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Hospital and surgeon variation in positive circumferential resection margin among rectal cancer patients

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ABSTRACT

Background: The objective of this study was to evaluate variation in positive CRM at the surgeon and hospital levels and assess impact on disease-specific survival.
Methods: Patients with stage I-III rectal cancer were identified in New York State. Bayesian hierarchical regressions estimated observed-to-expected (O/E) ratios for each surgeon/hospital. Competing-risks analyses estimated disease-specific survival among patients who were treated by surgeons/hospitals with O/E > 1 compared to those with O/E ratio ≤ 1.
Results: Among 1,251 patients, 208 (17%) had a positive CRM. Of the 345 surgeons and 118 hospitals in the study, 99 (29%) and 48 (40%) treated a higher number of patients with CRM than expected, respectively. Patients treated by surgeons with O/E > 1 (HR = 1.38, 95% CI = 1.16, 1.67) and those treated at hospitals with O/E > 1 (HR = 1.44, 95% CI = 1.11, 1.85) had worse disease-specific survival.
Discussion: Surgeon and hospital performance in positive CRM is associated with worse prognosis suggesting opportunities to enhance referral patterns and standardize care.

Introduction

Rectal cancer has a high mortality rate in the United States; thus, improving quality of care remains an important nationwide priority.[1] Several studies have reported unnecessary disparity in the treatment and management of rectal cancer suggesting the need to standardize the delivery of care.[2–11] One important performance measure in rectal cancer management is circumferential resection margin (CRM) positivity, which has been shown to be associated with local recurrence and worse long-term survival.[12] Recently, the National Accreditation Program for Rectal Cancer (NAPRC) was developed to optimize rectal cancer management and has stressed the importance of the status of the circumferential resection margin in achieving optimal outcomes.[13–15]

Given that the evolving healthcare system is shifting towards value-based payment models that prioritize the delivery of high-quality care, it is going to be increasingly important to measure performance metrics that adequately profile and identify opportunities for improvement. Such endeavors can allow individual providers to compare themselves to a relevant benchmark, identify addressable gaps in training, and help patients make informed decisions about who and where they receive healthcare.[16] Multidisciplinary care is needed in rectal cancer from pre-operative through post-operative care to assess the risk of a positive CRM, provide appropriate neoadjuvant treatment, expertly resect and ultimately assess the margin; as such, CRM can serve as a quality metric of multidisciplinary care management.

Recent population-based studies have reported patient, tumor, and treatment related characteristics associated with positive CRM.[17–19] For example, one study using the National Cancer Data Base reported clinical T and N stage, histologic type, tumor size, tumor grade, lymphovascular invasion, perineural invasion, and type of operation were significantly associated with positive CRM. While other studies have investigated surgeon and hospital factors associated with positive CRM,[20–22] no study has simultaneously evaluated variation in positive CRM across individual surgeons and hospitals. Understanding how much of the variation is explained by differences between surgeons as opposed to differences between

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hospitals has implications for implementing quality improvement programs.

The purpose of this study was to estimate observed-to-expected (O/E) ratios of positive CRM as a risk-adjusted measure of surgeon and hospital quality in rectal cancer and to evaluate the impact of this variation on disease-specific survival. We hypothesized that there would be large differences in O/E ratios between surgeons and hospitals and that performance in positive CRM would be associated with worse disease-specific survival.

Methods

Study population and data source

The study design was a retrospective cohort study of stage I-III rectal cancer cases reported to the New York State Cancer Registry (NYSCR). The NYSCR is a cancer surveillance database that collects patient, tumor, and treatment data on all cancer cases in New York State (NYS). These data were merged with the Statewide Planning and Research Cooperative System (SPARCS) at the NYS Department of Health as has been done before.[23–27] SPARCS is an all payer claims database that collects patient, treatment, and provider data for every hospital discharge, ambulatory surgery, and emergency department admission in NYS. Institutional Review Board approval was obtained from both the NYS Department of Health (DPRB #1412-05) and the University of Rochester Medical Center (IRB #00054886).

The NYSCR was queried to identify stage I-III rectal cancer patients diagnosed between 2010 and 2014 by International Classification of Diseases for Oncology codes. The study cohort was then restricted to those with adenocarcinoma and those who had a documented surgical resection within six months of diagnosis identified by International Classification of Diseases, 9th Edition procedure codes. Patients with missing data were excluded.

