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Postoperative paralytic ileus after major oncological procedures in the enhanced recovery after surgery era: A population based analysis

Sebastiano Nazzani[a,b,c,*], Marco Bandini[a,b,d], Felix Preisser[a,b,e], Elio Mazzone[a,b,d], Michele Marchioni[a,f], Zhe Tian[a], Robert Stubinski[c], Maria Chiara Clementi[c], Fred Saad[a,b], Shahrokh F. Shariat[g], Emanuele Montanari[h], Alberto Briganti[d], Luca Carmignani[c], Pierre I. Karakiewicz[a,b]

[a] Cancer Prognostics and Health Outcomes Unit, University of Montreal Health Center, Montreal, Quebec, Canada
[b] Centre de Recherche du Centre Hospitalier de L'Université de Montréal (CR-CHUM), Institut du Cancer de Montréal, Montréal, Québec, Canada
[c] Academic Department of Urology, IRCCS Policlinico San Donato, University of Milan, Milan, Italy
[d] Division of Oncology/Unit of Urology, URI, IRCCS Ospedale San Raffaele, Milan, Italy, Vita-Salute San Raffaele University, Milan, Italy
[e] Martini Klinik, University Medical Center Hamburg-Eppendorf, Hamburg, Germany
[f] Department of Urology, SS Annunziata Hospital, "G.D'Annunzio" University of Chieti, Chieti, Italy
[g] Department of Urology, Medical University of Vienna, Vienna, Austria
[h] Department of Urology, IRCCS Fondazione Ca' Granda-Ospedale Maggiore Policlinico, University of Milan, Milan, Italy

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ABSTRACT

Background: Enhanced recovery after surgery (ERAS) protocols have been developed and implemented as of 2001 and may have significantly reduced several complication types including paralytic ileus. However, no formal analyses targeted paralytic ileus rates after contemporary major surgical oncology procedures. We examined temporal trends of paralytic ileus following ten major oncological surgical procedures. The effect of paralytic ileus on length of stay (LOS) and total hospital charges was examined. Univariable and multivariable linear and logistic regression analyses were used.

Methods: Between 2003 and 2013, we retrospectively identified patients, who underwent prostatectomy, colectomy, cystectomy, mastectomy, gastrectomy, hysterectomy, nephrectomy, oophorectomy, lung resection or pancreatectomy within the Nationwide Inpatient Sample. A total of 3 431 602 patients were included in our analyses. Annual paralytic ileus rate differences after major oncological surgical procedures were evaluated using linear regression. Multivariable logistic regression analyses were used to test for paralytic ileus rates determinants, as well as on the effect of paralytic ileus rates on LOS and hospital charges.

Results: Paralytic ileus rates ranged from 0.1% (mastectomy) to 23.2% (cystectomy) after ten examined major oncological surgical procedures. Overall annual paralytic ileus rates did not change [estimated annual percentage change (EAPC) + 0.1%, p = 0.7]. Multivariable logistic regression derived predicted probabilities (PP) of paralytic ileus were highest for cystectomy (PP: 26.1%) and colectomy (PP: 17.15%) and were lowest for lung resection (PP: 2.22%) and mastectomy (PP: 0.16%). In analyses predicting LOS above the 75th percentile, paralytic ileus effect after mastectomy (OR: 14.66) and prostatectomy (OR: 13.21) ranked, as highest and second highest respectively. In analyses predicting hospital charges above the 75th percentile, paralytic ileus effect after mastectomy (OR: 2.21) and oophorectomy (OR: 1.99) ranked as highest and second highest respectively.

Conclusions: Despite implementation of ERAS protocols paralytic ileus rates have not decreased over time. Gastrointestinal procedures are among the highest contributors of paralytic ileus. Moreover, procedures with short LOS represent the strongest relative contributors to LOS increases and increases in hospitalization costs.

1. Introduction

Paralytic ileus is a common response after surgical trauma with a complex pathogenesis. Paralytic ileus prolongs length of stay (LOS) and increases hospital charges. Specifically, the impact of paralytic ileus has been estimated to be $750 million to $1 billion in the United States [1].

* Corresponding author. Academic Urology Department, IRCCS Policlinico San Donato, Università degli Studi di Milano Italy.
E-mail address: sebastiano.nazzani@yahoo.com (S. Nazzani).

