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Care fragmentation is associated with increased short-term mortality during postoperative readmissions: A systematic review and meta-analysis

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ABSTRACT

Background: Recent trends toward regionalization of complex surgical procedures may increase the risk for care fragmentation during readmissions. Conflicting conclusions have been reported regarding risk factors and consequences of nonindex readmissions (ie, readmission to a separate hospital than the one where surgery was originally performed). We seek to perform a comprehensive review of existing literature.
Methods: Four electronic databases were searched to identify all eligible studies examining the risk factors and outcomes of postoperative nonindex readmission. The pooled odds ratio and 95% confidence interval were calculated using a random-effects model.
Results: A total of 444 studies were retrieved from database searches and 23 were included after applying eligibility criteria. Nonindex readmissions constituted 10%–47% of 30-day readmissions. Risk factors for nonindex readmission predominantly represented proxy variables for patient care access that may not be modifiable, such as residing in a location further away from the original hospital, being older in age, living in rural areas, and having lower income. Nonindex readmissions occurred more commonly under urgent conditions. Ten of the 14 studies that employed short-term mortality as the primary outcome concluded that nonindex readmissions were significantly associated with higher mortality after adjusting for available confounders.
Conclusion: The findings of the current study suggest that nonindex readmission is a common phenomenon after surgery and is associated with increased mortality. Further studies are required to evaluate whether enhancing health information continuity between hospitals would be helpful for mitigating the adverse consequences of care fragmentation.

Introduction

Demonstration of positive correlations between perioperative outcomes and operative volume in recent literature[15–18] has served as the major impetus for regionalization, whereby patients are increasingly being referred to tertiary medical centers in lieu of local hospitals for complex and major operations in the United States.[19,20] A primary concern with the regionalization model is its detrimental effect on continuity of care after discharge. Many patients travel long distances to receive surgery and may not have access to the original hospital when urgent complications occur.[21,22] Given that most health systems do not yet share electronic medical records,[23] physicians managing patients who receive surgery at outlying hospitals are frequently not provided with information about prior issues and services relevant to patients' current care.[24] This lack of care continuity (ie, care fragmentation) may be especially pronounced after complex operations, where lack of familiarity with the anticipated postoperative course might be an obstacle to appropriate and efficient care.[25]

Although there is extensive literature addressing risk factors for postoperative readmission,[26,27] limited data are available regarding the epidemiology and consequences of care fragmentation during postoperative rehospitalizations. Existing reports are contradictory

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regarding the significance of particular risk factors, and prognostic implications of care fragmentation are contradictory in the existing literature.[5,7,28,29] The disagreements among these studies may be related to the nature of the particular procedure of interest and the limitations associated with the data sources. We hypothesized that a pooled analysis of adequately adjusted studies would be able to demonstrate inferior outcomes associated with postoperative care fragmentation. To comprehensively assess the effect of care fragmentation on postoperative readmission outcomes, we performed a systematic review and meta-analysis of relevant studies, examining the association between nonindex readmissions and short-term mortality in patients who underwent surgery.

Methods

Data source and search strategy

We performed a systematic review according to guidelines described in the Cochrane Collaboration Handbook.[30]. The primary question of interest was whether nonindex readmission was associated with increased risk of adverse outcomes after surgery. Nonindex readmission was defined as rehospitalization after surgery to a facility that is different from where the original surgery was performed. A search strategy was designed and implemented to capture all relevant studies from the available literature. The following electronic databases were searched from their date of establishment to February 2018: PubMed, Scopus, Web of Science, and Google Scholar. The search strategy was tailored to each database and used a combination of search terms to capture two key concepts: *surgery* and *care fragmentation*. Three reviewers (Y.J., B.C., and U.K.) independently screened the resulting titles and abstracts so that each citation was reviewed by at least two reviewers. Full text articles for titles and abstracts marked as relevant by any of the three reviewers were retrieved. The predetermined inclusion and exclusion criteria were applied to the resulting list of full-text articles by these three researchers, following a similar process. The reference lists from any identified full-text articles were also screened for relevant studies, reducing the possibility of missing studies. Studies were finalized for inclusion in the systematic review after discussion with a fourth reviewer (Y.S.). Disagreements were adjudicated by collaborative discussion. We used Mendeley (Elsevier, Amsterdam, Netherlands) to organize citations.

