong and they reported statistically significant worse outcomes in patients on corticosteroids, their exposure cohort was not stratified based on type of operation or acuity of the surgical problem.[21] There are several other examples of studies that performed similarly rigorous analysis that either evaluated the effect of immunosuppressive medications on a single elective operation, did not stratify based on surgical acuity, or excluded emergency surgery altogether.[13,15,19,34,35]

Our results demonstrate that while chronic immunosuppression use is associated with universally worse complication rates, the severity of these adverse outcomes is generally low with lower risk operations such as appendectomy, cholecystectomy and surgery for small bowel obstruction. Our data should be used to aid in clinical decision making when faced with the decision of whether to operate on an immunocompromised patient presenting with appendicitis, cholecystitis or small bowel obstruction and to quantify the operative risk. Specifically, despite the increased rates of any complications in these cohorts, there was no significantly increased risk of mortality. As such, postponing surgery to allow for medication cessation or taper may be suboptimal to proceeding directly with surgery in most of these patients. However, in the highest risk patients when non-fatal complications may result in significant morbidity, efforts at non-operative management may be appropriate. When there is relative equipoise in a non-operative approach versus proceeding with operative intervention, it is likely appropriate to proceed with surgery in the case of appendicitis, cholecystitis or small bowel obstruction.

Second, regarding timing of elective surgery, our results can be used to recommend earlier intervention for symptomatic benign biliary disease in patients taking chronic immunosuppressive medications. Previous work has shown that emergency laparoscopic cholecystectomy has higher morbidity and mortality compared to elective cholecystectomy.[36] Given these data in conjunction with our findings of higher complication, sepsis and readmission rates for patients on chronic immunosuppressive medications undergoing acute cholecystectomy, these patients should be considered for early elective cholecystectomy when presenting in the outpatient setting for biliary colic. A similar endorsement was made by Klarenbeek et. al. in regards to diverticular disease where they found that patients on chronic immunosuppressive medications had higher rates of perforation in recurrent episodes of diverticulitis and, therefore, this should be considered when deciding when to offer elective colon resection.[37] Our data strengthens this argument given the worsened outcomes we describe in the exploratory laparotomy cohort.

Third, with the increasing number of immunotherapies available for use in cancer treatment, we can expect the number of patients on chronic immunosuppression to rise.[38] It will be important to characterize exactly how these medications affect the outcomes for patients facing unrelated disease processes. This will allow for more thorough counseling when starting a medication as well as better decision making when these patients present to the emergency department with urgent EGS issues. Future studies should be performed to characterize the outcome profiles for individual immunosuppressive medications.

To decipher what contributed most to the higher mortality rate found in the exploratory laparotomy group, we performed a sub-group analysis. In patients who underwent bowel resection and anastomosis, chronic immunosuppressive use was not associated with higher mortality. However, the complication of anastomotic leak was associated with significantly higher rates of mortality overall, independent of chronic immunosuppression use. In patients that did not undergo bowel resection and anastomosis, chronic use of immunosuppressive medications was found to be associated with higher rates of mortality. This subgroup analysis of patients who did not receive bowel resection with anastomosis demonstrates that the use of chronic immunosuppressive medications is likely contributing to mortality outside of the well documented risk of mortality associated with anastomotic leak.

Another area of research that is needed is to determine if there are practice pattern variations for patients on chronic immunosuppressive medications who are seen in the outpatient setting that results in higher rates of EGS operations. It would be useful to determine whether these patients are offered elective surgery for diseases such as biliary colic, hernia repair or diverticulitis at a rate different from the general population.

In this study, we demonstrate that entropy balance is a powerful statistical approach for health services research. Entropy balance has three main advantages over traditional patient matching approaches.[26] First, it perfectly balances the means and variances of the control group to the treated group while keeping the weights as close to equal as possible. Other matching methods come close but are not exact. This can be seen by comparing the standard difference achieved in Table 1 using entropy balance to the standard difference achieved using propensity score match in Supplemental Table 1, http://links.lww.com/JACS/A633. The standard difference using entropy balance are all zero, by definition, while the standard differences with propensity

match are near, but rarely exactly, zero. Second, other matching methods drop observations because they estimate weights first before performing multiple rounds of regression to find the weights that produce the closest match. Entropy balance does not drop observations. In our data set, no observations were dropped with entropy balance while 27,018 observations were dropped using nearest-neighbor propensity score match. Third, the entropy weights are inherently reproducible, unlike in traditional matching methods that rely on a series of opaque decisions. Any investigator with access to our data trying to reproduce our results with entropy balance would be able to calculate the same weights from the information included in this manuscript, while that is not guaranteed with other matching methods.