Positive CRM and disease specific survival

CRM was reported by the NYSCR as a continuous variable by every 0.1 mm to the margin. A positive CRM was defined as ≤1 mm as has been done before.[17] Disease-specific survival was the primary outcome for the study and was defined as cause of death indicating rectal or metastatic cancer death. Time to death was calculated from date of surgery to date of death from NYS Vital Records.

Patient, surgeon, and hospital predictors

Independent predictors used for risk-adjustment included the following patient and tumor characteristics: patient's age (>65), gender, race/ethnicity (White, Black, Other), Medicaid insurance, scheduled admission, comorbidity score, receipt of neoadjuvant chemoradiation, type of operation (lower anterior resection (LAR), abdominal perineal resection (APR), and other), minimally invasive approach, and American Joint Committee on Cancer (AJCC) stage (I-III). Surgeon characteristics included board certification in colorectal surgery, tertiles of surgeon volume (1,2-5,6+), and years of experience (0-10,11-20, 21+). Hospital-level covariates included academic hospital status, rural hospital status, and tertiles of hospital volume (1-5, 6-14, 15+).

Observed-to expected ratios of positive CRM

Distributions of independent variables for patients who had a positive CRM (≤1 mm) and a negative CRM were compared. To account for patients nested within surgeons nested within hospitals, the unique surgeon and hospital identifiers were used as clustering variables in 3-level Bayesian hierarchical regression models for all steps. Given that a modest proportion of surgeons operated on a small number of patients within the study period, Bayesian semi-informative priors were used to facilitate partial pooling of information across clusters to reliably estimate the random effects even for low volume surgeons.

A Bayesian 3-level logistic regression model that included all patient, surgeon, and hospital-level covariates was used to identify variables that were correlated with positive CRM. Patient-level predictors that were statistically significantly associated with positive CRM were included in the final risk-adjusted logistic regression model that estimated the probability of having a positive CRM for each patient. The expected number of patients with a positive CRM for each surgeon and hospital was calculated by summing the risk-adjusted probabilities of positive CRM for all patients that were treated by/at each surgeon and hospital. The observed number of patients with a positive CRM for each surgeon and hospital was the total number of patients who had a positive CRM for each surgeon and hospital. The number of observed was divided by the number of expected (O/E) to calculate a surgeon and hospital-specific ratio. A ratio >1 indicated that the surgeon/hospital had a higher number of positive CRM cases than expected and a ratio <1 indicated that the surgeon/hospital had a lower number of positive CRM cases than expected.

Survival analysis

Kaplan–Meier curves were used to compare disease specific survival distributions across patients treated by surgeons/hospitals who had a higher number of positive CRM cases than expected compared to those that did not have a higher number. The log-rank test was used determine whether disease-specific survival rates varied between groups. Subsequently, separate hierarchical multivariable competing-risks models that accounted for clustering of patients within surgeons and hospitals were used to estimate the association between positive CRM performance (O/E > 1) and disease-specific survival.

Results

A total of 1,251 rectal cancer patients treated at 118 hospitals by 345 surgeons met inclusion criteria. Among these, 208 patients (17%) had a positive CRM. The positive CRM rate ranged from 0 to 100% for both surgeons and hospitals. The median age in the sample was 62 years; approximately 42% were female, 8% had Medicaid insurance, and 49% underwent LAR. The proportion of patients with a positive CRM increased every year between 2010 and 2013 and then decreased from 21% to 16% in 2014. Patient characteristics stratified by whether patients had a positive CRM can be seen in Table 1.

Independent predictors of positive CRM and O/E ratios

Multivariable analysis evaluated independent patient, surgeon, and hospital-level correlates of positive CRM (Table 2). Receipt of neoadjuvant chemoradiation, scheduled admission, and board-certification in colorectal surgery were associated with decreased odds of having a positive CRM. Increasing stage, APR and other operation types relative to LAR, and being diagnosed in more recent years was associated with having a positive CRM. Interestingly, neither surgeon nor hospital volume was associated with positive CRM. After adjustment for all patient, surgeon, and hospital factors, 52% and 59% of the surgeon and hospital-level variation remained unexplained.

Table 1
Bivariate analyses.

