Roma, 25 agosto 2025

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Alla c.a.
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Dott.ssa Manuela Lanzarin,
Assessore Sanità Regione Veneto
Dott.ssa Giovanna Scroccaro,
Coordinamento Regionale per le Attività Oncologiche (CRAO)
E p.c.
Dott. Luca Zaia,
Presidente Regione Veneto

Oggetto: conseguenze e direttive delle Aziende ospedaliere in merito ai DDR n. 46 e 47 del 9 luglio 2025 *"Criteri per l'individuazione dei Centri di Riferimento chirurgici per i pazienti affetti da tumori dello stomaco, colon e retto"*

In merito al recente ***Decreto n° 47 del 9 Luglio 2025***, *oggetto: Approvazione del Documento "Criteri per l'individuazione dei Centri di Riferimento chirurgici per i pazienti affetti da tumori del colon e del retto" e al DDR n. 46 del 09 luglio 2025 Approvazione del documento "Criteri per l'individuazione dei Centri di Riferimento chirurgici per i pazienti affetti da tumori dello stomaco",*

ACOI (**Associazione Chirurghi Ospedalieri Italiani**), che conta oltre 5000 iscritti su tutto il territorio nazionale intende manifestare la grande preoccupazione per gli effetti che tale nuovo assetto organizzativo potrà determinare su alcune delle strutture ospedaliere Hub e Spoke del Veneto.

In particolare, ci si riferisce a quanto emanato recentemente da alcune Aziende Ospedaliere del Veneto circa il mancato raggiungimento della soglia delle
U.U.O.O. chirurgiche (per tumori dello stomaco, colon e retto) con conseguente *"mancato obiettivo per le Aziende ULSS e conseguenti penalizzazioni".* Nelle stesse si *autorizzavano gli interventi di chirurgia oncologica, per le patologie in oggetto, solo le U.O. di tutti i Centri Hub e solo alcuni Spoke.*

Alla luce delle considerazioni già sottoposte al CRAO in data 8 agosto 2025 e che sono riportate in allegato, ACOI ha attentamente valutato anche la produzione scientifica sull'argomento che non dimostra una chiara ed esplicita evidenza sul rapporto volumi e benefici in chirurgia gastrica e colo-rettale, bensì dimostra
quanto segue:

• **Meta-analisi su casistiche internazionali**:
maggior volume ospedaliero/chirurgo → riduzione della mortalità a 30 giorni e miglioramenti di processo (linfonodi ≥12, leak, CRM nel retto) [1,3].
• **Esperienza cumulativa del singolo chirurgo**:
predittore forte di sopravvivenza a 5 anni (oltre al volumedel centro) [1].
• **Assenza di una "soglia universale"** per il colon e lo stomaco; evidenza più stringente per centralizzare il retto in team dedicati [2,3].

• Nuova meta-analisi (45 studi; 2,0M pazienti):
ospedali ad alto volume → ↓ mortalità dopo resezione del colon (OR 0,73) e del retto (OR 0,75); **plateau ≈30 resezioni rettali/anno**, **nessuna soglia chiara** per il colon [9].

• TOO (Textbook Oncologic Outcome) — systematic review:
parametri ricorrenti = R0/CRM−, **LN≥12**, **nessuna CD≥III**,
LOS ≤ P75, **nessuna riammissione 30 gg**, **nessuna mortalità 30 gg**; spinta alla standardizzazione [10].

• **Dati PNE 2022–2023** (colon): mortalità grezza nazionale ~3,7%; più bassa nei centri ≥50/anno rispetto a <50/anno (~3,18% vs ~4,48%). Copertura dell'aggiustata alta sopra soglia e bassa nei microvolumi ⇒serve audit con riskadjustment robusto [6].

Vanno pertanto altresì considerati:

Indicatori oggettivi di qualità (TOO)

• Oncologici di processo: R0
• Esiti clinici: Mortalità 30 gg (riskadjusted) ≤ benchmark (benchmark = soglia di riferimento definita dall'audit);
• Complicanze ClavienDindo ≥III e FailuretoRescue ≤ benchmark; Riammissione 30 gg ≤ benchmark; degenza ≤ **P75** regionale (P75 = 75° percentile della degenza);
• uso appropriato di ICU postop (no routine non indicata).
• Percorso: tempi diagnosistagingchirurgia;
• referto istopatologico standardizzato.

Soglia minima differita (dopo 12 mesi)
• Soglie minime tarate su esiti reali, densità demografica, tempi di viaggio e capacità dei CR/OR.
• **Rischio critico:** ritardi di trattamento da centralizzazione "solo per numeri".
L'umbrella meta-analysis BMJ 2020 mostra che ogni 4 settimane di ritardo aumentano i rischi: per la chirurgia colon HR ~1,06 (95% CI 1,01–1,12); per chemioterapia adiuvante colon/retto HR 1,13 (1,09–1,17) [8].

In conclusione, come dimostrato in letteratura, è utile passare da un approccio "numerico" ad uno "basato sugli esiti misurati", con equità, prossimità e tempi certi di cura con un impatto atteso che riguarda:
• Riduzione di mortalità e complicanze maggiori; migliore R0/CRM; riduzione FTR, degenze e riammissioni.
• **Riduzione significativa delle liste d'attesa chirurgiche** e rispetto delle finestre temporali (Dx→Chir; Chir→Adiuvante) tramite governance di rete e slot dedicati.
• Più equità grazie a percorsi standardizzati e prossimità del pre/postoperatorio.
• Trasparenza: confronto pubblico e miglioramento continuo.

Riferimenti bibliografici essenziali:
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doi: 10.1097/JS9.0000000000003168.
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ACOI pertanto chiede che vi sia una chiara delibera regionale programmatica prima che le Aziende Ospedaliere procedano, come purtroppo sta già succedendo, ad emanare delle direttive interne a solo scopo del raggiungimento di un obiettivo aziendale (per evitare "pesanti penalizzazioni") senza una previa delibera regionale di indirizzo.

Certi di un Vostro celere interessamento, restiamo a disposizione per una qualsiasi collaborazione scientifica e riorganizzativa.

Il Presidente ACOI
(Associazione Chirurghi Ospedalieri Italiani)
Vincenzo Bottino

Il Presidente SIPAD
(Società Italiana di Patologia dell'Apparato Digerente)
Salvatore Ramuscello

TYPE Systematic Review
PUBLISHED 26 May 2025
DOI 10.3389/fonc.2025.1474008

OPEN ACCESS

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RECEIVED 06 August 2024
ACCEPTED 04 April 2025
PUBLISHED 26 May 2025

CITATION
Arrighini GS, Martinino A, Zecchin Ferrara V,
Lorenzon L and Giovinazzo F (2025)
Textbook oncologic outcomes in colorectal
cancer surgery: a systematic review.
Front. Oncol. 15:1474008.
doi: 10.3389/fonc.2025.1474008

Textbook oncologic outcomes in colorectal cancer surgery: a systematic review

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Introduction: The concept of "textbook outcome" has been updated to encompass the principles of surgical oncology and the related outcomes [textbook oncologic outcome (TOO)]. This systematic review aims to synthesize the numerous definitions of TOO in the context of colorectal surgery. The goal is to promote the development of a definition that has universal recognition and worldwide acceptability, hence improving surgical quality standards and patient outcomes.

Methods: A systematic literature review was conducted using PRISMA guidelines. The databases PubMed, Web of Science, and Scopus were searched for studies that addressed TOO in colorectal cancer surgeries. The database search was conducted on 30 April 2024, and the primary study's quality was assessed using the Newcastle–Ottawa Scale.

Results: A total of 13 studies were included. Common TOO parameters included radical resection, lymph node (LN) yield ≥12, no Clavien-Dindo grade ≥III complications, length of stay (75th percentile), no 30-day readmissions, and no 30-day mortality. Factors influencing TOO achievement included surgical risk, gender, tumor stage, and socioeconomic factors. Patients achieving TOO showed better long-term survival. Variability in TOO definitions highlighted the need for standardization.

Conclusion: TOO is an effective indicator for evaluating the quality of colorectal cancer surgery. It provides a comprehensive evaluation of surgical outcomes, which helps in guiding patient decisions and measuring hospital performance. By standardizing the parameters of TOO, the consistency and quality of care across different institutions can be improved. We propose a unified definition of TOO for colorectal cancer surgery: radical resection, LN yield ≥12, no Clavien-Dindo grade ≥III complications, length of stay (75th percentile), no 30-day readmissions, and no 30-day mortality.

KEYWORDS

colorectal surgery, colorectal cancer, colon cancer, textbook outcome, textbook oncologic outcome, surgical quality

Introduction

Colon cancer is still one of the most common types of cancer, contributing considerably to the global increase in cancer-related deaths. Despite advancements in multimodal treatments that have enhanced patient outcomes, the disease continues to pose a substantial health challenge (1, 2). The quality of oncologic surgery has historically been assessed using a range of metrics, including postoperative mortality and morbidity, lymph node (LN) yield, reoperation rates, readmission rates, and cancer-related survival. These days, the evaluation of care quality has become more and more important (3, 4), as research indicates that patients are prepared to go further to receive higher quality care and prefer to select their treatment hospital based on its result statistics (5, 6).

A proposed composite quality score known as "textbook outcome" (TO) represents the optimal "textbook" hospitalization for complicated surgical operations by integrating multiple postoperative endpoints (7, 8). TO is the percentage of patients who receive ideal surgical care and for whom all intended short-term goals of care are achieved. Notably, TO extends beyond mere event recording to underscore the disparities in performance across medical institutions. This distinctive feature elevates TO as a potent instrument for hospital comparison, enabling the identification of exemplary practices that might set a standard for excellence (7, 9). Based on the TO framework, the textbook oncologic outcome (TOO) concept is a composite outcome measure that is attained after an oncological operation when all desired quality criteria are satisfied (10). Achievement of TOO has been demonstrated to be linked to increased long-term survival across a range of malignancies, including colon and rectal cancers, underscoring its clinical usefulness as a criterion for surgical cancer treatment quality (11).