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For example, for colorectal procedures and small bowel resections, the cost savings related to a LOS reduction of only 1 or 2 days could be substantial [2].

The enhanced recovery after surgery (ERAS) protocols were pioneered in the field of colorectal surgery to reduce the LOS and maintain optimal organ function after the stress of surgery. Institutional data demonstrated shorter LOS after ERAS implementation in colorectal, urological and gynecological surgery [3–5]. Since their inception, ERAS protocols were also implemented in thoracic and head and neck surgery. The benefits of ERAS were validated in institutional analyses. However, they were not confirmed in population-based studies.

To address lack of population based validation of ERAS benefit, we tested annual paralytic ileus rates after ten major oncological surgical procedures [6]: prostatectomy, colectomy, cystectomy, mastectomy, gastrectomy, hysterectomy, nephrectomy, oophorectomy, lung resection and pancreatectomy. Moreover, we examined risk factors predisposing to paralytic ileus, as well as its association with LOS and hospital charges.

2. Patients and methods

2.1. Data source

To assess the incidence of paralytic ileus after major oncological surgical procedures, we relied on the National Impatient Sample database (2003–2013). The Nationwide Inpatient Sample is a set of longitudinal hospital inpatient databases included in the Healthcare Cost and Utilization Project family, created by the Agency for Healthcare Research and Quality through a Federal-State-Industry partnership [7]. The database includes 20% of United States inpatient hospitalizations, with discharge abstracts from 8 million hospital stays. It incorporates patient and hospital information, including Medicare, Medicaid, private insurance and other insurance type patients.

2.2. Study population

Ten major oncological surgical procedures were identified according to previously established methodology, namely: prostatectomy, colectomy, cystectomy, mastectomy, gastrectomy, hysterectomy, nephrectomy, oophorectomy, lung resection and pancreatectomy [6]. All procedures and diagnoses were coded using the *International Classification of Disease, 9*th *revision, Clinical Modification* (ICD–9–CM). Surgical approach was coded as either open or minimally invasive (542.1; 545.1; 174; 174.2).

2.3. Outcomes of interest

ICD-9-CM code 560.1 was utilized to identify paralytic ileus. Prolonged LOS was defined as hospital stay duration above the 75th percentile for each examined major oncological surgical procedure. Elevated hospital charges were defined as amounts above the 75th percentile for each of ten examined major oncological surgical procedure.

2.4. Patient and hospital characteristics

Patient age, gender, race/ethnicity (Caucasian, African American and Others), Charlson comorbidity index (CCI) [8,9] and insurance status (private insurance, Medicare, Medicaid, and other) were defined according to Nationwide Inpatient Sample information. Tobacco use disorder (305.1) [10] and diabetes (648.0, 249.X and 250) were also include among covariates. Post-operative complications were coded in ten different categories (intraoperative, transfusion, respiratory, vascular, gastrointestinal, cardiac, wound, genitourinary, infection, neurological and miscellaneous) [11]. Additional risk variables consisted of hospital region (Northeast, Midwest, South, West) [12], hospital size (small, medium and large) and hospital teaching vs. non-teaching status. Teaching institutions had an American Medical Association-approved residency program, were a member of the Council of Teaching Hospitals, or had a ratio of 0.25 or higher of full-time equivalent interns and residents to non-nursing home beds [7]. Lastly, annual major oncological surgical procedures hospital volume (low, medium and high), representing the number of major oncological surgical procedures performed at each participating institution during each study calendar year was calculated independently for each of the ten examined major oncological surgical procedures.

2.5. Statistical analysis

Data distribution was adjusted according to the provided Nationwide Inpatient Sample population weights to render estimates more accurate nationally. All analyses were performed on the weighted population.

First, medians and interquartile ranges, as well as frequencies and proportions were reported for continuous (age and LOS) and categorical variables (gender, race, insurance status, CCI, annual major oncological surgical procedure hospital volume, region, hospital size, teaching status, surgical approach, smoke and diabetes [8,13,14]), respectively. The statistical significance of differences in medians and proportions was evaluated with the Kruskal-Wallis and chi-square tests.