Article eligibility and selection criteria

To be included in the systematic review, studies had to meet several inclusion criteria. Only original research reports, including both full publication and conference abstracts, were considered. The study population had to include surgical patients who received surgery and were readmitted to hospitals in the United States. In addition, patients had to be stratified based on whether their readmission occurred at the original hospital where they received surgery (ie, index readmission) or a different hospital (ie, nonindex readmission). No restriction was placed on study year or language. Studies describing either outcomes or risk factors for nonindex readmission after surgery were both included.

Data synthesis

Two reviewers independently extracted the following data from the included studies: authors, year, surgical procedure, data source, data collection years, 30-day readmission rate, number of readmitted patients, nonindex readmission incidence, outcome parameters examined, risk factors for nonindex readmission, whether significant differences in baseline mortality risk were found among comparison groups, and whether the authors concluded a positive association between nonindex readmission and elevated short-term mortality.

The primary outcome of interest was short-term mortality, defined as either inhospital mortality during readmission or mortality within 30 days of index surgery. Secondary outcomes of interest included readmission length of stay, hospitalization cost, and risk of repeat readmissions.

Evaluation of risk of bias

We used the Risk Of Bias in Non-Randomized Studies of Interventions (ROBINS-I) tool developed by Sterne et al.[31] to assess the quality of the studies that reported conclusions regarding the association between nonindex readmission and short-term mortality. The broad categories for risk of bias in ROBIN-I were interpreted in the context of the current research question, in which the “exposure variable” refers to nonindex readmission and the “outcome” refers to short-term mortality. Risk levels were categorized as low, moderate, high, or serious for each of the seven domains of risk of bias specified in ROBINS-I. The lower the designated risk level a study has, the better quality its methodology is. Two reviewers (Y.J. and Y.S.) performed independent, unmasked risk of bias assessment. Disagreements were resolved via in-person discussion.

Statistical analysis

During systematic review, a descriptive synthesis of the incidence, risk factors, and outcomes associated with nonindex readmission was performed. In addition, studies with an explicit report of adjusted odds ratios for short-term mortality associated with nonindex readmissions were included for meta-analysis. Adjusted odds ratios from included studies were pooled using the Mantel-Haenszel Odds Ratio with 95% confidence interval. Statistical heterogeneity of effect was assessed using the Higgins I^2 statistic. Random effects were assumed for the meta-analysis. Meta-analysis data were stored and analyzed using Stata 13.0 software (StataCorp, College Station, TX).

Results

Summary of included studies

A total of 444 studies were retrieved from database searches. After title and abstract screening, 82 remained for full-text evaluation, after which 23 studies were included for systematic review. The study selection process is summarized in a PRISMA flowchart (Fig 1).

Other than two studies representing institutional case series with sample size less than 150,[8,32] most studies represented population-based analyses of either statewide[11–14,33–37] or national databases.[1–4,7,10,28,38–40] Although no restrictions were placed on study type, all included studies relevant to postoperative care fragmentation were retrospective cohort studies. Characteristics of the included studies are presented in Table 1.

Initial hospitalization characteristics

A total of 1,689,934 readmitted surgical patients were captured by the conglomerate of included studies, with a pooled 20.3% (343,292/1,689,934) nonindex readmission rate. Nonindex readmissions constituted 10.2%–47% of 30-day readmissions, with only one study[8] reporting an exceptionally high nonindex readmission rate of 79%. Nonindex readmission rate was higher after elective procedures, up to 47% after pancreaticoduodenectomies and 37.4% after head and neck cancer surgeries.[34,36,40] However, there was no obvious association between 30-day readmission rate and nonindex

Table 1
Overview of included studies.