	Positive CRM	Negative CRM	p-value
	N = 208 (17%)	N = 1043 (84%)	
Age > 65	100 (48.1)	449 (43.0)	0.208
Male	131 (63.0)	591 (56.7)	0.108
Diagnosis Year			0.024
2010	26 (12.5)	202 (19.4)	
2011	28 (13.5)	174 (16.7)	
2012	45 (21.6)	184 (17.6)	
2013	64 (30.8)	243 (23.3)	
2014	45 (21.6)	240 (23.0)	
Medicaid	21 (10.1)	78 (7.5)	0.256
AJCC Stage			0.001
1	32 (15.4)	288 (27.6)	
2	71 (34.1)	282 (27.0)	
3	105 (50.5)	473 (45.3)	
Race			0.415
White	154 (74.0)	735 (70.5)	
African-American	13 (6.2)	92 (8.8)	
Other	41 (19.7)	216 (20.7)	
Scheduled Admission	178 (85.6)	917 (87.9)	0.413
ECS Comorbidity Category			0.096
1	115 (55.3)	659 (63.2)	
2	58 (27.9)	246 (23.6)	
3	35 (16.8)	138 (13.2)	
Neoadjuvant Chemoradiation	103 (49.5)	543 (52.1)	0.553
Type of Operation			<0.001
LAR	77 (37.0)	536 (51.4)	
APR	96 (46.2)	334 (32.0)	
Other	35 (16.8)	173 (16.6)	
Minimally Invasive Approach	86 (41.3)	439 (42.1)	0.903
Surgeon Volume Tertile			0.621
1	52 (25.0)	281 (26.9)	
2–5	101 (48.6)	468 (44.9)	
6+	55 (26.4)	294 (28.2)	
Years in Practice			0.213
0–10	65 (31.2)	372 (35.7)	
11–20	66 (31.7)	348 (33.4)	
21+	77 (37.0)	323 (31.0)	
Board Colorectal Surgery	101 (48.6)	685 (65.7)	0.020
Hospital Volume Tertile			0.815
1–5	69 (33.2)	370 (35.5)	
6–14	67 (32.2)	327 (31.4)	
15+	72 (34.6)	346 (33.2)	
Academic Hospital	115 (55.3)	566 (54.3)	0.846
Rural Hospital	9 (4.3)	27 (2.6)	0.253

Hospital and surgeon specific O/E ratios using case-mix risk adjustment varied widely. Caterpillar plots were generated to further visualize the distributions (Fig. 1). Approximately 45% of the hospitals did not have any patients with a positive CRM and 65% of surgeons did not have any patients with a positive CRM. Surgeons and hospitals with higher than expected cases of positive CRM (O/E ratio > 1) treated 521 and 624 patients, respectively. The majority (74%) of surgeons with higher than expected cases of positive CRM operated at least once at hospital with higher than expected cases of positive CRM.

Table 2
Bayesian hierarchical logistic regression of factors associated with positive CRM.

Risk Factor	Adjusted Odds Ratio (95% CI)
Neoadjuvant Chemoradiation	0.60 (0.42,0.83)
Scheduled Admission	0.69 (0.50, 0.97)
Colorectal Board Certification	0.43 (0.19, 0.78)
AJCC Stage	
I	1.00 (Reference)
II	2.44 (1.95, 3.34)
IIII	2.17 (1.78,2.92)
Operation Type	
LAR	1.00 (Reference)
APR	2.59 (2.11, 3.24)
Other	1.94 (1.09 3.23)

Survival analyses

The cohort had a 5-year disease-specific survival rate of 88% with a median follow up time of 42 months. The 5-year disease-specific survival rate for patients who were treated by hospitals with an O/E ratio >1 was 86% versus 91% for those treated by hospitals with an O/E ratio ≤ 1 ($p < 0.0001$) (Fig. 2). With respect to surgeons, the 5-year disease-specific survival rate for patients who were treated by those with O/E ratio >1 was 85% versus 90% for those treated by surgeons with an O/E ratio ≤ 1 ($p < 0.0001$) (Fig. 3). In the multivariable competing risks model that adjusted for all patient (including individual level CRM positivity), surgeon, and hospital factors, the results suggested that both surgeon and hospital performance in positive CRM status was associated with 5-year disease-specific survival. Patients treated by hospitals with higher than expected cases of positive CRM had a 38% increase in the hazard of death due to rectal cancer (HR = 1.38, 95% CI = 1.16, 1.67). Similarly, patients operated by surgeons with higher than expected cases of positive CRM had a 44% increase in the hazard of death due to rectal cancer (HR = 1.44, 95% CI = 1.11, 1.85).