This systematic review is designed to summarize the various definitions of TOO within the contexts of colon and rectal cancer surgeries. The aim is to foster the establishment of a definition that gains widespread recognition and international acceptance. By achieving a uniform understanding and application of TOO, this effort seeks to enhance the benchmarking of surgical quality and improve patient outcomes in this medical domain.

Methods

PICO process and search strategy

"In *patients undergoing colorectal surgery* (P), does *TOO* (I) compared to *traditional quality metrics*, like postoperative mortality and morbidity (C), influence *a comprehensive set of primary and secondary outcomes* (O) reflecting the multifaceted nature of colorectal cancer surgery?

A systematic literature review was carried out in accordance with PRISMA guidelines to deepen comprehension of the topic and offer valuable perspectives to the medical field. Our research involved searching PubMed, Web of Science, and Scopus databases. We utilized the search terms "colon cancer", "rectal cancer", "colorectal", "textbook outcome", and "TOO". Additionally, we identified articles from the references of the retrieved publications. The date of the search was 30 April 2024.

Abbreviations: TO, textbook outcome; TOO, textbook oncologic outcome; CC, colon cancer; RC, rectal cancer.

Inclusion and exclusion criteria

All English language studies that addressed TOO in colorectal cancer surgery were included. Non-English language studies, no full-text available studies, case series, and case reports were excluded from our analysis.

Study selection, data extraction, and quality assessment

Two researchers (G.S.A. and A.M.) independently evaluated study titles and abstracts using predefined search parameters to select studies that met the entry criteria. The same two researchers (G.S.A. and A.M.) assessed the complete texts for inclusion and gathered data. In cases of discrepancy, a third reviewer was consulted (V.Z.F.). G.S.A. and V.Z.F. subsequently examined all selected articles and collected the data using Excel(R).

For each included article, general study characteristics such as study design, year, country, sample size, and database used were extracted, along with all reported parameters used to define TOO. These parameters included radical resection, LN yield $\geq$12, Clavien-Dindo complications, 30- or 90-day mortality, 30- or 90-day readmissions, length of hospital stay, reintervention, ostomy, and additional outcome measures such as conversion to open surgery, discharge destination, colonoscopy timing, surgery within 6 weeks, and receipt of adjuvant chemotherapy. Patient-related factors and predictors of TOO achievement, such as age, sex, cancer stage, surgical approach, and socioeconomic determinants, were also recorded. The Newcastle–Ottawa scale was used to evaluate the studies' quality. 0–2 was regarded as low quality, 3–5 as acceptable, and 6–9 as good or outstanding. Not a single study was an RCT. We decided against conducting a meta-analysis due to the heterogeneity in outcome reporting and variations in study populations and methodologies.

Results

Following the initial search, 111 articles were collected. After eliminating duplicates and conducting a screening of titles and abstracts, we identified 17 articles published by April 2024 for inclusion. Four of these articles were removed from consideration for the reasons listed below: (1) full text was not available, 3 were not related to colon surgery; thus, 13 studies were suitable for review (Figure 1). In terms of the subjects covered, eight studies discussed TOO in colon cancer surgery, (2) TOO in colorectal cancer with a distinction between colon and rectum patients, while (3) studies did

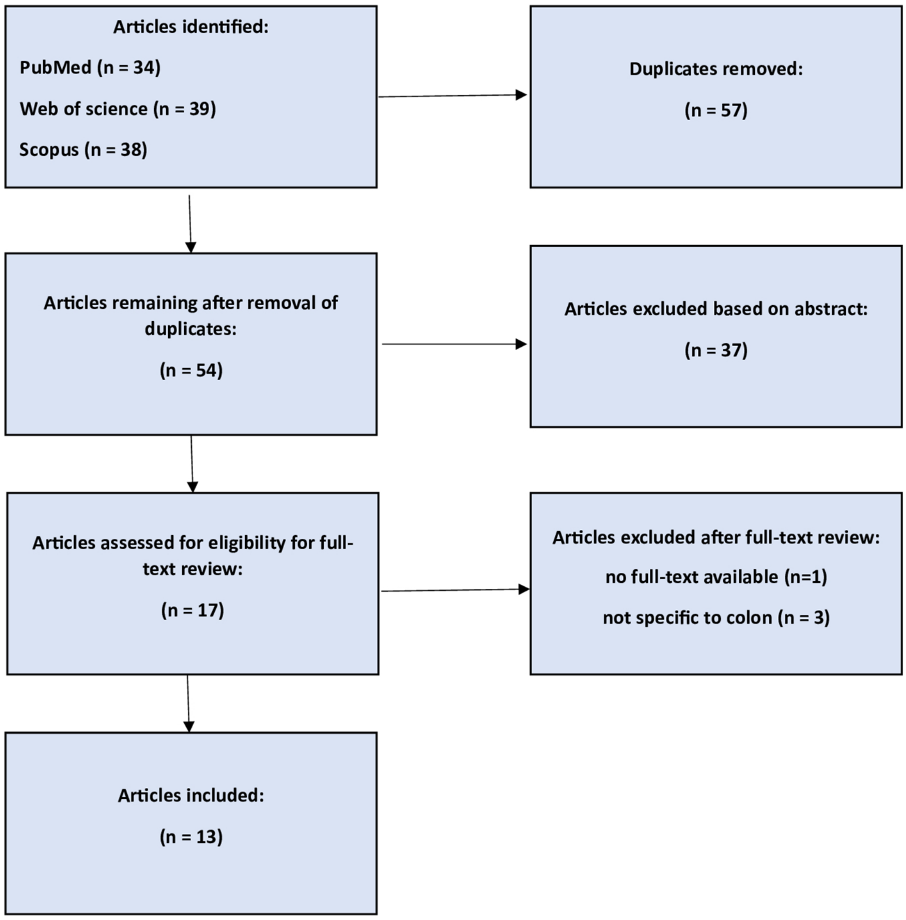

FIGURE 1
PRISMA flow diagram.

not have a distinction between colon and rectum patients. Table 1 displays the studies' characteristics, and Supplementary Table S1 reports the studies' quality assessment.

Colon cancer surgery and TOO

Our comprehensive investigation revealed seven papers that examine the TOO in colon cancer surgery (Table 2). The study included 205,877 patients who underwent colon cancer surgery and were registered for TOO. A total of 124,420 patients achieved TOO, while 81,457 did not. Of the seven papers, one was published in 2024 (12), two were published in 2023 (13, 14), one in 2021 (15), one in 2020 (9), and one in 2013 (7); three of them were single-center studies (9, 13, 14) while four were multicenter studies (7, 12, 15, 16). Most of the patients come from a multicenter study based on the National Cancer Database (170,120 patients) (15).

All the publications, except one (12), included radical resection as a TOO parameter (7, 9, 13–16). Four studies examined the number of LNs with a threshold of ≥12 (9, 13–15). One study included no Clavien-Dindo grade ≥III complications in the first 30 days as a TOO variable (13); one study included no Clavien-Dindo grade ≥II complications in the first 30 days (14).

Length of stay (LOS) was included in six studies: three studies mentioned a stay of <14 days (7, 13, 16), one study a stay of ≤5 days (12), one study a stay of ≤11 days. In one study, the median LOS varied according to the year and method of surgery, from 6 days for an open colectomy in 2010 to 4 days for a robot-assisted colectomy in 2015 (15).

Five studies mentioned no readmission in the first 30 days as a TOO parameter (9, 12–15). Six studies included no 30-day mortality as a TOO parameter (7, 12–16). No ostomy was considered in three studies (7, 9, 16) and in one study, no unplanned ostomy was considered a TOO variable (14). Receipt of stage-appropriate adjuvant chemotherapy was included in one study (15). Non-reintervention was included in three studies without specifying the time point (7, 14, 16) and two studies specified within 30 days (9, 12).

Some studies mentioned unique TOO parameters: no adverse outcome without a specific time point (16) and within 30 days (7), colonoscopy before/after surgery within 6 months (9), meeting all TOO parameters within 6 weeks (9), and no postoperative complications (12).

TABLE 1 Colon and colorectal cancer surgery textbook oncologic outcomes.

Colon cancer surgery	Year	Scope
Textbook outcome in colon carcinoma: implications for overall survival and disease-free survival.	2023	Definition of TOO.
The association between the composite quality measure “textbook outcome” and long-term survival in operated colon cancer.	2020	Definition of TOO.
Achieving a Textbook Outcome in Colon Cancer Surgery Is Associated with Improved Long-Term Survival.	2023	Definition of TOO.
Focusing on desired outcomes of care after colon cancer resections; hospital variations in “textbook outcome.”	2013	Definition of TOO.
A Novel Machine Learning Approach to Predict Textbook Outcome in Colectomy.	2024	Definition of TOO.
Assessment of Cancer Center Variation in Textbook Oncologic Outcomes Following Colectomy for Adenocarcinoma	2021	Definition of TOO.
Identifying best performing hospitals in colorectal cancer care; is it possible?	2020	Definition of TOO.
Colorectal cancer surgery (with distinction between colon and rectal surgery)	**Year**	**Scope**
Frailty assessment can predict textbook outcomes in senior adults after minimally invasive colorectal cancer surgery.	2023	Definition of TOO.
Textbook Oncological Outcomes for Robotic Colorectal Cancer Resections: An Observational Study of Five Robotic Colorectal Units.	2023	Definition of TOO.
Impact of safety-net hospital burden on achievement of textbook oncologic outcomes following resection in for Stages I–IV colorectal cancer.	2024	Definition of TOO.
Colorectal cancer surgery (with no distinction between colon and rectal surgery)	**Year**	**Scope**
Textbook outcome contributes to long-term prognosis in elderly colorectal cancer patients.	2023	Definition of TOO.
Association between the environmental quality index and textbook outcomes among Medicare beneficiaries undergoing surgery for colorectal cancer (CRC).	2023	Definition of TOO.
The Association of Food Insecurity and Surgical Outcomes Among Patients Undergoing Surgery for Colorectal Cancer.	2023	Definition of TOO.