Authors	Year	Procedure	Data source	Data collection years	Number of readmitted patients (persons)	Number of nonindex readmissions (persons)	Outcomes	Conclusions: Higher in-hospital mortality among nonindex readmissions?
Brooke et al.[1]	2015	12 high-risk surgeries	100% Medicare database	2001–2011	1,388,022	276,976 (20.0%)	90-day mortality, in-hospital mortality	Yes
Burke et al.[2]	2018	Both medical and surgical patients were described, including CABG~ and THA/TKA+	NRD	2013	Did not provide specific data for postsurgical patients	Did not provide specific data for postsurgical patients	In-hospital mortality, LOS	Yes
Chappidi et al.[38]	2017	Urology oncologic surgeries	NRD	2013	6,927	1,618 (23.4%)	N/A	N/A
Chappidi et al.[7]	2017	Radical Cystectomy	NRD	2013	2,018	571 (28.3%)	In-hospital mortality, cost, readmissions	No
Cloyd et al.[36]	2017	Colorectal surgery	OSHPD	2008–2012	14,401	3,511 (24.4%)	N/A	N/A
Dexter et al.[39]	2017	Surgical diagnoses	NRD	2013	4,166	971 (23.3%)	N/A	N/A
Glebova et al.[8]	2014	Complex aneurysm repair	Johns Hopkins institutional database	2002–2013	33	26 (78.8%)	In-hospital mortality, cost	No
Gore et al.[28]	2011	Urinary diversion	5% Medicare database	1998–2005	468	165 (35.3%)	90-day, 2-year mortality	Yes
Graboyes et al.[9]	2016	Head and neck cancer surgery	California SID	2008–2010	561	210 (37.4%)	In-hospital mortality, LOS	Yes
Havens et al.[10]	2017	Emergency general surgery	Medicare inpatient database	2008–2011	109,443	20,396 (18.6%)	30-day mortality	Yes
Hua et al.[11]	2017	Critical Illness, including postoperative conditions	SPARCS	2008–2013	14,463	4787 (33.1%)	In-hospital mortality, LOS, cost	Yes
Justiniano et al.[12]	2017	Colorectal surgery	SPARCS	2004–2014	20,016	2,683 (13.4%)	30-day mortality	Yes
Justiniano et al.[34]	2017	Colorectal surgery	SPARCS	2004–2014	20,016	2,683 (13.4%)	1-year overall survival, cancer-specific survival	Yes
Kothari et al.[13]	2017	Liver transplantation	Florida and California SID	2006–2011	7,584	1,236 (16.5%)	30-day mortality, readmission	Yes
Pak et al.[14]	2015	Radical Cystectomy	SPARCS	2009–2012	658	129 (19.6%)	30- and 90-day mortality, LOS, cost, readmission	Yes
Rattan et al.[40]	2017	Colorectal Surgery	NRD	2013–2014	5,591	569 (10.2%)	N/A	N/A
Ryoo et al.[37]	2009	Gastric resection	OSHPD	2994–2004	3,172	837 (26.4%)	1-year mortality	Yes
Saunders et al.[3]	2014	Abdominal Aortic Aneurysm Repair	CMS Chronic Conditions Warehouse	2009-2009	885	259 (29.3%)	In-hospital mortality, cost	No
Stitzenberg et al.[4]	2017	Major cancer surgery	Linked SEER–Medicare Database	2001–2007	7,903	2,634 (33.3%)	In-hospital and 90-day mortality	No
Tosoian et al.[41]	2014	Pancreatectomy	Linked Johns Hopkins institutional database–Maryland statewide database	2005–2010	134	29 (21.6%)	N/A	N/A
Tsai et al.[5]	2015	Major surgeries	Medicare inpatient database	2009–2011	93,062	23,278 (25.0%)	30-day mortality	Yes
Yermilove et al.	2009	Pancreateicoduod enectomy	Linked California Cancer Registry–OSHPD	1994–2003	1,194	561 (47.0%)	N/A	N/A
Zheng et al.[6]	2016	Major cancer surgeries	California SID	2004–2011	9,233	1,846 (20.0%)	In-hospital mortality, readmission	Yes

CABG, coronary artery bypass graft; *THA/TKA*, total hip arthroplasty/total knee arthroplasty; *LOS*, length of stay; *N/A*, not applicable, study did not report readmission outcome; *NRD*, nationwide readmissions database; *OSHPD*, California Office of Statewide Health Planning and Development; *SID*, State Inpatient Database; *SPARCS*, New York Statewide Planning and Research Cooperative System; *CMS*, Center for Medicare and Medicaid Services; *SEER*, Surveillance, Epidemiology, and End Results.

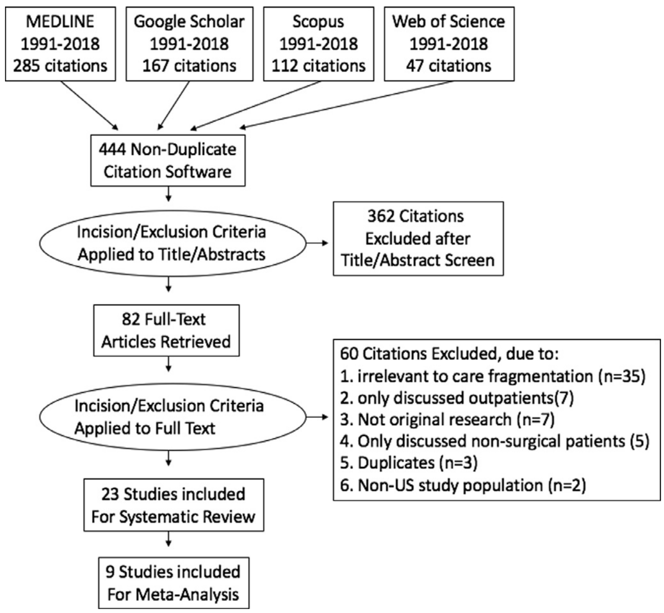

Fig. 1. PRISMA flowchart of the study selection process. A total of 444 studies were retrieved from database searches. After title and abstract screening, 82 remained for full-text evaluation, after which 23 studies were included for systematic review.