Second, adjusted paralytic ileus rate was generated by multivariable logistic regression. Then estimated annual percentage change (EAPC), was generated using log linear regression methodology [15]. The latter was applied also to test CCI ≥ rates over time. Third, three sets of separate multivariable logistic regression models examined three specific end-points: 1) the first set of multivariable logistic regression models tested patient and hospital determinants of paralytic ileus after major oncological surgical procedures, 2) the second set of multivariable logistic regression models tested the effect of paralytic ileus on rates of prolonged (≥75th percentile) length of stay, 3) the third set of multivariable logistic regression models tested the effect of paralytic ileus on rates of elevated (≥75th percentile) hospital charges. Moreover, endpoints 2) and 3) were subsequently individually re-examined for each major oncological surgical procedure. Specifically, the effect of paralytic ileus on prolonged length of stay and the effect of paralytic ileus on elevated hospital charges were tested with a separate multivariable logistic regression for each of the ten examined major oncological surgical procedures. Analyses were performed using the R software environment for statistical computing and graphics (version 3.3.0; http://www.r-project.org/).

3. Results

3.1. General characteristics of the study populations

We studied 3 431 602 patients treated with one of the ten examined major oncological surgical procedure. Overall, 8% of patients were discharged with the diagnosis of paralytic ileus. Median age at surgery was 64 years (IQR 56–73). Median LOS was 4 days (IQR 2–7), LOS was longer (8 vs. 3 days), when paralytic ileus was diagnosed (Table 1). Patients with paralytic ileus were more frequently older (68 vs. 64 years), male (51.8 vs 48.2%), Caucasian (69.1%) and with CCI = 0 (59%). Non-teaching hospital status (43.1 vs. 41.1%) and highest hospital surgical volume accounted for higher proportions of paralytic ileus (33.7 vs. 35.6%) (Table 1). The proportion of patients with CCI ≥1 increased over time (EAPC: +1.7%, $p < 0.0001$).

3.2. Temporal trend analyses of paralytic ileus rates

Between 2003 and 2013, the estimated annual paralytic ileus rate did not change (EAPC: +0.1%, $p = 0.7$). Within individual major oncological surgical procedures, colectomy (EAPC: +1.86%, $p = 0.02$),

Table 1
Weighted descriptive characteristics of 3,431,602 patients older than 18 years undergoing major oncological surgical procedure, Nationwide Inpatient Sample, 2003–2013.

Variables	(%)	(%)	(%)
	Overall	Without paralytic ileus	With paralytic ileus
Weighted No. (%) of patients	3,431,602 (100.0)	3,154,701 (91.93)	276,901 (8.07)
Age at surgery			
Median	64	64	68
IQR	56–73	55–72	59–77
Length of stay			
Median	4	3	8
IQR	2–7	2–7	6–13
Year of surgery			
2003–2008	61.2	61.3	60.5
2009–2013	38.8	38.7	39.5
Gender			
Female	55.4	56	48.2
Male	44.6	44	51.8
Race			
Caucasian	62.9	62.9	62.6
African American	8	8	8.5
Other	29.1	29.2	29
CCI			
0	63.6	64.1	59
1	25	25	25.4
≥2	11.3	11	15.6
Hospital teaching status			
Non-teaching	41.5	41.1	43.1
Teaching	58.5	58.9	53.7
Annual hospital volume			
Low	32.5	34	30.5
Medium	33.8	34.2	33.9
High	33.7	33.7	35.6
Hospital region			
South	35.6	35.4	38
Midwest	23.5	23.3	25.6
Northeast	21.6	22.2	15.2
West	19.3	19.1	21.2
Insurance status			
Private	44.1	45	34
Medicaid	4.8	4.9	3.6
Medicare	46.3	45.3	58.1
Other	4.7	4.8	4.3
Hospital size			
Large	68.4	68.5	68
Medium	21.5	21.4	22.2
Small	10.1	10.1	9.7
Procedure			
Prostatectomy	19.8	20.7	9.5
Colectomy	18.8	16.9	41.3
Cystectomy	2.6	2.1	8.2
Gastrectomy	2.2	2.1	2.8
Hysterectomy	15.5	15.5	15.2
Mastectomy	15.6	16.9	0.3
Nephrectomy	11	10.7	13.7
Oophorectomy	2.2	2	3.4
Pancreatectomy	2	1.9	3
Lung resection	10.3	11	2.6
Comorbidities			
Diabetes	17.3	17.2	17.8
Smoke	9.9	10	8.4
Surgical Approach	10.3	11	2.6
Open	85.1	84.8	88
Minimally invasive	14.9	15.2	12

cystectomy (EAPC: +1.71%, p = 0.02), pancreatectomy (EAPC: +1.52%, p = 0.04) and gastrectomy (EAPC: +1.29%, p = 0.004) exhibited an increase in estimated annual paralytic ileus rates. Conversely, hysterectomy (EAPC: −3.01%, p = 0.01) and oophorectomy (EAPC: −1.91%, p = 0.01) exhibited a decrease (Fig. 1). No statistically significant paralytic ileus rates differences were recorded for other major oncological surgical procedures.