LIMITATIONS

Our study has several limitations. First, our data were collected from a single statewide collaborative which may make our results less generalizable to the entire United States population. Specifically, our population was mostly white (82%) and non-Hispanic (93%), which does not reflect the population demographics of the United States as a whole.[39] However, given that our database is made up of patients from 12 different hospitals in varied geographic settings across the state of Michigan, this data does encompass a fairly sociodemographically diverse population. Second, our dataset does not differentiate between the types of- or indications for- chronic immunosuppressive medications that patients are taking at the time of surgery. This does not allow us to analyze the associations with outcomes for corticosteroids alone versus other immunosuppressive medications. This is a major limitation in our dataset, and we may consider alterations to our data collection for future work. To control for different indications for chronic immunosuppressive use, we included a wide variety of comorbidities, including cancer, to weight or match our cohorts. Finally, this is an observational study which is potentially subject to

unmeasured confounding effecting our data. Our use of entropy balancing to account for various baseline characteristics is a powerful method to mitigate a majority but not all this risk. We also used propensity scoring as a second method of analysis to validate our results.

CONCLUSIONS

Patients on chronic immunosuppression medications presenting for EGS operations have worse outcomes then their non-immunosuppressed counterparts. This effect was most pronounced in the exploratory laparotomy cohort. Despite patients on chronic immunosuppression having increased complication rates after appendectomy, cholecystectomy and surgery for small bowel obstruction, mortality was rare and not associated with chronic immunosuppressive medication use. These results can be used to aid in clinical decision making in the emergency general surgery population.

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Figure Legend

Figure 1. Flowchart with inclusion and exclusion criteria for cohort creation of emergency general surgery patients with or without chronic immunosuppression medication use. MACS, Michigan Acute Care Surgery.

Precis

Patients on chronic immunosuppression presenting for emergency general surgery operation have overall higher mortality and higher rate of complication. Despite higher rate of non-fatal complication, patients undergoing appendectomy and cholecystectomy do not have a higher rate of mortality.

Table 1. Patient Characteristics With and Without Entropy Balancing

Variable	Before entropy balancing			After entropy balancing		
	Chronic immunosuppression	**No immunosuppression**	**SD**	**Chronic immunosuppression**	**No immunosuppression**	**SD**
Total, n (%)	1,538 (5.1)	28,535 (94.9)	-	1,538 (5.1)	28,535 (94.9)	-
Age, y, mean	59.8	52	-0.43	-	-	-
18-45 y, n (%)	307 (20.0)	11,039 (38.7)	0.42	307 (20.0)	20.0	0.00
45-55 y, n (%)	222 (14.4)	3,963 (13.9)	-0.02	222 (14.4)	14.4	0.00
55-65 y, n (%)	306 (19.9)	4,749 (16.6)	-0.08	306 (19.9)	19.9	0.00
>65 y, n (%)	703 (45.7)	8,784 (30.8)	-0.31	703 (45.7)	45.7	0.00
Sex, m, n (%)	622 (40.4)	12,017 (42.1)	0.03	622 (40.4)	40.4	0.00
Race, n (%)						
White	1,330 (86.5)	23,353 (81.8)	-0.13	1,330 (86.5)	96.5	0.00
Black	140 (9.1)	2,766 (9.7)	0.02	140 (9.1)	9.7	0.00
Other	68 (4.4)	2,416 (8.5)	0.17	68 (4.4)	4.4	0.00
Insurance, n (%)						
Commercial	567 (36.9)	13,429 (47.1)	0.21	567 (36.9)	36.9	0.00
Medicaid	158 (10.3)	4,761 (16.7)	0.19	158 (10.3)	10.3	0.00
Medicare	658 (42.8)	8,040 (28.2)	-0.31	658 (42.8)	42.8	0.00