Discussion

There remains concern of unnecessary heterogeneity in the treatment and management of rectal cancer in the United States suggesting the importance of benchmarking the quality of care. Using data from a statewide cancer surveillance registry, we estimated risk-adjusted hospital and surgeon O/E ratios for positive CRM in rectal cancer. Even after adjustment for case-mix, wide variation in O/E ratios suggested that there are large differences in surgeon and hospital performance and quality with respect to CRM status. We also noted that several patient factors correlated with positive CRM. Interestingly, we did not find any differences in positive CRM rates with respect to surgeon volume, surgeon experience, hospital volume, hospital academic status, and hospital rural status. Colorectal board certification was associated with fewer unsatisfactory margins.

Patients treated by poorer surgeon and hospital performers had worse long-term disease specific-survival independent of patient-level CRM positivity. Furthermore, at the aggregate level, poor hospital performers had higher average hospital 5-year death rates (disease-specific death, 14.0% versus 10.5%; overall death, 24.8% versus 23.8%). The fact that the discrepancy was higher when evaluating disease-specific death as opposed to overall death suggests that poor hospital performers are delivering poor rectal cancer-specific quality of care. These findings also suggest global performance in positive CRM can affect the aggregate long-term death distribution of hospitals as well as individual patient outcomes. These patterns were true even among patients who did not have a positive CRM (when comparing two patients who did not have CRM, those patients treated by global poor performers in CRM had worse survival).

Previous research has reported variation in the rate of positive CRM across individual surgeons. One study conducted in the United Kingdom for example reported differences in the rate of positive CRM and suggested this could be explained by the wide discrepancy in the knowledge and skills of individual surgeons.[20] Similarly, one study using the National Cancer Database identified large differences in positive CRM rates across individual hospitals.[22] While still being important contributions to the literature, the main limitation of both studies was that they only evaluated variation at one level (either surgeon or hospital), making it difficult to estimate

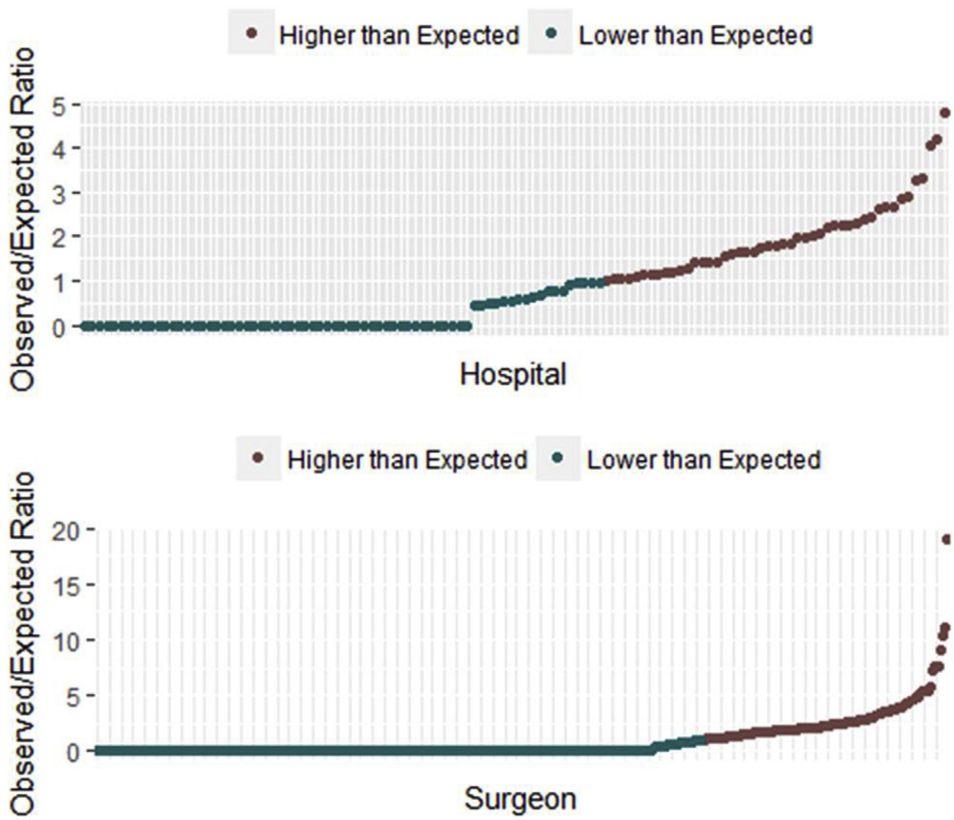

Fig. 1. Risk-adjusted hospital and surgeon observed-to-expected ratios.