3.3. Multivariable logistic regression models testing for patient and hospital determinants of paralytic ileus after major oncological surgical procedure

According to multivariable predicted probability (PP) of paralytic ileus after major oncological surgical procedure (Fig. 2), the highest rate was recorded after cystectomy (PP: 26.1%, standard deviation [SD]: 0.04), followed by colectomy (PP: 17.1%, SD: 0.01) and pancreatectomy (PP: 12.8%, SD: 0.03). The lowest rates of paralytic ileus were recorded after lung resection (PP: 2.2%, SD: 0.002) and mastectomy (PP: 0.2%, SD: 0.0001).

Patient risk factors associated with paralytic ileus after major oncological surgical procedure were older age (55–64 years odds ratio [OR]: 1.08, p < 0.0001; ≥65 years OR: 1.27, p < 0.0001), male gender (OR: 1.35, p < 0.0001), year of diagnosis between 2009 and 2013 (OR: 1.13, p < 0.0001) and African American race (OR: 1.13, p < 0.0001). CCI score 1 (OR: 1.07, p < 0.0001) resulted in a marginal paralytic ileus increase. Conversely, a CCI score ≥2 (OR: 0.98, p = 0.004) resulted in a marginal decrease. Finally, minimally invasive approach (OR: 0.89, p < 0.0001), diabetes (OR: 0.87, p < 0.0001), tobacco dependence (OR: 0.97, p < 0.0001) and teaching status (OR: 0.9, p < 0.0001) were associated with lower rates of paralytic ileus after major oncological surgical procedures (Table 2).

3.4. Multivariable logistic regression models testing the effect of paralytic ileus on prolonged (≥75th percentile) length of stay

Stratification according to presence or absence of paralytic ileus after major oncological surgical procedure was associated with prolonged (≥75th percentile) LOS (OR: 2.33, 95% CI: 2.27–2.40, p < 0.0001). In eight of ten major oncological surgical procedure-specific models examining the length of stay above the 75th percentile, paralytic ileus achieved independent predictor status (Table 3).

3.5. Multivariable logistic regression models testing the effect of paralytic ileus on elevated (≥75th percentile) hospital charges

Stratification according to presence or absence of paralytic ileus after major oncological surgical procedure was associated with elevated (≥75th percentile) hospital charges (OR: 1.26, 95%CI: 1.23–1.29, p < 0.0001). In nine of ten major oncological surgical procedure-specific models examining the hospital charges above the 75th percentile, paralytic ileus achieved independent predictor status (Table 4).

4. Discussion

Paralytic ileus is defined as ileus lasting more than three days after surgery [16]. In general the pathogenesis of paralytic ileus is not completely understood. However, its impact on patient comfort, as well as, on LOS and total hospital charges is not trivial [17].

Based on the importance of paralytic ileus, numerous efforts focused on paralytic ileus understanding and rate reduction, such efforts were first described as early as in reports originate from 1859 [18]. However, the first structured protocol originated from ERAS initiative. Besides focusing on paralytic ileus, ERAS protocols aimed at resolving issues that delay recovery and cause complications after major surgery [19]. To date, the efficacy of ERAS was validated within either single institution or multi-institutional studies [4,20,21]. However, contemporary population-based assessments of paralytic ileus using large administrative databases have not been reported. In consequence, it cannot be confirmed that ERAS effectively reduces paralytic ileus rates outside of dedicated centers. Based on these considerations, we sought to examine population-level trends in paralytic ileus following major oncological surgical procedures. To accomplish this task, we specifically focused on patients who underwent one of ten major oncological