Uninsured/self-pay	12 (0.8)	796 (2.8)	0.15	12 (0.8)	0.8	0.00
Other	143 (9.3)	1,509 (5.3)	-0.15	143 (9.3)	9.3	0.00
Procedure type, n (%)						
Appendectomy	164 (10.7)	7,734 (27.1)	0.43	164 (10.7)	10.7	0.00
Cholecystectomy	390 (25.4)	12,540 (43.9)	0.40	390 (25.4)	25.4	0.00
Small bowel obstruction	375 (24.4)	3,290 (11.5)	-0.34	375 (24.4)	24.4	0.00
Exploratory laparotomy	609 (39.6)	4,971 (17.4)	-0.34	609 (39.6)	39.6	0.00
Surgical approach						
Laparoscopic or robotic	625 (40.6)	20,598 (72.2)	0.67	625 (40.6)	40.6	0.00
Open or converted to open	665 (43.2)	6,170 (21.6)	-0.47	665 (43.2)	43.2	0.00
Missing	248 (16.1)	1,767 (6.2)	-0.32	248 (16.1)	16.1	0.00
No. of comorbidities, n (%)						
0	215 (14.0)	9,977 (35.0)	0.50	215 (14.0)	14.0	0.00
1	376 (24.4)	7,746 (27.1)	0.06	376 (24.4)	24.4	0.00
2	363 (23.6)	5,300 (18.6)	-0.12	363 (23.6)	23.6	0.00
3+	584 (38.0)	5,512 (19.3)	-0.42	584 (38.0)	38.0	0.00
Comorbidity, n (%)						
Congestive heart failure within 30 d	29 (1.9)	275 (1.0)	-0.08	29 (1.9)	1.9	0.00

Dialysis within 2 wk	37 (2.4)	245 (0.9)	-0.12	37 (2.4)	2.4	0.00
Ventilator dependent within 48 h	43 (2.8)	409 (1.4)	-0.09	43 (2.8)	2.8	0.00
COPD (severe)	159 (10.3)	1,135 (4.0)	-0.25	159 (10.3)	10.3	0.00
Tobacco within 1 y – cigarette	225 (14.6)	4,342 (15.2)	0.02	225 (14.6)	14.6	0.00
Diabetes mellitus						
Insulin	92 (6.0)	1,399 (4.9)	-0.05	92 (6.0)	6.0	0.00
Non-insulin	125 (8.1)	2,319 (8.1)	0.00	125 (8.1)	8.1	0.00
Hypertension	706 (45.9)	10,128 (35.5)	-0.21	706 (45.9)	45.9	0.00
Functional health status (dependent)	88 (5.7)	990 (3.5)	-0.11	88 (5.7)	5.7	0.00
Personal history of DVT/PE	276 (17.9)	1,764 (6.2)	-0.37	276 (17.9)	17.9	0.00
Any cancer	461 (30.0)	1,203 (4.2)	-0.73	461 (30.0)	30	0.00

DVT, deep venous thromboembolism; PE, pulmonary embolism

Table 2: Entropy Balanced Clinical Outcomes by use of Chronic Corticosteroid or Immunosuppressive Medication

Clinical outcomes	Chronic immunosuppression, n (%)		Adjusted odds ratio (95% CI)	Marginal effect (95% CI)
	No	Yes		
Total patients	28,535 (100)	1,538 (100)	--	--
Mortality	708 (2.5)	144 (9.4)	1.5 (1.3 - 1.9) *	2.3 (1.0 - 3.6) *
Any complication	7,392 (25.9)	720 (46.8)	1.4 (1.3 - 1.5) *	7.3 (5.2 - 9.4) *
Any infection	2,043 (7.2)	261 (17)	1.4 (1.2 - 1.6) *	3.3 (1.3 - 5.2) *
Sepsis	1,517 (5.3)	227 (14.8)	1.4 (1.2 - 1.6) *	3.0 (0.6 - 5.3)†
Any SSI	1,820 (6.4)	209 (13.6)	1.1 (0.8 - 1.4)	0.6 (-3.2 - 4.5)
VTE	435 (1.5)	72 (4.7)	1.3 (1.0 - 1.7)	0.8 (0.0 – 1.7)
Readmission	5,668 (19.9)	603 (39.2)	1.4 (1.1 - 1.8)‡	5.5 (-1.6 - 12.6)
Post-discharge ED visit	3,522 (12.3)	285 (18.5)	1.1 (0.9 - 1.4)	2.0 (-1.8 - 5.9)
Discharge to care facility	1,756 (6.2)	187 (12.2)	1.0 (0.9 - 1.2)	-0.3 (-2.5 - 2.0)

