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# Development of a Clinically Actionable Incisional Hernia Risk Model after Colectomy Using the Healthcare Cost and Utilization Project



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**BACKGROUND:** Incisional hernia remains a persistent and burdensome complication after colectomy. Through individualized risk-assessment and prediction models, we aimed to improve preoperative risk counseling for patients undergoing colectomy; identify modifiable preoperative risk factors; and encourage the use of evidence-based risk-prediction instruments in the clinical setting.

**STUDY DESIGN:** A retrospective review of the Healthcare Cost and Utilization Project data was conducted for all patients undergoing either open or laparoscopic colectomy as identified through the state inpatient databases of California, Florida, and New York in 2009. Incidence of incisional hernia repair was collected from both the state inpatient databases and the state ambulatory surgery and services databases in the 3 states between index surgery and 2011. Hernia risk was calculated with multivariable hierarchical logistic regression modeling and validated using bootstrapping techniques. Exclusion criteria included concurrent hernia, metastasis, mortality, and age younger than 18 years. Inflation-adjusted expenditure estimates were calculated.

**RESULTS:** Overall, 30,741 patients underwent colectomy, one-third of these procedures performed laparoscopically. Incisional hernia repair was performed in 2,563 patients (8.3%) (27-month follow-up). Fourteen significant risk factors were identified, including open surgery (odds ratio = 1.49;  $p < 0.0001$ ), obesity (odds ratio = 1.49;  $p < 0.0001$ ), and alcohol abuse (odds ratio = 1.39;  $p = 0.010$ ). Extreme-risk patients experienced the highest incidence of incisional hernia (19.8%) vs low-risk patients (3.9%) (C-statistic = 0.67).

**CONCLUSIONS:** We present a clinically actionable model of incisional hernia using all-payer claims after colectomy. The data presented can structure preoperative risk counseling, identify modifiable patient-specific risk factors, and advance the field of risk prediction using claims data. (J Am Coll Surg 2017;225:274–284. © 2017 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

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Incisional hernia (IH) remains a significant postoperative complication, carrying with it excessive morbidity and a profound financial healthcare burden. More than 2 million patients undergo abdominal surgery in the US annually, and 300,000 experience an IH necessitating surgical treatment.<sup>1,2</sup> With continued rising costs of healthcare in the US in excess of \$2.8 trillion, and costs anticipated to approach 20% of the Gross Domestic Product by 2020, there is a need for effective cost-conscious healthcare delivery.<sup>3,4</sup> Specifically, the estimated healthcare expenditures related to hernias in the US increased 52% from 2007 to 2011, accounting for an estimated \$7.3 billion annually.<sup>5</sup> Despite techniques such as muscle flaps, mesh reinforcement, and optimized suture selection, IH remains a challenge with reported

**Abbreviations and Acronyms**

|      |   |
|------|---|
| HCUP | = Healthcare Cost and Utilization Project |
| IH   | = incisional hernia                       |
| OR   | = odds ratio                              |
| PMP  | = prophylactic mesh placement             |
| SID  | = state inpatient database                |

incidences approaching 40% after elective midline laparotomy.<sup>6-10</sup>

Colon resection, in particular, carries considerable risk for postoperative IH, and has been cited to be as high as 35% after colectomy.<sup>11</sup> Although hernia is a recognizable dilemma after colectomy, there remains limited data evaluating long-term outcomes related to IH.<sup>12-17</sup> In addition, despite the perceived popularity of minimally invasive surgery and laparoscopic colectomy, the use of open colectomy remains common, with only a slight decline from 48% to 40% from 2000 to 2011. Identifying higher-risk patients undergoing colectomy remains a critical and clinically relevant opportunity to mitigate risk through identification of modifiable risk factors.<sup>18</sup>

Despite the clear public health benefits for reducing risk of IH, few studies have examined IH as a target for quality improvement in the field of colorectal surgery. Due to the delay in onset of the problem and frequent surgical care fragmentation, IH remains difficult to track and study, and, consequently, occurrences have been historically underestimated and poorly defined.<sup>19,20</sup> Given the pervasiveness of hernia after abdominal surgery and the volume of colon resections performed annually, there is a pressing need to develop usable risk-assessment models capable of being translated into clinical practice.<sup>21</sup> In effort to address the understudied problem of IH, as it pertains to elective open and laparoscopic colon resection, we propose a novel study approach using claims data to track patients across encounters in multiple states using the state-level, visit-linked inpatient Healthcare Cost and Utilization Project (HCUP) data. Through risk-assessment and prediction models, we aim to delineate the clear need for improved preoperative risk counseling; identify modifiable perioperative risk factors in patients undergoing elective colon resection; and encourage the use of evidence-based risk-prediction instruments in the clinical setting.

**METHODS****Study design**

We conducted a retrospective cohort study using administrative data from the 2007 through 2011 California, Florida, and New York state inpatient databases

(SID).<sup>22</sup> These data are compiled at the state-level from administrative, clinical, and billing information standardized across states, and made publically available through the HCUP.<sup>23</sup> The inpatient databases are a census of discharges from all acute care, nonfederal, community hospitals. These chosen states were selected for analysis because of their geographic diversity; availability of encrypted identifiers allowing for the longitudinal study of patients' healthcare use, including readmissions; and their large populations, which collectively accounted for 24.4% of the US adult population in 2010.<sup>24</sup> Importantly, because these are state databases, we are able to capture outcomes of readmissions and costs across different hospitals, not only those that occur at the index hospitalization of the procedure.

History of abdominal operations and IH were obtained from the SID in the 2 states between 2007 and the colectomy. All additional abdominal procedures were collected from the SID from the 3 states between index operations performed in 2009 and repair of IH (or end of 2011, if no repair). Patients were identified and selected using ICD-9 diagnostic and procedure codes (Table 1). Patients with an earlier diagnosis of IH or those who underwent IH repair before, or concurrently with, the index procedure were excluded from the study.

Additionally, to evaluate a hospital's costs of providing care, we added the total hospital costs from the initial inpatient encounter with costs incurred during all subsequent hospital readmissions that met our criteria. These costs were then converted to costs using the HCUP cost-to-charge ratio file and adjusted for inflation to 2010 US dollars using the medical component of the Consumer Price Index. Similar to the hospital readmission measure, hospital cost assessment was limited to those patients who survived the hospitalization.<sup>25,26</sup>

**Data collection**

Patient characteristics including state, age, race, sex, income based on ZIP code, emergency admission, admission source, and insurance status were determined from information directly provided in the SID. Patient comorbidities were assigned using ICD-9 codes. In addition to the inclusion of factors known to be associated with IH risk, an enhanced Elixhauser algorithm was used, as described by Quan and colleagues,<sup>27</sup> which identifies 31 chronic medical conditions, supplemented with other relevant diagnostic codes.<sup>28</sup> A condition was considered to be present on admission if it was listed as a diagnosis during a hospitalization at any point in the 24 months preceding surgery.

Demographic information and concurrent comorbidities from Elixhauser indices were obtained from the

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