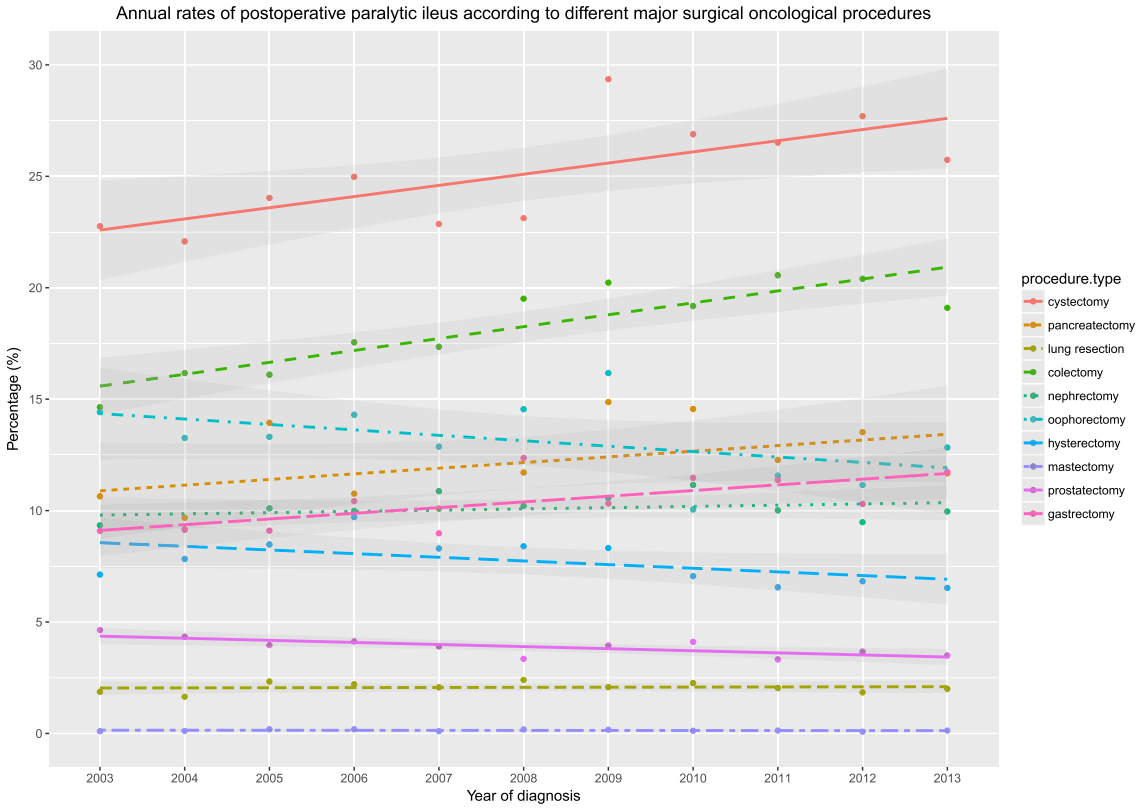

Fig. 1. Annual rates of paralytic ileus according to different major surgical oncological procedures in 3,431,602 patients, Nationwide Inpatient Sample, 2003–2013.