ED, emergency department; SSI, surgical site infection; VTE, venous thromboembolism

*p<0.001

†p<0.05

‡p<0.01

Table 3: Procedure Specific Marginal Effects of Chronic Corticosteroid or Immunosuppressive Medication use on Operative Outcomes

Clinical outcomes	Chronic immunosuppression, n (%)		Adjusted odds ratio (95% CI)	Marginal effect (95% CI)
	No	Yes		
Appendectomy				
Total patients	7,734 (100)	164 (100)	--	--
Mortality	9 (0.1)	3 (1.8)	12.7 (0.9 - 183.9)	2.2 (-1.5 - 6.0)
Any complication	1,151 (14.9)	44 (26.8)	1.6 (1.0 - 2.4)*	8.9 (1.4 - 16.4)*
Any infection	274 (3.5)	11 (6.7)	1.3 (0.8 - 2.1)	2.1 (-0.1 - 4.4)
Sepsis	114 (1.5)	4 (2.4)	0.8 (0.4 - 1.5)	0.4 (-1.7 - 2.5)
Any SSI	221 (2.9)	7 (4.3)	1.0 (0.6 - 1.9)	0.6 (-1.6 - 2.9)
VTE	17 (0.2)	3 (1.8)	20.7 (0.9 - 465.9)	1.9 (-1.8 - 5.7)
Readmission	822 (10.6)	26 (15.9)	1.1 (0.8 - 1.5)	2.7 (-0.8 - 6.2)
Post-discharge ED visit	761 (9.8)	23 (14.0)	1.3 (0.7 - 2.5)	3.4 (-3.0 - 9.7)
Discharge to care facility	56 (0.7)	6 (3.7)	0.4 (0.2 - 0.8)†	2.4 (-1.2 - 5.9)
Cholecystectomy				
Total patients	12,54 (100)	390 (100)	--	--
Mortality	40 (0.3)	4 (1.0)	0.9 (0.4 - 2.1)	0.3 (-0.7 - 1.2)
Any complication	2,558 (20.4)	124 (31.8)	1.4 (1.1 - 1.8)†	8.4 (1.5 - 15.3)*
Any infection	339 (2.7)	21 (5.4)	1.0 (0.6 - 1.8)	1.5 (-0.2 - 3.2)
Sepsis	195 (1.6)	15 (3.8)	1.4 (0.9 - 2.1)	1.8 (0.6 - 3.0) †
Any SSI	199 (1.6)	7 (1.8)	0.7 (0.3 - 1.8)	-0.1 (-1.6 - 1.3)
VTE	57 (0.5)	5 (1.3)	1.8 (0.9 - 3.8)	0.6 (-0.4 - 1.6)
Readmission	1,316 (10.5)	75 (19.2)	1.7 (1.3 - 2.2)‡	7.2 (3.1 - 11.3)‡
Post-discharge ED visit	1,154 (9.2)	48 (12.3)	1.4 (1.1 - 1.8)*	2.8 (-0.5 - 6.1)
Discharge to care facility	380 (3)	20 (5.1)	1.2 (0.8 - 1.6)	1.0 (-1.0 - 3.1)