readmission incidence when stratified by procedure type (Fig 2; Supplementary Table 1).

Nearly 50% of the included studies reported discrepant baseline mortality risks between patients being readmitted to index and nonindex hospitals.[1,4,6,11,14,34–36,39–41] Patients with nonindex readmission were generally older,[4,6,7,13,14,34,40] had more baseline comorbidities,[4,6,14,34,36] resided in rural or less populated areas[1,6,7] and households with lower income.[4,40] Furthermore, patients who experienced longer length of stay,[4,7,9,28,36] postoperative complications[34,36] or nonhome discharge disposition[7,9,34,36,39] during the initial hospitalization were more likely to be hospitalized at a nonindex facility during readmission. The remainder of investigations either did not report patient risk factors for nonindex readmission[2,12,37] or did not identify baseline differences between the two comparison groups.[3,5,8,13,28,38,42]

Interestingly, greater travel distance between patient residence and initial hospital was identified as the most influential factor predicting subsequent nonindex readmission among many studies.[1,3,5,11,36,42] Havens et al reported that patients who lived at least 8 miles from the index hospital were more likely to undergo readmission to a nonindex hospital than patients living within 8 miles.[42] Cloyd et al reported that the odds of nonindex readmission began to increase significantly when patients lived more than 10 miles away from the index hospital.[36] Tsai et al have found that patients who had nonindex readmission lived a mean 20.7 miles away from the index hospital compared with 7.4 miles among patients with index readmissions.[5]

Substantial conflict existed between studies regarding index hospital characteristics predicting subsequent nonindex readmissions. On the one hand, several studies reported that surgery at small,[2,40] nonteaching[2,3] hospitals were more likely to be followed by nonindex readmissions, and other studies indicated that nonindex readmissions happened more commonly after surgery at large,[1,9,10] high-volume,[4,40] high fill rate (>80%),[6] well-staffed,[1] teaching,[1,10] safety-net[10] hospitals.

Readmission characteristics

Indications for nonindex readmissions were significantly different from index readmissions. Studies consistently found that patients were more likely to undergo nonindex readmission for