Overall, the most frequently included parameters were radical resection, LN yield ≥ 12, LOS, no 30-day mortality, no 30-day readmissions, no ostomy, and no reintervention.

Colorectal cancer surgery with distinction between colon and rectum patients and TOO

We identified three papers that examine textbook outcome in colorectal cancer surgery with the distinction between colon and rectum patients (Table 3). The study includes 488,117 patients. Total colon cancer patients: 367,975; achieved TOO for colon surgery: 255,815; not achieved TOO for colon surgery: 112,160. Total rectal cancer patients: 84,922; achieved TOO for rectal surgery: 46,287; not achieved TOO for rectal surgery: 38,635. Total rectosigmoid junction cancer patients: 35,220; achieved TOO for rectosigmoid junction surgery: 23,376; not achieved TOO for rectosigmoid junction surgery: 11,844. Two papers were published in 2023 (17, 18) and one in 2024 (11). Most of the patients come from a multicenter study based on the National Cancer Database (487,195 patients) (11).

TOO parameters were the same for colon and rectal surgery. The only difference observed between the TOO parameters for colon and rectal cancer was in one study that defined the LOS for both: the LOS for rectal cancer surgery should be ≤14 days, while for colon cancer surgery, it should be ≤5 days (17). In another study, a hospital stay within the 75th percentile of the whole cohort was defined as normal LOS, and it turned out to be ≥8 days for non-metastasectomy patients and ≥9 days for metastasectomy patients (11). One study mentioned that the LOS should be ≤14 days (18). Two studies included radical resection (11, 18); one study included no Clavien-Dindo grade ≥III complications without a specific time point (18) and another one within 90 days (17). No 30-day readmission and no 30-day mortality were mentioned in two studies (11, 18), while one study mentioned no reintervention and no readmission without a specific time point (17). Most parameters are the same or similar to TOO parameters seen in colon cancer patients.

Colorectal cancer surgery with no distinction between colon and rectum patients and TOO

We identified three papers that examine textbook outcome in colorectal cancer surgery with no distinction between colon and rectum patients (Table 4). A total of 87,421 patients who had colorectal cancer surgery and had registered for TOO were included in the trial. A total of 49,399 patients achieved TOO, while 43,022

TABLE 2 Colon surgery textbook outcomes.

Article (setting, period)	Rubio García JJ et al. (Single center, 2012-2016)	Yang CC et al. (Single center, 2010-2014)	Manatakis DK et al. (Single center, 2010-2020)	Kolfschoten NE et al. (Multicenter, 2010)	Ashraf Ganjouei A et al. (Multi-center, 2014-2020)	Sweigert PJ et al (Multi-center, 2010-2015)	Van Groningen JT et al. (Multicenter, 2013-2015)
Patients	*Total*: 564 *Achieved TOO*: 281 (50%) *Not achieved TOO*: 283	*Total*: 804 *Achieved TOO*: 478 (59%) *Not achieved TOO*: 326	*Total*: 128 *Achieved TOO*: 77 (60%) *Not achieved TOO*: 51	*Total: 5582 Achieved TOO: 2735 (49%) Not achieved TOO: 2847*	*Total: 20,498 Achieved TOO: 13,532 (66%) Not achieved TOO: 6,966*	*Total: 170,120 Achieved TOO: 93,204 (55%) Not achieved TOO: 76,916*	*Total: 8181 Achieved TOO: 5113 (62%) Not achieved TOO: 3068*
TO variable							
Radical resection	yes	yes	yes	yes	no	yes	yes
Lymph node (LN) yield ≥ 12	yes	yes	yes	no	no	yes	no
No Clavien-Dindo grade ≥ III or ≥ II complications in the first 30 days	yes (≥ III)	no	yes (≥ II)	no	no	no	no
Hospital stay < 14 days	yes	no	yes (75th percentile of the study population: ≤ 11 days)	yes	yes (≤ 5 days)	Yes (≤ 75th percentile by year and operative approach)	yes
No 30-day readmission	yes	yes	yes	no	yes	yes	no
No 30-day mortality	yes	no	yes	yes	yes	yes	yes
No ostomy	no	yes	no	yes	no	no	yes
No reintervention	no	yes (no 30-day reintervention)	yes	yes	yes (no 30-day reintervention)	no	yes
Colonoscopy before/after surgery within 6 months	no	yes	no	no	no	no	No
Met the mentioned healthcare parameters within 6 weeks	no	yes	no	no	no	no	no
No unplanned stoma	no	no	yes	no	no	no	no
No adverse outcome within 30 days.	no	no	no	yes (within 30 days)	no	no	yes
No postoperative complications	no	no	no	no	yes	no	yes
Receipt of stage-appropriate adjuvant chemotherapy	no	no	no	no	no	yes	no

TABLE 3 Colorectal surgery (with distinction between colon and rectum patients) textbook outcomes.

Article (setting, period)	Azevedo JM et al. (Multicenter, 2012-2022)	Taffurelli G et al. (Single center, 2017-2021)	Wong P et al. (Multicenter, 2010-2019)
Patients	*-Total CC patients: 104 Achieved TOO for CS: 84(81%) Not achieved TOO for CS: 20 -Total RC patients: 397 Achieved TOO for RS:304(77%) Not achieved TOO for RS:93*	*-Total CC patients:316 Achieved TOO for CS: 217(69%) Not achieved TOO for CS: 99 -Total RC patients: 105 Achieved TOO for RS:72(73%) fot achieved TOO for RS:33*	*-Total CC patients:367,555 Achieved TOO for CS: 255,514(70%) Not achieved TOO for CS: 112,041 -Total RJC patients:35,220 Achieved TOO for RJS: 23,376(66%) Not achieved TOO for RJS: 11,844 -Total RC patients: 84,420 Achieved TOO for RS:45,911 (54%) Not achieved TOO RS:38,509*
Radical resection	yes	No	yes
No Clavien-Dindo grade ≥ III complications	yes	yes (no 90 days C–D grade ≥ III complications)	no
Length of hospital stay (LOS) ≤ 14 days	yes	yes (LOS ≤ 5 days for CS and ≤ 14 days for RS)	yes (≥ 8 days for non metastasectomy (Stages I–III) patients and ≥ 9 days for patients that received additional metastasectomy)
No 30-day readmission	yes	Yes	yes
No 30-day mortality	yes	No	yes
No conversion to open surgery	yes	No	no
No reintervention	no	Yes	no
No discharge to a rehabilitation/nursing home facility.	no	Yes	no
No postoperative changes in the living situation	no	Yes	no
Lymph node (LN) yield ≥ 12	no	No	yes
Receipt of stage-appropriate adjuvant chemotherapy	no	No	yes
90-day survival	No	Yes	no

CC, colon cancer; CS, colon surgery.
RC, rectal cancer; RS, rectal surgery.
RJC, rectosigmoid junction cancer; RJS, rectosigmoid junction surgery.

10.3389/fonc.2025.1474008

TABLE 4 Colorectal Surgery (with no distinction between colon and rectum patients) textbook outcomes.

Article (Setting, period)	Chanza FS et al. (Multicenter, 2004-2015)	Azap L et al. (Multicenter, 2010-2015)	Maeda Y et al. (Single center, 2005-2016)
Patients	*Total*: 40939 *Achieved TOO*: 23580(56%) *Not achieved TOO*: 12359	*Total*: 46296 *Achieved TOO*: 25739(56%) *Not achieved TOO*: 20557	*Total*: 186 *Achieved TOO*: 80(43%) *Not achieved TOO*: 106
No 90-day mortality.	yes	yes	No
No 90-day readmission	yes	yes	No
No postoperative complications	yes	yes	No
No extended LOS (beyond the 75th percentile).	yes	yes	No
No 30-day readmission	no	no	yes
Radical resection	no	no	yes
Lymph node (LN) yield ≥ 12	no	no	yes
No Clavien-Dindo grade ≥ II complications in the first 30 days	no	no	yes
No ostomy	no	no	yes
Surgery within 6 weeks	no	no	yes

did not. All papers were published in 2023. Two of them were multicenter studies (19, 20) while one was a single-center study (21).

Two studies had the same TOO definitions: no prolonged LOS beyond the 75th percentile, no 90-day mortality, no 90-day readmission, and no postoperative complications (19, 20). One study included all TOO parameters that had previously been observed in studies involving only colon cancer patients: radical resection, LN yield ≥12, no Clavien-Dindo grade ≥II complications in the first 30 days, no 30-day readmission, and no ostomy (21).

Factors influencing the achievement of TOO

The characteristics of the TOO and non-TOO groups were compared in a study by Rubio García et al (13). It was found that the non-TOO group had a higher proportion of patients who presented surgical risk and that the TOO group had a significantly higher proportion of females. Differences were also found in the pT classification, with a significantly higher proportion of T3 and T4 and a higher mean number of isolated LNs in the TOO group than in the non-TOO group. Additionally, the laparoscopic approach was more common among TOO patients.

LN yield >12, no stoma, and no adverse outcome were the outcome parameters that most frequently kept patients from reaching a textbook outcome, according to Ching-Chieh Yang et al. (9) Likewise, Yuto Maeda et al. (21) demonstrated the same factors, such as LN yield >12 and absence of adverse events, which resulted in low rates of achieving TOO.

Compared to patients without a textbook outcome, those who achieved TOO had a higher 5-year DSS (9, 14).

Dimitrios K. Manatakis et al. (14) demonstrated factors preventing TOO were older age, left-sided and pT4 cancers. These factors also prevented TOO in another study made by N.E. Kolfschoten et al (7).

In order to evaluate hospital performance, N.E. Kolfschoten et al. utilized TOO, which provides insightful information about the standard of care given to patients with colon cancer and makes it easier to make significant comparisons across different healthcare facilities.