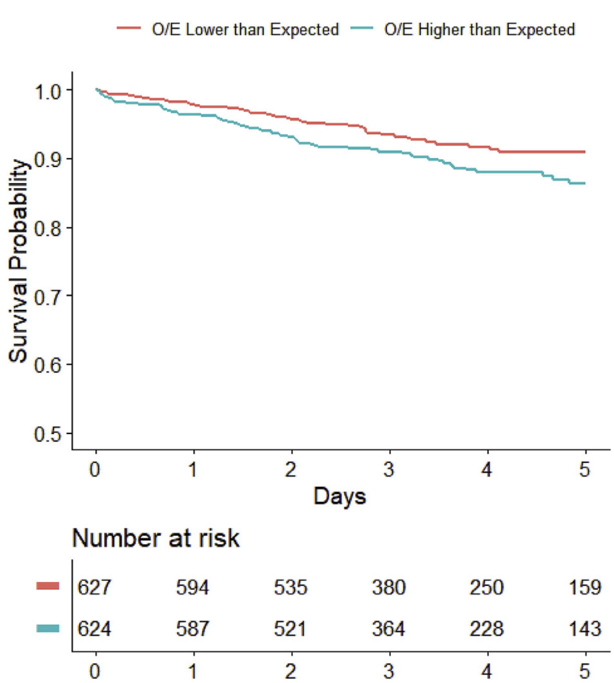

Fig. 2. Kaplan-meir curves comparing hospital O/E ratios for positive CRM.

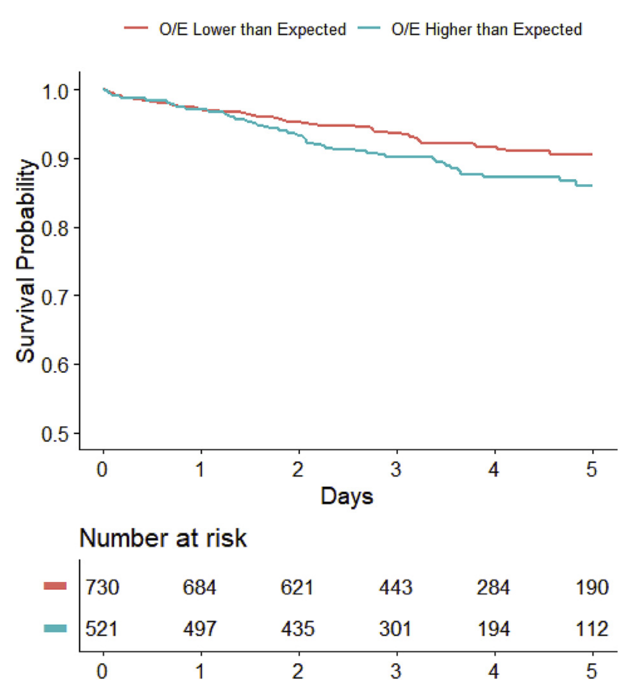

Fig. 3. Kaplan-meir curves comparing surgeon O/E ratios for positive CRM.

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how much of the variation is accounted by each level. Our study used a multilevel framework to incorporate the effect of both the surgeon and the hospital and confirmed that there is independent variation at both levels. Furthermore, 74% of the worst performing surgeons operated at a worst performing hospital suggesting a more complex relationship between surgeon and hospital quality in CRM status.

Proponents of evaluating performance measures advocate for their use in implementing and monitoring continuous quality improvement strategies.[28–32] In rectal cancer, positive CRM has been accepted as a reliable performance measure because it is something that can be directly influenced at the surgeon/hospital level and is one of the strongest correlates of local recurrence and subsequently survival. With respect to surgeon performance, positive CRM reflects the quality and adequacy of the TME performed.[33–35] A high-quality TME is achieved by removal of all positive lymph nodes from the mesorectum and no indication of mesenteric tumor deposits. At the hospital level, this suggests that organizational policies that promote multidisciplinary care may be able to highlight more emphasis of achieving adequate TMEs.