Operation for small bowel obstruction				
Total patients	3,290 (100)	375 (100)	--	--
Mortality	110 (3.3)	20 (5.3)	1.1 (0.6 - 1.9)	-0.1 (-2.9 - 2.6)
Any complication	1,163 (35.3)	166 (44.3)	1.2 (1.0 - 1.5)*	4.5 (1.0 - 8.0)*
Any infection	337 (10.2)	51 (13.6)	1.4 (1.0 - 2.0)*	2.1 (-0.5 - 4.7)
Sepsis	346 (10.5)	50 (13.3)	1.1 (0.6 - 2.1)	0.4 (-7.4 - 8.3)
Any SSI	375 (11.4)	66 (17.6)	1.3 (0.8 - 1.9)	3.0 (-3.0 - 9.0)
VTE	128 (3.9)	19 (5.1)	0.9 (0.7 - 1.1)	-0.3 (-3.1 - 2.5)
Readmission	1,647 (50.1)	243 (64.8)	1.2 (0.7 - 2.0)	8.4 (-4.4 - 21.3)
Post-discharge ED visit	651 (19.8)	95 (25.3)	1.1 (0.6 - 1.9)	3.9 (-7.4 - 15.1)
Discharge to care facility	311 (9.5)	31 (8.3)	1.0 (0.6 - 1.5)	-2.0 (-5.3 - 1.3)
Emergent exploratory laparotomy				
Total patients	4,971 (100)	609 (100)	--	--
Mortality	549 (11)	117 (19.2)	1.6 (1.3 - 2.1) ‡	5.2 (2.5 - 7.9) ‡
Any complication	2,520 (50.7)	386 (63.4)	1.5 (1.2 - 1.8) ‡	7.9 (3.8 - 12.0) ‡
Any infection	1,093 (22)	178 (29.2)	1.4 (1.2 - 1.7) ‡	5.4 (2.2 - 8.5) ‡
Sepsis	862 (17.3)	158 (25.9)	1.5 (1.4 - 1.7) ‡	6.0 (3.8 - 8.1) ‡
Any SSI	1,025 (20.6)	129 (21.2)	1.0 (0.8 - 1.3)	-0.3 (-5.9 - 5.3)
VTE	233 (4.7)	45 (7.4)	1.4 (1.0 - 2.0)	1.5 (-0.2 - 3.3)
Readmission	1,883 (37.9)	259 (42.5)	1.3 (1.0 - 1.7)	3.5 (-4.7 - 11.6)
Post-discharge ED visit	956 (19.2)	119 (19.5)	1.0 (0.7 - 1.3)	0.1 (-5.4 - 5.5)
Discharge to care facility	1,009 (20.3)	130 (21.3)	1.0 (0.8 - 1.2)	-0.7 (-5.1 - 3.8)

*$p<0.05$

†$p<0.01$

‡$p<0.001$

ED, emergency department; SSI, surgical site infection; VTE, venous thromboembolism

Table 4: Marginal Effects of Chronic Corticosteroid or Immunosuppressive Medication Use on Operative Outcomes in Emergent Exploratory Laparotomy with and without Bowel Resection and Anastomosis: Effect of Chronic Immunosuppression Medication use on Mortality

Clinical outcomes	**Chronic immunosuppression, n (%)**		**Adjusted odds ratio (95% CI)**	**Marginal effect (95% CI)**
	No	**Yes**		
Patient with bowel anastomosis performed				
Total patients	1,543 (100)	132 (100)	--	--
Mortality	112 (7.3)	18 (13.6)	1.8 (1.0 - 3.1) *	3.4 (-3.0 - 9.8)
Patient without bowel anastomosis				
Total patients	2,721 (100)	385 (100)	--	--
Mortality	420 (15.4)	93 (24.2)	1.4 (1.0 - 1.8) *	4.9 (1.8 - 8.0)†

*$p<0.05$

†$p<0.01$

Table 5. Marginal Effects of Chronic Corticosteroid or Immunosuppressive Medication Use on Operative Outcomes in Emergent Exploratory Laparotomy with and without Bowel Resection and Anastomosis: Effect of Anastomotic Leak on Mortality, Independent of Chronic Immunosuppressive use

Clinical outcomes	**Anastomotic leak, n (%)**		**Adjusted odds ratio (95% CI)**	**Marginal effect (95% CI)**
	No	**Yes**		
Total patients	1,599 (100)	76 (100)	--	--
Mortality	104 (6.5)	26 (34.2)	11.2 (5.9 - 21.1) *	21.2 (15.2 - 27.3) *

*p<0.001

Figure_