Another work by Ashraf Ganjouei et al. (12) sought to use machine learning methods to provide a decision assistance tool for textbook outcomes. The researchers analyzed data from over 20,000 patients collected from the American College of Surgeons National Surgical Quality Improvement Program database. Patients who achieved a TOO were younger, had lower ASA class, and had an independent functional status compared to those who did not. Following the robotic procedure, TOO was more commonly obtained (76.9%), followed by the laparoscopic procedure (68.3%). Among patients who underwent open colectomy, only 38.8% achieved a TOO. Patients who underwent minimally invasive colectomy had significantly shorter hospital LOS, fewer postoperative complications, lower 30-day readmission rates and lower 30-day mortality rates compared to patients who underwent open colectomy.

Giovanni Taffurelli et al. (17) noted that when minimally invasive surgery, improved recovery protocols, and multidisciplinary management were all used at the same time, most older patients having colorectal cancer surgery could achieve TOO.

According to a study by José Moreira Azevedo et al. (18), robotic colorectal cancer surgery in robotic centers has a high rate of TOO. Even in specialized robotic colorectal facilities, extended resections—like APER—retain a higher chance of failing to reach a TOO in comparison to non-extended resections.

Patients who had a TOO tended to be younger, non-Hispanic White, and more likely to have private insurance, according to Sweigert et al. (15) and Wong et al (11). Individuals who received minimally invasive procedures and had a tumor on the right side were also more likely to have had a TOO. Laparoscopic and robotic techniques were independently linked to increased chances of TOO as compared with open or converted cases. Conversely, there was a correlation found between decreased probabilities of TOO and older age, non-Hispanic Black ethnicity, Hispanic ethnicity, and nonprivate insurance. The likelihood of TOO was also found to be lower in the presence of lymphovascular invasion and increased pathologic tumor stage.

T. Julia T. van Groningen et al. (16) determined TOO's rankability. The amount of result variation between hospitals that cannot be attributed to random fluctuation is known as rankability. As a result, it might represent the portion of hospital variance attributable to real variations in hospital settings as well as potential variations in care quality. This metric was employed to demonstrate the consistency of hospital rankings based on the particular result. After colon cancer surgery, the rankability of TOO was 54.1%, indicating that about half of the observed differences might be attributed to chance and the other half to the quality of treatment received.

The study by Wong et al. shows that patients treated at safety-net hospitals (SNH), which have a higher proportion of uninsured or Medicaid patients (more than 10%), have a significantly lower likelihood of achieving TOO. Of the 487,195 colorectal cancer patients studied, 66.7% achieved TOO overall. However, those treated at high-burden hospitals (HBH) had an odds ratio (OR) of 0.83 for achieving TOO compared to patients at low-burden hospitals (LBH), reflecting a marked disparity. Key factors affecting TOO achievement at HBHs include the lower rates of adequate lymphadenectomy (87.3%), prolonged LOS (76.3%), and reduced receipt of adjuvant chemotherapy (60.3% for Stage III and 54.1% for Stage IV). Sweigert et al. highlight that insurance status strongly influences the likelihood of achieving TOO. Among the 170,120 patients analyzed, only 54.8% achieved TOO. Patients with private insurance had a higher probability of achieving TOO (OR 1.16) compared to those on Medicaid (OR 0.64) or those uninsured (OR 0.68). This disparity is linked to access to advanced treatments and follow-up care, including timely adjuvant chemotherapy, which was achieved in 83% of the cohort (11). Azap et al. show that food insecurity significantly impacts surgical outcomes for colorectal cancer. Among the 46,296 patients who underwent surgery, 20.5% lived in high food insecurity counties. These patients had a 17% higher likelihood of undergoing non-elective surgeries (OR 1.17) and were 11% more likely to experience 90-day readmissions (OR 1.11). High food insecurity patients also had a 32% higher chance of extended hospital stays (OR 1.32) and were 19% less likely to achieve TOO (OR 0.81) compared to patients from low food insecurity counties (20). Shaikh et al. studied 40,939 colorectal cancer patients and found that environmental quality, as measured by the Environmental Quality Index (EQI), is significantly associated with TOO achievement. Patients residing in high EQI counties, which indicate poorer environmental conditions, were 6% less likely to achieve TOO (OR 0.94). This was particularly pronounced among Black patients, who had a 31% lower likelihood (OR 0.69) of achieving TOO when living in moderate-to-high EQI counties compared to White patients in low EQI counties. Additionally, high EQI areas were associated with higher rates of postoperative complications (21.5%) and extended hospital stays (18.2%), further reducing the chances of achieving an optimal outcome (19).

Discussion

Thirteen studies covering the topic of TOO in colon and rectal cancer surgery are compiled in this article. Several key themes and findings were identified across the studies. Firstly, the definition of TOO varied among them, but common components included radical resection, LN yield, absence of complications, length of hospital stay, readmissions, and mortality within a specified timeframe. Secondly, our investigation uncovered a consistent link between TOO and enhanced long-term survival outcomes, including both disease-specific survival and overall survival. In fact, compared to patients who did not fulfill TOO requirements, those who did tend to have superior outcomes in terms of survival rates (9, 14).

The detailed analysis of factors influencing the achievement of TOO underlines the complexity of achieving standardized outcomes in colorectal cancer surgery. Some studies introduce unique parameters that could enhance the assessment of TOO. For instance, the use of minimally invasive techniques has been shown to improve TOO achievement (12, 15, 18).

Surgeons are becoming more conscious of their responsibility to let patients know about the standard of treatment they offer. Traditionally, the evaluation of the quality of treatment has been based on discrete measures including duration of stay, distinct resection margin, 30-day readmission, and 30-day mortality (22–24). Nonetheless, patients have indicated a preference for summarized metrics over specific individual outcomes, possibly due to the lack of understanding for some of these individual outcomes (8, 15). In this situation, TOO is not only an important managerial tool, but it also plays a critical role in helping patients make decisions about which health treatments to seek. In order to ascertain the incidence of "true" optimal performance linked to the "ideal" clinical outcome, it provides a clear and easily interpreted statistic (25).

In well-funded institutions, implementing TOO can be more straightforward due to access to advanced surgical techniques, robotic systems, and experienced multidisciplinary teams. These centers should focus on refining TOO standards, ensuring consistent reporting, and using TOO as a metric for continuous quality improvement. In resource-constrained environments, achieving TOO may be more challenging due to limitations in technology and healthcare workforce. However, TOO can still serve as a valuable benchmark for improving outcomes by focusing on attainable goals such as reducing 30-day mortality and readmission rates and minimizing postoperative complications through better surgical planning and patient management. Steps like improving perioperative management, using evidence-based guidelines for colorectal surgery, and implementing enhanced recovery protocols can significantly impact TOO metrics even in less specialized centers. Also, remote consultation with high-volume centers could help surgeons in low-resource settings adopt best practices in colorectal cancer surgery, contributing to achieving TOO. Collaboration between institutions could allow resource-limited hospitals to improve TOO rates by accessing expert advice.

To enhance the clinical utility and universality of the TOO in colorectal cancer surgery, we propose a standardized definition incorporating six essential parameters: radical resection, LN yield ≥ 12, absence of Clavien-Dindo grade ≥ III complications, LOS within the 75th percentile, no 30-day readmissions, and no 30-day mortality. Each parameter plays a critical role in ensuring both the immediate quality and long-term efficacy of surgical oncologic care, as supported by our systematic review.

Ensuring complete resection with negative margins is critical for achieving TOO, as this directly impacts recurrence rates and disease-free survival. This parameter was consistently emphasized across studies, underscoring its significance for favorable prognosis.

Adequate LN retrieval, with a minimum yield of 12 nodes, is a widely accepted oncologic criterion in colorectal cancer surgery. This threshold ensures proper staging, guides adjuvant treatment decisions, and correlates with improved survival outcomes. Studies within our review that included LN yield as a TOO parameter consistently associated it with enhanced survival and more accurate staging.

Severe complications classified as Clavien-Dindo grade III or higher represent significant surgical and postoperative challenges, often leading to reinterventions, extended hospital stays, and increased patient morbidity. The absence of such complications is crucial for TOO. Our review highlights the strong association between lower complication rates and improved long-term outcomes.

A hospital stay within the 75th percentile of similar cases serves as a balanced indicator, promoting optimal recovery without prolonged hospitalization, which can introduce risks such as hospital-acquired infections, patient discomfort, and healthcare costs. Setting the LOS within this percentile not only offers a balanced recovery target but also aligns with enhanced recovery after surgery protocols, promoting optimized care pathways that facilitate safe and efficient discharge, as repeatedly noted in the studies reviewed.

Avoiding readmissions within 30 days post-surgery reflects the effectiveness of discharge planning, postoperative care, and patient education. By including this parameter in TOO, institutions are encouraged to focus on comprehensive discharge protocols and ensure patients receive adequate support post-discharge, minimizing unnecessary hospital utilization. Our review underscores that a lower readmission rate is closely associated with higher patient satisfaction and better long-term recovery, solidifying its place within the TOO definition.

Achieving zero mortality within the first 30 days following surgery is a fundamental criterion for TOO, directly reflecting the quality of surgical and postoperative care. In our review, studies consistently associate lower mortality rates with higher-quality surgical care and better institutional performance, supporting its inclusion as a parameter of TOO.

Together, these six parameters form a comprehensive, standardized definition of TOO that balances surgical quality with patient-centered outcomes, ensuring that high standards are met across different healthcare settings. This TOO definition is flexible enough to accommodate diverse healthcare environments while maintaining rigorous benchmarks, encouraging both resource-rich and limited settings to improve and evaluate their surgical performance based on universally accepted criteria. Standardizing these parameters not only supports consistency in surgical outcome reporting but also promotes comparability across institutions, facilitating advancements in TOO research, enhancing clinical quality measures, and ultimately contributing to improved patient outcomes.

Limitation

As far as the authors are aware, this is the first systematic review that summarizes TOO in surgery for colon and rectal cancer. It does, however, have some limitations. The retrospective nature of the studies included in this review introduces inherent limitations, such as selection bias and the potential for incomplete or inaccurate data collection. Retrospective studies rely on pre-existing records, which may not consistently capture all relevant patient information, leading to the underreporting of critical variables such as patient comorbidities, nutrition status, or socioeconomic factors. Furthermore, retrospective analyses limit our ability to establish causality between TOO and specific interventions or patient characteristics. For example, food insecurity and other socioeconomic determinants were not uniformly accounted for in all studies, which may have affected the interpretation of outcomes related to care quality.