Wide differences in surgeon and hospital quality also suggest that several factors can predict positive CRM. This study reported that several patient level factors including scheduled admission, AJCC stage, and type of operation are associated with positive CRM which has been observed before in the literature.[17–19] One difference is that in this study, receipt of neoadjuvant chemoradiation was associated with lower odds of positive CRM, while one study suggested that this was not the case.[17] Furthermore, our study is the first to report that colorectal board certification was associated with reduced positive CRM cases, suggesting that colorectal surgery fellowship provides better training in adequacy of TME. Interestingly, there were no differences in positive CRM rates across tertiles of both surgeon and hospital volume. While one study in the Netherlands suggested that higher case volume was associated with a reduction in positive CRM rates,[36] this has not been reported in the United States.[17] This inconsistency in the literature makes it difficult to assess the relative importance of case volume. What is clear is that predictors of CRM are multifactorial and other surgeon and hospital characteristics not collected in this study likely explain a lot of the remaining variation. While volume remains an important predictor of other outcomes, the study results suggest that other characteristics need to be considered when measuring quality and supports value-based care models that move away from solely prioritizing volume.

The findings from these results should be interpreted in light of several limitations. First, the study used administrative data, which has innate well known limitations. In particular, there may be underreporting of specific diagnoses for comorbidities which could lead to inadequate risk adjustment. This could artificially make it seem like some surgeons/hospitals are poor performers in positive CRM if the case-mix of their patients is less favorable. Second, some surgeons/hospitals treated a small number of patients thus making their observed-to-expected ratios less reliable as compared to surgeons and hospitals who treated a larger number of patients. We attempted to mitigate this by using Bayesian hierarchical regression which borrows power from large clusters to estimate reliable estimates for small clusters. Finally, these data are only generalizable to patients in New York State. The New York State Cardiac Surgery Reporting System[37] is an apt comparison to what we are trying to point out with our study. We support the effort to make these data publicly available because patients should have the option of choosing their surgeon and/or hospital based on outcomes. However, this is not something that is easily achievable without the backing of a large proportion of the colorectal surgery community, which has been limited to date.

Despite these limitations, this study has several strengths that allow the results to be important contributions to the current literature. First, the use of the NYSCR allowed us to identify a cohort of patients with a confirmed diagnosis of rectal cancer. Second, we were able to use Bayesian hierarchical regression to adjust for clustering of patients at both the surgeon and hospital level. Finally, we used disease-specific survival as the outcome as opposed to overall survival, which more adequately captures the impact on a relevant oncological endpoint.

Conclusion

In summary, we estimated surgeon and hospital specific O/E ratios of positive CRM adjusted for case-mix as a measure of rectal cancer quality of care and correlated them with disease-specific survival even after adjusting for patient level positive CRM. Wide variation in these estimates suggests that there is no single dimension in rectal cancer quality of care and that further research needs to be conducted in order to be able to explain reasons for such heterogeneity. As more quality improvement programs such as the NAPRC[13–15] begin to address deficiencies in the delivery of care, it will be increasingly important to provide relevant benchmarks and to assess if variation persists after implementation of these programs. This current study provides a snapshot of the benchmark and suggests that there is opportunity to improve the quality of rectal cancer care at both the surgeon and hospital level.

Conflicts of interest

No financial disclosures or conflicts of interest. This work was completed when the corresponding author Adan Z. Becerra, PhD was a PhD student at the University of Rochester. Dr. Becerra is now employed at Social & Scientific Systems, which was not involved in the current study.

Author contributions

1. *Carla F. Justiniano*: Data curation, formal analysis, writing-original draft, writing-review and editing.
2. *Christopher T. Aquina*: Data curation, methodology, writing-review and editing.
3. *Fergal J. Fleming*: Conceptualization, investigation, methodology, writing-review and editing.
4. *Zhaomin Xu*: Data curation, methodology, writing-review and editing.
5. *Francis P. Boscoe*: Resources, software, supervision, validation, writing-review and editing.
6. *Maria J. Schymura*: Resources, software, supervision, validation, writing-review and editing.
7. *Larissa K. Temple*: Resources, investigation, writing-review and editing.
8. *Adan Z. Becerra*: Conceptualization, investigation, methodology, project administration, supervision, writing-review and editing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2019.02.029.

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