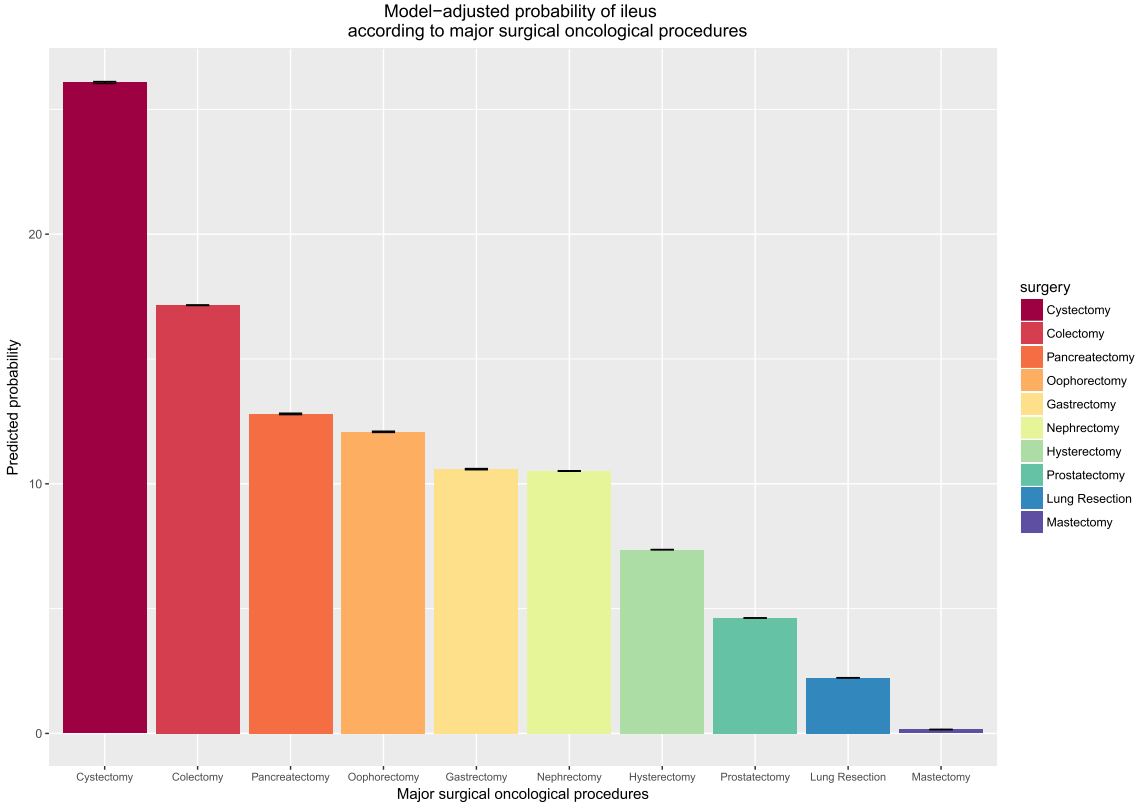

Fig. 2. Model − adjusted probability of paralytic ileus according to major surgical oncological procedures in 3,431,602 patients, Nationwide Inpatient Sample, 2003–2013.

Table 2
Multivariable logistic regression predicting paralytic ileus in 3 431 602 patients underwent one of ten major surgical oncology procedures, Nationwide Inpatient Sample, 2003–2013.

Predictors of ileus	OR	CI: 2.50%	CI: 97.50%	P values
Cystectomy (ref. Prostatectomy)	4.79	4.69	4.89	< 0.0001
Oophorectomy	3.73	3.63	3.83	< 0.0001
Colectomy	3.54	3.49	3.60	< 0.0001
Hysterectomy	2.59	2.54	2.65	< 0.0001
Nephrectomy	2.51	2.47	2.55	< 0.0001
Pancreatectomy	1.60	1.55	1.65	< 0.0001
Gastrectomy	1.19	1.16	1.23	< 0.0001
Lung Resection	0.33	0.32	0.33	< 0.0001
Mastectomy	0.05	0.04	0.05	< 0.0001
Length of stay	1.07	1.07	1.07	< 0.0001
Minimally Invasive (ref. open)	0.89	0.88	0.90	< 0.0001
Teaching hospital (ref. non-teaching)	0.90	0.89	0.91	< 0.0001
Annual hospital volume low (ref. high)	1.03	1.01	1.04	< 0.0001
Medium	1.08	1.07	1.09	< 0.0001
Hospital size small (ref. large)	1.02	1.00	1.03	0.0152
Medium	1.02	1.01	1.03	< 0.0001
2009–2013 (ref. 2003–2008)	1.13	1.12	1.14	< 0.0001
Age 55–64 (Ref. < 55)	1.08	1.07	1.09	< 0.0001
Age ≥65	1.27	1.25	1.29	< 0.0001
Male (Ref. female)	1.35	1.34	1.36	< 0.0001
African American (Ref. Caucasian)	1.13	1.11	1.15	< 0.0001
Other	0.96	0.95	0.97	< 0.0001
Charlson 1 (Ref. Charlson 0)	1.05	1.04	1.06	< 0.0001
Charlson ≥2	0.98	0.97	0.99	0.0036
Medicaid (Ref. private ins)	0.80	0.78	0.82	< 0.0001
Medicare	1.03	1.01	1.04	0.0003
Other	0.90	0.88	0.92	< 0.0001
Midwest (Ref. South)	1.04	1.03	1.05	< 0.0001
Northeast	0.64	0.64	0.65	< 0.0001
West	1.12	1.11	1.13	< 0.0001
Diabetes	0.87	0.86	0.88	< 0.0001
Tobacco dependence	0.97	0.96	0.99	0.0003

OR: Odds ratio, CI: confidence interval.