Heterogeneity is a limitation in this review, as the included studies vary widely in terms of patient populations, surgical techniques, and institutional settings. Differences in hospital volumes, surgical expertise, and access to resources can all contribute to variability in achieving TOO. For instance, the quality of care in SNHs or institutions serving high-risk populations, such as patients from food-insecure regions, may differ significantly from more resource-rich settings. This variability introduces challenges when trying to draw uniform conclusions about TOO, as the outcomes can be influenced by institutional capabilities, patient demographics, and clinical practices that differ across regions.

Additionally, patient-level factors such as age, cancer stage, and frailty also contribute to heterogeneity. Studies focusing on elderly populations, for example, reveal that frailty plays a crucial role in the likelihood of achieving TOO. This variability highlights the difficulty in comparing outcomes across diverse populations without accounting for these individual differences. The generalizability of the findings from this review is limited by the characteristics of the included patient cohorts and healthcare settings. Most of the studies are based on data from high-income countries, where access to advanced surgical techniques and postoperative care is more readily available. Consequently, these results may not be applicable to settings with limited healthcare resources. For example, outcomes from hospitals in low-resource settings, where access to minimally invasive techniques or specialized postoperative care is limited, are underrepresented in this analysis. Similarly, the findings may not apply to countries or regions with different healthcare structures, such as those where universal healthcare is not available, as factors like insurance status significantly affect TOO.

For these reasons, future studies should stratify TOO outcomes by socioeconomic factors, comorbidities, and surgical techniques to isolate the influence of each confounder. Adoption of a universal TOO definition is essential. Encourage reporting that includes patient-level variables such as SES, comorbidity burden, and surgical approach. Also, ensure that statistical models account for key confounders like age, tumor stage, ethnicity, and hospital type to better reflect the generalizability of TOO.

Conclusion

Although studies differ in terms of TOO definition and attainment rates, they all concur that one metric is not enough to fully represent the total success of colorectal cancer surgery. Based on the common characteristics identified in the studies included, we propose the adoption of six important factors to formulate a unified definition of TOO for colorectal cancer surgery: radical resection, LN yield ≥ 12, no Clavien-Dindo grade ≥III complications, LOS (75th percentile), no 30-day readmissions, and no 30-day mortality. TOO offers a comprehensive evaluation of surgical outcomes, serving as a valuable metric for optimizing patient care and improving long-term prognosis. It benefits patients in selecting a hospital and provides valuable feedback for healthcare professionals. Also, in low-resource environments, TOO serves as a standardized metric, guiding cost-effective interventions and reducing complications and resource usage.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Author contributions

GA: Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. AM: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. VZ: Data curation, Formal Analysis, Methodology, Writing – review & editing. LL: Data curation, Methodology, Supervision, Writing – review & editing. FG: Data curation, Formal Analysis, Methodology, Supervision, Validation, Visualization, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fonc.2025.1474008/full#supplementary-material

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Understanding Variation in In-hospital Mortality After Major Surgery in the United States

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Objectives: We aimed to quantify the contributions of patient characteristics (PC), hospital structural characteristics (HC), and hospital operative volumes (HOV) to in-hospital mortality (IHM) after major surgery in the United States (US).

Background: The volume-outcome relationship correlates higher HOV with decreased IHM. However, IHM after major surgery is multifactorial, and the relative contribution of PC, HC, and HOV to IHM after major surgery is unknown.

Study Design: Patients undergoing major pancreatic, esophageal, lung, bladder, and rectal operations between 2006 and 2011 were identified from the Nationwide Inpatient Sample linked to the American Hospital Association survey. Multilevel logistic regression models were constructed using PC, HC, and HOV to calculate attributable variability in IHM for each.

Results: Eighty thousand nine hundred sixty-nine patients across 1025 hospitals were included. Postoperative IHM ranged from 0.9% for rectal to 3.9% for esophageal surgery. Patient characteristics contributed most of the variability in IHM for esophageal (63%), pancreatic (62.9%), rectal (41.2%), and lung (44.4%) operations. HOV explained < 25% of variability for pancreatic, esophageal, lung, and rectal surgery. HC accounted for 16.9% and 17.4% of the variability in IHM for esophageal and rectal surgery. Unexplained variability in IHM was high in the lung (44.3%), bladder (39.3%), and rectal (33.7%) surgery subgroups.

Conclusions: Despite recent policy focus on the volume-outcome relationship, HOV was not the most important contributor to IHM for the major organ surgeries studied. PC remains the largest identifiable contributor to hospital mortality. Quality improvement initiatives should emphasize patient optimization and structural improvements, in addition to investigating the yet unexplained sources contributing to IHM.

Keywords: In-hospital mortality, volume-outcome relationship, volume pledge, hospital characteristics

(*Ann Surg* 2023;278:865–872)

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This study was presented in part at the Society of Surgical Oncology International Conference on Surgical Cancer Care, held between March 9 and March 12, 2022.

The data used in this study was sourced from the NIS and AHA databases, both of which are publicly available online.

All authors participated in the design and conception of this study. Data were acquired and analyzed by N.W. and Y.H.C. The manuscript was written by R.S.M., N.W., and Y.H.C. All authors were involved in the critical revision of the manuscript and approved its final form.

As neither the NIS nor the AHA contain any identifiable or protected health information, this study did not require formal institutional review board (IRB) approval.

The authors report no conflicts of interest.

Supplemental Digital Content is available for this article. Direct URL citations are provided in the HTML and PDF versions of this article on the journal's website, www.annalsofsurgery.com.

ISSN: 0003-4932/23/27806-0865

DOI: 10.1097/SLA.0000000000005862

In-hospital mortality (IHM) after surgery is multifactorial and influenced by patient factors (such as age,[1] comorbidity,[1] type of insurance,[2] and race[2]), hospital characteristics (such as the presence of critical care facilities[3] and teaching status[4]), and hospital case volume. However, over the last 2 decades, much of the policy focus has been on the role of case volume and the volume-outcome association to improve postoperative outcomes.

The volume-outcome association is the relationship between higher operating volumes with lower postoperative mortality. This has been demonstrated for a variety of surgeries (including rectal,[5,6] pancreatic,[7–9] esophageal,[9,10] lung,[11,12] and bladder[13,14]) and across different settings within and outside the United States .[15] This has led to recommendations for the establishment of volume thresholds for complex surgery, including a 'volume pledge' by prominent institutions.[16–18] Though minimum thresholds for specific surgeries are not enforced by the policy in the US, as is the case in several European countries,[19] surgical care has trended towards centralization.[20,21]

However, studies exploring the real-world impact of hospital case volume for complex surgery in contemporary practice have demonstrated mixed results with regard to postoperative outcomes, identifying additional factors that may be influencing this association.[22–24] A systematic review in 2016 highlighted stark methodological differences among studies exploring the volume-outcome relationship, ranging from the categorization or definition of hospital volumes to statistical approaches, statistical tests, and covariates included.[25] In addition, system-wide improvements in surgical care since the association was first identified have decreased postoperative mortality in general, leading to attenuation of the volume-outcome relationship and lower thresholds.[26,27] Other issues with centralization, such as exacerbating existing disparities, imposition of travel burdens, and fragmentation of care, have also been identified.[28]

Hospital case volume does not operate in a vacuum, and less is known about the volume-outcome association when looking through a holistic lens in the context of patient and hospital characteristics. For any single in-hospital mortality following major surgery, what is the role of each of these factors? The goal of this study was to attempt to quantify the relative contributions of patient characteristics, hospital structural characteristics, and hospital volume to IHM after major surgery in the US. Our hypothesis is that hospital case volume is not the most important contributor towards IHM following major surgery.

METHODS

Data Source

Data from the National (Nationwide) Inpatient Sample (NIS)[29] was linked to data from the American Hospital Association (AHA) Annual Survey[30] using the HOSPID (Health care Cost and Utilization Project hospital identifier) and AHAID (AHA identifier) variables available in the databases.

The National Inpatient Sample (NIS)

The NIS is the largest publicly available all-payer health care database in the US, designed to estimate national and regional inpatient utilization, cost, and outcomes, and is administrated by the Health care Cost and Utilization Project. It contains deidentified data of inpatient hospitalizations sourced from billing information acquired from non-Federal hospitals by state-level organizations, with each record including clinical and resource-use information from a solitary patient hospitalization. As an all-payer database, it includes patients insured through Medicare, Medicaid, private insurance, and those uninsured. Before 2012, the NIS was a stratified sample of 20% non-Federal hospitals with 100% of discharges from the sampled hospitals included, enabling hospital case volume calculations for each sampled hospital. This is not the case for subsequent years, hence limiting our study sample to the years before 2012 to enable us to include hospital case volume as a covariate.

The American Hospital Association (AHA) Annual Survey

The AHA database is the most comprehensive data set that provides information related to hospital utilization, resources, staffing, service lines, and facilities. It is produced and maintained by the AHA, with administration being added by state health care agencies and industry organizations. Historically, the response rate remains above 75% annually.

Patient and Hospital Inclusion/Exclusion Criteria

Data of adult patients who are 18 years of age and above undergoing operations of the pancreas, esophagus, bladder, lung, or rectum from 2006 to 2011 were identified and extracted from the NIS using the ICD (International Classification of Diseases)-9-CM (Clinical Modification) procedure codes. These specific operations were chosen due to the literature demonstrating strong hospital volume-outcome relationships for these procedures as well as to try and capture cancer diagnoses.[5–14] Using the variable ATYPE (admission type), only patients undergoing elective surgery were included; Figure 1.

Extracted Variables

The variables extracted from the AHA and NIS included the following:

- Patient Characteristics: Age, sex, race, primary payer, median household income, and type of surgery, All Patient Refined Diagnosis Related Groups Severity of Illness Subclass (APR-DRG SOI as defined by the Health care Cost and Utilization Project) and Elixhauser comorbidity index.[31] The APR-DRG is an inpatient visit classification system that assigns a diagnostic-related group, risk of mortality, and severity of illness subclass to classify patients into 4 groups of risk—minor, moderate, major, and extreme. Hence the APR-DRG measures both resource utilization as well as the severity of illness and risk of mortality.
- Hospital Structural Characteristics: Hospital location, capacity, and services (presence of emergency department, cancer program, trauma facility), teaching status and affiliated medical school, total hospital and intensive care unit (ICU) beds, bed size (cutoffs differ by region and teaching status[32]), staffing (registered nurses, physician full-time equivalents/bed), equipment available (interventional radiology, blood donor center, endoscopic retrograde cholangiopancreatography, computerized tomography scanning).
- Hospital Volume: Mean hospital volume per year was calculated as a continuous variable using the methodology proposed by Birkmeyer et al.[21] This helped smoothen annual fluctuations in hospital volume.

Mortality Groups

Reliability-adjusted IHM rate was calculated for each of the hospitals included in the data set. The hospitals were ranked in order of increasing average IHM rate, and then cutoffs for IHM rates were established to divide the number of patients into 3 mortality groups by tertile: low mortality (LM: <33rd percentile), medium mortality (MM: 33rd to 66th percentiles), and high mortality (HM: >66th percentile). These cutoffs were established a priori and allowed for adequate power in each mortality group for robust analyses. These mortality groups were computed for each surgery group, that is, pancreas, esophagus, bladder, lung, and rectum.

Statistical Analyses

Descriptive statistics were computed as mean ± SD/median for numeric variables, and frequencies (n) and percentages (%) for categorical variables. Comparisons were performed using the two-sample *t*-test, χ^2 tests, or Kruskal-Wallis test, as appropriate.

The primary endpoint was patient IHM. Mixed-effects, multilevel logistic regression models were used to identify predictors of mortality and calculate attributable percentage variability in IHM overall and separately for each type of surgery. The 3 models sequentially added patient characteristics (1), hospital volume (2), and hospital structural characteristics (3), with random intercepts for hospitals to account for the clustering effect to compute percentage variability explained by the addition of the variables in the model. Our initial modelling included both Elixhauser Index and APR-DRG SOI, which resulted in collinearity. Due to better model performance and improved explained variability, only APR-DRG SOI was retained for most models. The selection of hospital characteristics was based on clinical knowledge and on the results from the classification and regression tree (CART). This methodology was used to help select relevant variables from the large number available to us in the database. The initial selection was based on clinical knowledge of accreditation or services associated with optimal outcomes, such as the American College of Surgeons (ACS) approved cancer program, medical school affiliation, emergency services, advanced endoscopy, etc. A second subset of variables was then identified using CART from the remaining variables—hospital control, mean procedural volume, medical or surgical ICU bed, Physician FTE per bed, and nursing hours per patient. Thus, we used CART as an intermediate step to select the variables associated with IHM. Results were presented as odds ratios (OR) and 95% confidence intervals (CI). A P value of <0.05 was indicative of statistical significance. Analyses were performed using SAS (version 9.4, SAS Institute, Cary, North Carolina, USA) and R (version 4.1.3, R Foundation for Statistical Computing, Vienna, Austria) software.

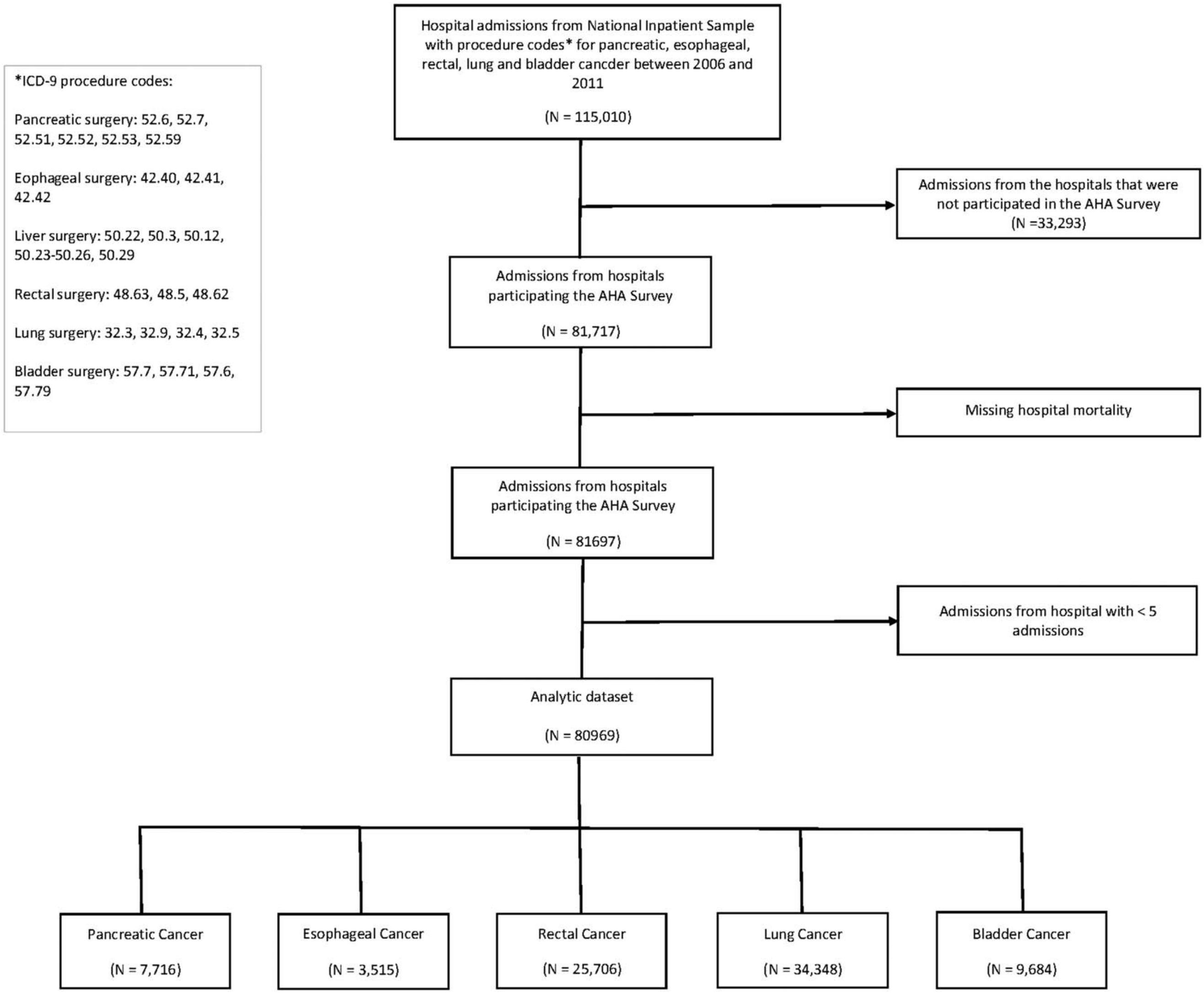

FIGURE 1. Inclusion and exclusion criteria strobe flow chart.

RESULTS

Demographics

A total of 80969 patients treated in 1025 hospitals were included in the study. The mean age of patients was 64.6 years, with 53% being male and the majority White (83.7%). The most common organ resections were lung (42.4%) and rectal (31.7%), followed by bladder (12%), pancreatic (9.5%), and esophageal (4.3%).

A total of 1470 (1.82%) patients died in-house during their postoperative hospital stay. The IHM rates decreased consistently over the study period, from 2.02% in 2006 to 1.55% in 2011. The postoperative IHM rates according to surgery type were as follows: 3.87% for esophageal, 2.73% for pancreatic, 2.13% for lung, 1.64% for bladder, and 0.91% for rectal operations. Patients who died were significantly older (71.4 ± 10.31 y vs. 64.4 ± 12.58 y; $P < 0.001$), had a higher median Elixhauser comorbidity index (14 vs. 2; $P < 0.001$), were more likely to be male (63.8% vs. 52.8%; $P < 0.001$), and to pay through Medicare (73.6% vs. 51.4%; $P < 0.001$); Table 1. Patient characteristics according to the individual type of surgery (pancreatic, esophageal, etc.) are in Supplementary Table 1, Supplemental Digital Content 1, http://links.lww.com/SLA/E488.

Among the 1025 hospitals included, 85.7% were located in urban settings. According to the AHA survey, 58.2% had a cancer program that was ACS (American College of Surgeons) approved, 46.4% were a certified trauma center, 85.4% had an emergency department, and 42.4% had an associated medical school (42.4%). The majority had interventional radiology facilities (65.4%), endoscopic retrograde cholangiopancreatography facilities (68.5%), multi-slice <64 (73.3%), and 64+ (62.8%) spiral computerized tomography (CT) facilities, and single photon emission CT facilities (65.2%).