Table 3
Multivariable logistic regression models, after fitting for age, gender, race, type of procedure, year of surgery, region of the hospital, teaching status, annual major oncological surgical procedures hospital volume, hospital size, Charlson comorbidity index, insurance status, diabetes, tobacco dependence, and complications, for predicting the effect of paralytic ileus on elevated length of stay (≥75th percentile) in 3 431 602 major oncological surgical procedure patients, Nationwide Inpatient Sample, 2003–2013.

Procedure specific effect of ileus on length of stay higher than the 75th percentile	OR	CI: 2.50%	CI: 97.50%	P values	Overall median length of stay, days (IQR)
Mastectomy	14.66	5.33	40.29	< 0.0001	2 (1–2)
Prostatectomy	13.21	11.84	14.74	< 0.0001	2 (1–3)
Hysterectomy	5.83	5.35	6.73	< 0.0001	3 (2–5)
Oophorectomy	3.08	2.66	3.57	< 0.0001	4 (2–7)
Cystectomy	2.66	2.04	2.95	< 0.0001	8 (7–11)
Nephrectomy	2.64	2.45	2.84	< 0.0001	4 (3–6)
Lung resection	2.16	1.87	2.49	< 0.0001	6 (4–9)
Colectomy	1.66	1.60	1.74	< 0.0001	7 (5–11)
Gastrectomy	0.96	0.83	1.11	0.5948	10 (8–16)
Pancreatectomy	0.94	0.82	1.09	0.4757	10 (7–16)

OR: Odds ratio, CI: confidence interval, IQR: interquartile range.

surgical procedures: prostatectomy, colectomy, cystectomy, mastectomy, gastrectomy, hysterectomy, nephrectomy, oophorectomy, lung resection and pancreatectomy. Our study yielded several noteworthy findings.

First, our population-based analyses revealed a rate of paralytic ileus after major oncological surgical procedure of 8%. paralytic ileus rates ranged from 0.01 after mastectomy to 23.5% after cystectomy. The wide range of paralytic ileus rates can be explained by differences in presence or extent of bowel manipulation. Additionally, paralytic ileus rates can also be explained by LOS associated with the ten examined major oncological surgical procedures. According to these hypotheses our data confirmed the importance of bowel manipulation and its extent. Moreover, our data also confirmed the highest rate of paralytic ileus after procedures with prolonged LOS [17,22].Our findings are in agreement with paralytic ileus incidence reported in contemporary literature that focuses on bowel surgery. For example, paralytic ileus rates after colectomy reported in our analyses virtually perfectly replicate the ones published by Iyer et al. [17]. Finally, our findings are consistent with institutional reports and randomized controlled trials from the field of urology and gynecology [22,23].

Table 4
Multivariable logistic regression models, after fitting for age, gender, race, type of procedure, year of surgery, region of the hospital, teaching status, annual major oncological surgical procedures hospital volume, hospital size, Charlson comorbidity index, insurance status, diabetes, tobacco dependence, and complications, for predicting the effect of paralytic ileus on elevated hospital charges (≥75th percentile) in 3 431 602 major oncological surgical procedure patients, Nationwide Inpatient Sample, 2003–2013.

Procedure specific effect of ileus on hospital charges higher than the 75th percentile	OR	CI: 2.50%	CI: 97.50%	P values
Mastectomy	2.21	1.49	3.29	0.0001
Oophorectomy	1.99	1.63	2.42	< 0.0001
Lung resection	1.84	1.61	2.12	< 0.0001
Prostatectomy	1.67	1.53	1.81	< 0.0001
Hysterectomy	1.52	1.32	1.76	< 0.0001
Nephrectomy	1.26	1.17	1.36	< 0.0001
Cystectomy	1.18	1.06	1.32	0.0020
Colectomy	1.12	1.07	1.17	< 0.0001
Gastrectomy	0.90	0.77	1.03	0.1514
Pancreatectomy	0.86	0.74	0.99	0.0363

OR: Odds ratio, CI: confidence interval.