Hospital Characteristics Across Mortality Groups

After the categorization of hospitals by mortality rate, 546 hospitals (53.3%) belonged to the low mortality (LM) group, 124 (12.1%) to the medium mortality (MM) group, and 355 (34.6%) to the high mortality (HM) group. The categorization of hospitals by mortality group, with mortality rates specific to each

TABLE 1. Patient Characteristics According to Vital Status at End of Hospitalization

Variable	Total (N = 80969)	Vital Status at the end of Hospitalization: Alive (N = 79499)	IHM (N = 1470)	P
Age (y)	—	—	—	< 0.001
Mean ± SD	64.6 ± 12.57	64.4 ± 12.58	71.4 ± 10.31	—
Median	66.0	66.0	73.0	—
Sex	—	—	—	< 0.001
Male	42882 (53.0)	41944 (52.8)	938 (63.8)	—
Female	37975 (47.0)	37443 (47.2)	532 (36.2)	—
Race	—	—	—	0.013
White	57871 (83.7)	56850 (83.7)	1021 (83.1)	—
Black	3988 (5.8)	3895 (5.7)	93 (7.6)	—
Hispanic	3739 (5.4)	3673 (5.4)	66 (5.4)	—
Other	3553 (5.1)	3505 (5.2)	48 (3.9)	—
Primary Payer	—	—	—	< 0.001
Medicare	41869 (51.8)	40788 (51.4)	1081 (73.6)	—
Medicaid	3877 (4.8)	3817 (4.8)	60 (4.1)	—
Private/Other	35140 (43.4)	34812 (43.8)	328 (22.3)	—
Median Household Income	—	—	—	< 0.001
First Quartile	13758 (17.4)	13458 (17.3)	300 (20.8)	—
Second Quartile	18448 (23.3)	18065 (23.2)	383 (26.6)	—
Third Quartile	21055 (26.6)	20683 (26.6)	372 (25.8)	—
Fourth Quartile	26006 (32.8)	25620 (32.9)	386 (26.8)	—
Type of Surgery	—	—	—	< 0.001
Pancreatic	7716 (9.5)	7505 (9.4)	211 (14.4)	—
Esophageal	3515 (4.3)	3379 (4.3)	136 (9.3)	—
Rectal	25706 (31.7)	25473 (32.0)	233 (15.9)	—
Lung	34348 (42.4)	33617 (42.3)	731 (49.7)	—
Bladder	9684 (12.0)	9525 (12.0)	159 (10.8)	—
Elixhauser Comorbidities	—	—	—	< 0.001
0-1	32559 (40.2)	32272 (40.6)	287 (19.5)	—
2-3	34306 (42.4)	33727 (42.4)	579 (39.4)	—
> 3	14104 (17.4)	13500 (17.0)	604 (41.1)	—
Elixhauser CI	—	—	—	< 0.001
Mean ± SD	5.9 ± 8.92	5.7 ± 8.75	16.0 ± 11.87	—
Median	3.0	2.0	14.0	—
APR-DRG SOI Subclass	—	—	—	< 0.001
Minor loss of function	18640 (23.0)	18626 (23.4)	14 (1.0)	—
Moderate loss of function	33783 (41.7)	33714 (42.4)	69 (4.7)	—
Major loss of function	22225 (27.4)	22007 (27.7)	218 (14.8)	—
Extreme loss of function	6321 (7.8)	5152 (6.5)	1169 (79.5)	—

APR-DRG SOI: All Patient Refined Diagnosis Related Groups Severity of Illness.
IHM indicates In-hospital Mortality.

surgery type, is shown in Supplementary Table 2, Supplemental Digital Content 2, http://links.lww.com/SLA/E489.

Hospitals in the MM group had the highest median volumes (17.3 cases per day), the median number of hospitals (379), and intensive care unit beds (22). They were also the most likely to be a certified trauma center (59.7%), have an ACS-approved cancer program (71.8%), have an associated medical school (62.1%), have interventional radiology facilities (81.5%), a blood donor center (42.7%), electron beam (28.2%) and single photon emission CT (81.5%) facilities present. The MM group also had the lowest percentage of hospitals in rural settings (2.4%). The differences in hospital characteristics according to hospital mortality group are shown in Supplementary Table 3, Supplemental Digital Content 3, http://links.lww.com/SLA/E490.

Patient Characteristics Across Hospital Mortality Groups

Differences in patient characteristics across the LM, MM, and HM hospital groups are shown in Table 2. When analyzed according to surgery type, the rectal and bladder surgery subgroups had the highest percentage of patients operated at LM hospitals (57.2% and 52.9%, respectively). Hospitals in the HM group had significantly more patients on Medicare compared with MM and LM groups (53.9% vs. 49.8% and 51.7%, respectively; $P < 0.001$) and patients with a higher median Elixhauser comorbidity index score (3.0 vs. 2.0 for MM and LM; $P < 0.001$). There was a significantly ($P < 0.001$) lower percentage of patients in the fourth quartile of median household income among the HM hospitals (24.4%), as compared with MM hospitals (35.6%) and LM (38%).

Multivariable Analyses With Explained Variance

On multilevel logistic regression across all surgeries, IHM was associated with age (OR: 1.26 [95% CI: 1.21–1.31] for per 5 y older), Elixhauser score (OR 1.73 [95% CI 1.44–2.08] for 2-3 vs. 0-1; 4.31 [95% CI 3.59–5.19] for 4+ vs. 0-1), mean hospital volume (0.96 per 10 case increase [95% CI 0.93–0.99]), and type of surgery; Table 3. Individual subgroup regression analyses for each surgery type are shown in Supplementary Tables 4-8, Supplemental Digital Content 4, http://links.lww.com/SLA/E491, Supplemental Digital Content 5, http://links.lww.com/SLA/E492, Supplemental Digital Content 6, http://links.lww.com/SLA/E493, Supplemental Digital Content 7, http://links.lww.com/SLA/E494, Supplemental Digital Content 8, http://links.lww.com/SLA/E495. Notably, on multivariable analyses case volume was not associated with improved IHM for any of the surgery types on models limited to each surgery subgroup.

The distribution of variability in IHM attributable to hospital, patient, and unknown factors is shown in Figure 2. Hospital volume accounted for less variability in IHM than patient characteristics across all subgroups barring bladder surgery. It ranged from 7.6% and 7.7% in lung and rectal surgery to 23.2% and 29% in pancreatic and bladder surgery, respectively. Patient characteristics accounted for the greatest variability in IHM in esophageal (63%), pancreatic (62.9%), lung (44.4%), and rectal (41.2%) surgery. Hospital structural characteristics accounted for <20% of the variability in IHM across all subgroups. Importantly, unexplained variability in IHM was high in the lung (44.3%), bladder (39.3%), and rectal (33.7%) surgery subgroups and low in pancreatic (6%) and esophageal (4.8%) surgery.

DISCUSSION

In this study, we show that patient characteristics contribute most to in-hospital mortality (ranging from 19.5% in bladder surgery to 63% in esophageal surgery) for major organ surgery in the United States. Hospital case volume accounts for 7.7% to 29%, and hospital structural characteristics are between 3.6% to 17.4% of the variability in IHM. Importantly, more than a third of variability in IHM after rectal, lung, and bladder surgery remains unexplained.

Given that patient characteristics are the largest contributors to IHM after major organ surgery, health systems should focus on risk identification, risk stratification, and risk mitigation

TABLE 2. Patient Characteristics across Hospital Mortality Groups

Variable	Number of patients across hospital mortality groups			P
	Low (N = 26963)	Medium (N = 27948)	High (N = 26058)	
No. Hospitals	546	124	355	-
Age (y)	—	—	—	< 0.001†
Mean ± SD	64.7 ± 12.57	64.1 ± 12.66	64.9 ± 12.47	—
Median	66.0	65.0	66.0	—
Sex‡	—	—	—	< 0.013*
Male	14103 (52.4)	14803 (53.0)	13976 (53.7)	—
Female	12809 (47.6)	13109 (47.0)	12057 (46.3)	—
Race‡	—	—	—	< 0.001*
White	19575 (83.5)	20464 (83.8)	17832 (83.7)	—
Black	1295 (5.5)	1290 (5.3)	1403 (6.6)	—
Hispanic	1314 (5.6)	1332 (5.5)	1093 (5.1)	—
Other	1259 (5.4)	1330 (5.4)	964 (4.5)	—
Race	(dicho-	tomized)‡	—	—
—	0.62*			
White	19575 (83.5)	20464 (83.8)	17832 (83.7)	—
Non-White	3868 (16.5)	3952 (16.2)	3460 (16.3)	—
Primary Payer‡	—	—	—	< 0.001*
Medicare	13931 (51.7)	13920 (49.8)	14018 (53.9)	—
Medicaid	1309 (4.9)	1235 (4.4)	1333 (5.1)	—
Private/Other	11684 (43.4)	12776 (45.7)	10680 (41.0)	—
Median Household Income‡	—	—	—	< 0.001*
First Quartile	4101 (15.6)	4113 (15.0)	5544 (21.8)	—
Second Quartile	5661 (21.5)	5966 (21.8)	6821 (26.8)	—
Third Quartile	6567 (24.9)	7596 (27.7)	6892 (27.0)	—
Fourth Quartile	10024 (38.0)	9751 (35.6)	6231 (24.4)	—
Type of Surgery	—	—	—	< 0.001*
Pancreatic	2301 (8.5)	3223 (11.5)	2192 (8.4)	
Esophageal	928 (3.4)	1681 (6.0)	906 (3.5)	—
Rectal	9424 (35.0)	7841 (28.1)	8441 (32.4)	—
Lung	11135 (41.3)	11652 (41.7)	11561 (44.4)	—
Bladder	3175 (11.8)	3551 (12.7)	2958 (11.4)	—
Elixhauser CI	—	—	—	< 0.001†
Mean ± SD	5.6 ± 8.61	5.9 ± 8.93	6.2 ± 9.21	—
Median	2.0	2.0	3.0	—

*χ^2 *P* value.
†Kruskal-Wallis *P* value.
‡those missing were excluded from analysis.
CI indicates Comorbidity Index.

to decrease postoperative mortality. Although the urgency of many operations limits the ability to make meaningful changes in patient functional status and health before surgery, the increasing use of neo-adjuvant therapy for patients with cancer presents a window of opportunity in many cases. Even short-term changes in behavior, such as smoking cessation, are associated with positive outcomes. Several efforts in this regard are notable. Patient prehabilitation (targeted physical and psychological optimization of modifiable risk factors before surgery) has been shown to improve postoperative outcomes, including morbidity, IHM, hospital length of stay, patient quality of life, recovery times, and the need for further intervention.[33] However, widespread formal implementation is challenging and requires coordination between patients, social services, and the medical system. One archetype of a successful prehabilitation initiative is the Strong for Surgery program, which was initially launched at the University of Washington in 2012 and subsequently assimilated by the American College of Surgeons (ACS) as an ACS Quality program.[34] Currently adopted by more than 200 hospitals in the US, Strong for Surgery engages diverse stakeholders in health care systems, including patients themselves, to achieve patient optimization before surgery.[34] Prehabilitation is also an important component of Enhanced Recovery after Surgery (ERAS) programs, which have gained traction across hospitals in the United States over the last 2 decades and have been shown to improve outcomes.[35–37]

Our findings also highlight the contribution of hospital structural characteristics to variability in IHM, particularly in rectal (17.4%), esophageal (16.9%), and bladder (12.2%) surgery. The presence of sophisticated clinical services in hospitals has been identified as an important mediator of the volume-IHM relationship.[3] Mortality rates in hospitals are determined not only by the incidence of complications but also by hospitals' capacity to manage postoperative complications effectively, with "failure to rescue" being a feature of hospitals with high IHM.[38,39] Hospital characteristics are a major determinant of failure to rescue, as they determine which hospitals are better equipped to detect and manage serious postoperative complications. These include hospital structural factors such as equipment and technology, ICU capacity and care models, staffing models, teaching status, as well as human resources such as the availability of intensivists, rapid response teams, nurse practitioners, and physician assistants.[40,41] For example, the presence of a dedicated cancer program has been shown to better predict IHM than volume or other hospital characteristics.[42] While certain baseline hospital structural characteristics may be considered prerequisites for performing complex operations, the implementation and economic viability of such changes at the level of individual hospitals may be challenging. In the interim, other options to improve outcomes, such as the triage of higher-risk patients to better-resourced hospitals, should be considered.[43]

Another important consideration often under-appreciated by policymakers is patient preference. In a classic study, Finlayson et al showed that even when the mortality risk after surgery was double at a local center, 45% of patients would still prefer to stay rather than travel regionally to a center with half the mortality risk.[44] Similarly, the majority of patients undergoing gastrectomy in the state of California did so at hospitals closest to their residence, with no evidence of decision-making being driven by evidence.[45] In another study, 74% of patients reported barriers to traveling, most commonly financial and insurance coverage. Yet the majority signaled a willingness to travel if some of these barriers could be addressed.[46] In aggregate, these studies suggest that successful implementation of the volume-outcome association will need to remove barriers to equitable access.

Our data also brings into question whether policy based on arbitrary case volume thresholds, such as those proposed in the Volume Pledge, should be used as the primary basis for quality improvement. According to the current case volume thresholds, more than 70% of hospitals across the country would be ineligible to perform complex surgery of the esophagus, pancreas, rectum, or lung.[18,26] Prescriptive implementation of volume thresholds to promote centralization may exacerbate serious inequalities in access to health care and care fragmentation, particularly for minority and disadvantaged groups.[28,47,48] Focus on hospital case volume is an attempt to improve outcomes by increasing case volume as a tangible, actionable quality improvement measure. However, as the past 2 decades and further research have demonstrated, this does not account for patient preferences, access barriers, and insurance referral patterns. Although there is no

TABLE 3. Multi-Level Logistic Regression for In-hospital Mortality (IHM)

Variable	Comparison	Model 1 OR 95% CI	Model 1 P	Model 2 OR 95% CI	Model 2 P	Model 3 OR 95% CI	Model 3 P
Age	Per 5 y	1.20 (1.15–1.25)	< 0.001	1.20 (1.15–1.24)	< 0.001	1.20 (1.15–1.26)	< 0.001
Sex	Female vs. Male	0.91 (0.79–1.03)	0.14	0.90 (0.79–1.03)	0.13	0.91 (0.79–1.05)	0.18
Race	White vs. Non-white	0.82 (0.69–0.98)	0.03	0.83 (0.70–0.98)	0.03	0.85 (0.70–1.02)	0.08
Insurance	Medicaid vs. Private/others	1.08 (0.76–1.53)	0.66	1.08 (0.76–1.54)	0.65	1.27 (0.89–1.82)	0.19
	Medicare vs. Private/others	1.00 (0.83–1.19)	0.96	1.00 (0.83–1.19)	0.97	1.02 (0.84–1.23)	0.85
APR-DRG Severity	Per 1 level increase	13.93 (12.38–15.66)	< 0.001	13.86 (12.32–15.59)	< 0.001	13.97 (12.30–15.87)	< 0.001
Cancer type	Bladder vs. Rectal	0.74 (0.58–0.95)	0.02	0.76 (0.59–0.96)	0.02	0.74 (0.57–0.96)	0.02
	Esophageal vs. Rectal	1.23 (0.95–1.60)	0.12	1.26 (0.96–1.64)	0.09	1.34 (1.02–1.78)	0.04
	Lung vs. Rectal	2.02 (1.69–2.41)	< 0.001	2.01 (1.69–2.41)	< 0.001	2.02 (1.66–2.45)	< 0.001
	Pancreatic vs. Rectal	1.29 (1.03–1.61)	0.03	1.32 (1.06–1.65)	0.02	1.33 (1.04–1.70)	0.02
Mean volume	Per 10 procedure increase	—	—	0.97 (0.95–1.00)	0.02	0.97 (0.94–1.00)	0.06
Hospital control	For profit vs. Government	—	—	—	—	1.06 (0.46–2.45)	0.89
	Non-government/Not for profit	—	—	—	—	0.95 (0.75–1.20)	0.66
Hospital region (NIS)	NE vs. W	—	—	—	—	1.04 (0.83–1.30)	0.74
	MW vs. W	—	—	—	—	0.79 (0.60–1.05)	0.11
	S vs. W	—	—	—	—	0.98 (0.79–1.21)	0.83
Physician FTE/bed	Per 1 FTE increase per bed	—	—	—	—	0.99 (0.82–1.19)	0.88
RN hours per patient day	Per 1 h increase per patient day	—	—	—	—	0.99 (0.96–1.03)	0.61
% variability explained		33.8%		34.8%		47.7%	

Model 1: Patient characteristics
Model 2: Patient characteristics + Hospital Volume.
Model 3: Patient characteristics + Hospital Volume + Hospital Structural Characteristics.
APR-DRG SOI indicates All Patient Refined Diagnosis Related Groups Severity of Illness Subclass; CI, confidence interval; FTE, Full-Time Equivalent; H/PD, hour/patient day (Model 1, Patient characteristics; NGO, Non-Government Organization; OR, odds ratio; RN, Registered Nurse.

question that there is a signal associated with volume and outcomes, we believe too much emphasis has been placed on actual case numbers rather than a holistic approach to identify other areas of improvement.

A more effective and potentially more equitable policy would focus on patient prehabilitation and improving hospital resources. Other unexplained sources of variability should also be identified and are likely related to variables that are difficult to capture in large databases, such as a hospital culture of safety, continuous quality improvement implementation, and complex interactions between comorbidities, surgery, and outcomes. These can be better studied with the analysis of institutional data sets with higher clinical granularity, strengthened by artificial intelligence methods such as natural language processing and machine learning.[49]

Our study has limitations that must be acknowledged. Firstly, IHM being the only outcome explored in our study precludes the extrapolation of our findings to other outcomes such as 30- or 90-day mortality. The proportions of attributable variation in mortality may be different for these endpoints. Secondly, the data presented in this study may not be reflective of contemporary trends as the NIS allows volume analyses only

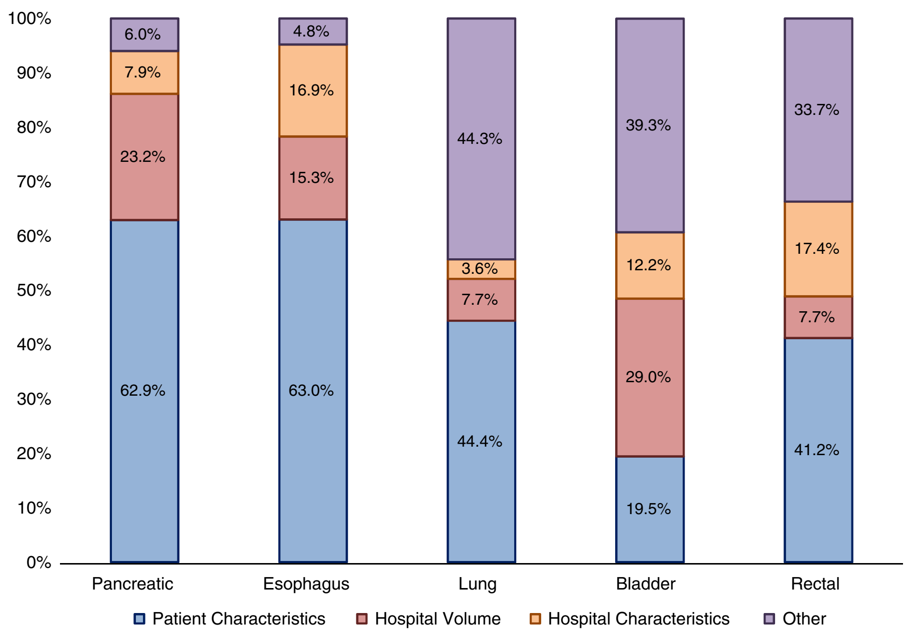

FIGURE 2. Distribution of attributable variability in mortality across the types of major surgery.

until the 2012 data set. The lack of clinical granularity precludes more in-depth or detailed analyses. In particular, the use of Elixhauser Index or APR-DRG categories for risk adjustment leaves the potential for confounding factors not included in the data and residual selection bias. One example is the lack of pathologic information; hence we are unable to distinguish between cancer and non-cancer operations. It is likely that there would be some *a priori* differences in patients undergoing operations for benign versus malignant conditions. This limitation is inherent in the use of large data sets for observational studies. Nevertheless, limiting the study population to only those patients undergoing elective surgery helps to control for what is likely the major source of selection bias in this population.

CONCLUSION

Although the last few decades have seen much emphasis placed on the volume-outcome relationship for complex surgery in the US, case volume was not the most important contributor to IHM after pancreatic, lung, bladder, rectal, or esophageal surgery. In fact, most of the variability in IHM was attributable to patient characteristics, and to a lesser extent, hospital structural characteristics, and resources. In addition, considerable variability remained unexplained, particularly for lung, bladder, and rectal surgeries. We believe these observations highlight the need to reconsider the emphasis on hospital case volume and pivot to patient optimization and structural improvements to hospitals, in addition to investigating the yet unexplained sources contributing to IHM.

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