Second, we did not identify a decrease in overall paralytic ileus rates after major oncological surgical procedures, over time. Even though overall paralytic ileus rates did not differ, we did observe changes over time when analyses were repeated for each of ten specific procedures. In major oncological surgical procedures specific analyses paralytic ileus rate after cystectomy (EAPC: + 2.89), colectomy (EAPC: + 1.47), pancreatectomy (EAPC: + 1.89) and gastrectomy (EAPC: + 1.47) was on the rise. Conversely, in paralytic ileus rate analyses after hysterectomy (EAPC: − 2.4) and oophorectomy (EAPC: − 1.85) was on declining. The rising rates of paralytic ileus are worrisome especially in the light of procedure specific ERAS protocols after cystectomy and colectomy. Increasing paralytic ileus rates may be indicative of a suboptimal ERAS protocols adherence or implementation. Alternatively increasing paralytic ileus rates may also be indicative of case mix changes overtime, whereby more contemporary patients are at greater risk of paralytic ileus. This hypothesis was indeed confirmed. We recorded an increase of proportion of patients treated with major oncological surgical procedures with CCI ≥1.

Third, to the best of our knowledge, we are first to report predicted paralytic ileus probability after specific major oncological surgical procedures, according to established methodology [24]. Specifically, cystectomy (26.1%), pancreatectomy (17.1%) and gastrectomy (12.8%) were associated with the highest PP of paralytic ileus. Conversely, lung resection (2.2%) and mastectomy (0.2%) were associated with the lowest PP of paralytic ileus. These rates suggest a strong direct relationship between major abdominal surgeries, where bowel resection occurs and paralytic ileus. Conversely, procedures of lesser complexity, as well as those that are performed outside of the abdominal cavity,

expectedly resulted in the lowest PP of paralytic ileus rates.

Fourth, we identified a number of paralytic ileus risk factors. These consist of older age (55–64 years OR: 1.08, $p < 0.0001$; ≥65 years OR: 1.27, $p < 0.0001$), male gender (OR: 1.35, $p < 0.0001$) and more contemporary year of diagnosis (OR: 1.2, $p < 0.0001$). Conversely, lower paralytic ileus rates were recorded after minimally invasive approach (OR:0.89, $p < 0.0001$) and when surgery was performed in teaching hospitals (OR:0.9, $p < 0.0001$). Our findings are in agreement with institutional series, where male gender and older age [25] were also predictors of higher paralytic ileus rates. Similarly, our analyses are also in agreement with institutional series regarding lower paralytic ileus rates after minimally invasive surgery [26]. In consequence, our population-based findings validate the importance of established risk factors that were identified within institutional analyses.

Fifth, our study represents the first population based report that validates the relationship between paralytic ileus rates and LOS. Specifically, LOS was longer in patients with paralytic ileus than in their counterpart without paralytic ileus. Moreover, it is noteworthy that the effect of paralytic ileus on LOS was strongest for major oncological surgical procedures with short LOS. This relationship may be explained by the relative rarity of paralytic ileus in patients treated with short LOS major oncological surgical procedures and where paralytic ileus occurs very unfrequently (mastectomy, prostatectomy). Conversely, the magnitude of paralytic ileus effect on LOS was less pronounced after major oncological surgical procedures that are typically associated with longer LOS and after which paralytic ileus occurs more frequently (gastrectomy, pancreatectomy). Similarly, we also observed a relationship between paralytic ileus and elevated hospital charges. However, the magnitude of the positive relation between paralytic ileus and hospital charges was less pronounced.

Our study is not devoid of limitations, which apply to all studies with retrospective designs. Additionally, our study was unable to adjust for tumor characteristics. Moreover, we were unable to control for some risk factors, such as laboratory values, opioid use and anesthesia-specific considerations. Finally, the Nationwide Inpatient Sample database only allows to assess in-hospital complications.

5. Conclusions

Despite implementation of ERAS protocols paralytic ileus rates have not decreased over time. Gastrointestinal procedures are among the highest contributors of paralytic ileus. Moreover, procedures with short LOS represent the strongest relative contributors to LOS increases and increases in hospitalization costs.

Author contributions

Sebastiano Nazzani and Zhe Tian had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Conflicts of interest

None to declare.

Financial disclosures

Sebastiano Nazzani certifies that all conflicts of interest, including specific financial interests and relationships and affiliations relevant to the subject matter or materials discussed in the manuscript (eg, employment/affiliation, grants or funding, consultancies, honoraria, stock ownership or options, expert testimony, royalties, or patents filed, received, or pending), are the following: None.

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