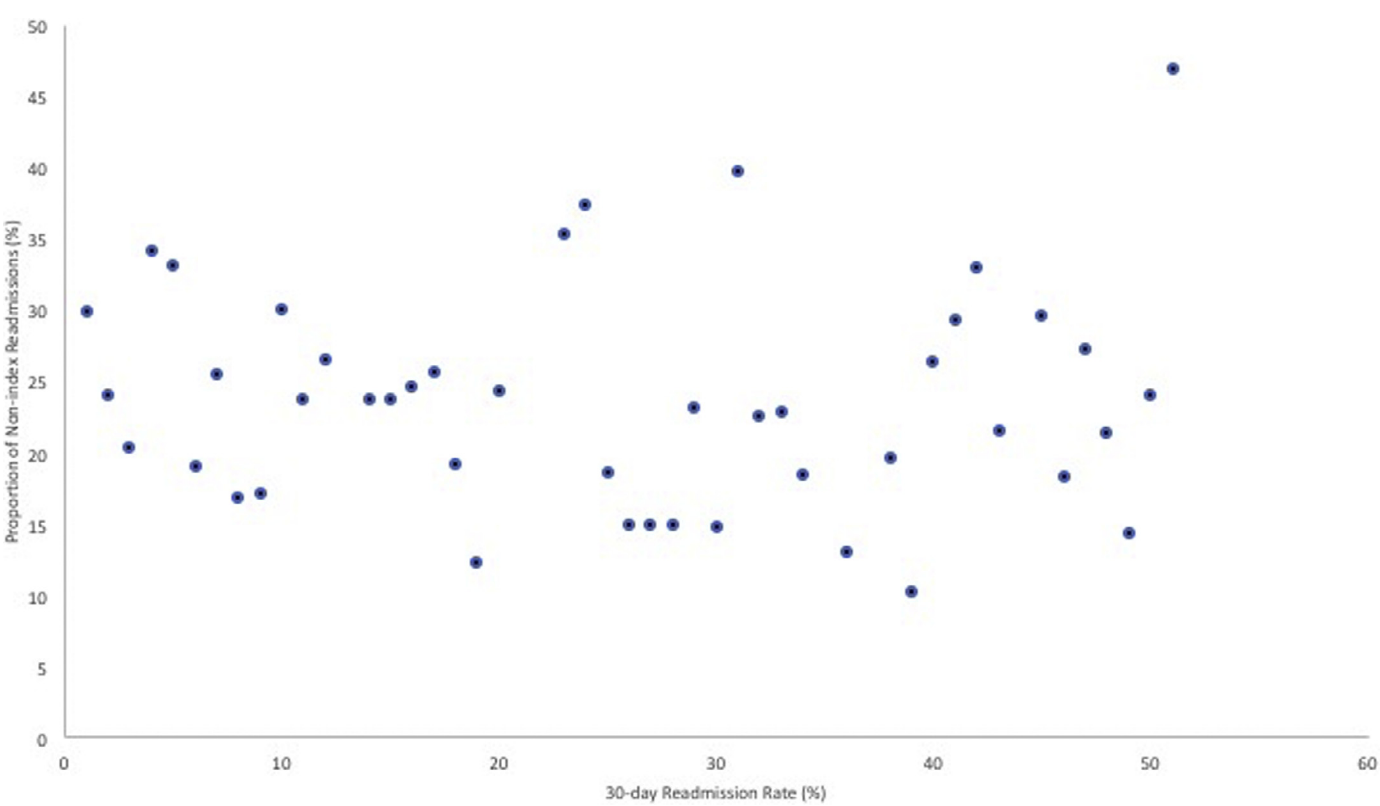

Fig. 2. Scatterplot of relationship between 30-day readmission rate and nonindex readmission rate. No obvious association between 30-day readmission rate and nonindex readmission incidence were found after stratification by procedure type.

medical complications, such as pneumonia and myocardial infarction, and index readmissions were more commonly associated with surgical complications.[1,3,4,8,9,11,13,43] Moreover, nonindex readmissions were more likely to occur for urgent or emergent indications.[1,3,6] The average time interval to nonindex readmission was found to be longer than index readmissions.[1,6,7,13,14,34]

Contradictions between studies existed regarding characteristics of the readmission destination. Hua et al.[11] and Zheng et al.[6] reported nonindex facilities to be smaller, nonteaching hospitals with fewer beds. On the other hand, Brooke et al.[1] found these attributes to be associated with index facilities. Finally, Burke et al.[2] and Chappidi et al.[38] found no significant differences in hospital characteristics between index and nonindex readmission destinations.

Primary outcome: Short-term mortality

Of the 14 studies[1–14] that employed in-hospital or 30-day mortality as the primary outcome, the majority concluded that nonindex readmissions were significantly associated with higher mortality after adjusting for available confounders,[1,2,5,6,9–14] although Pak et al found this association to vanish after accounting for an increasingly robust inclusion of variables in their model.[14] Although no study reported improved outcomes after nonindex readmissions, there were 4 that studies found no significant difference between nonindex and index readmission patients.[3,4,7,8]

Of these, a total of 9 studies reported an adjusted odds ratio for short-term mortality, defined as 30-day or in-hospital mortality, in a uniform manner to allow for pooled statistical synthesis. Other than studies that did not examine short-term mortality, studies were excluded from meta-analysis if they did not report results of adjusted analysis,[1] perform adjusted analyses for short-term mortality,[3,4] have observed zero 30-day mortality in both groups,[8] or reported effect estimates other than adjusted odds ratio.[11] Results of our pooled analyses showed that nonindex readmission was associated with an odds ratio of 1.18 (95% confidence interval 1.15–1.21) for short-term mortality (Fig 3). However, statistical heterogeneity was considered high with a Higgins I^2 statistic of 93.6%, which was likely a result of the disparate sample sizes between studies.

Secondary outcomes: Longer-term mortality, readmission length-of-stay, costs, repeated readmissions

Mid-term mortality, such as 90-day[1] or 1-year,[4,34,37] was also found to be higher among patients with nonindex readmissions. Nonindex readmission was reportedly associated with longer readmission length of stay,[2,10] higher risk of subsequent readmissions,[6,13] more cardiology and radiology testing,[11] and higher hospitalization costs.[40]

On the contrary, Glebova et al.[8] found that nonindex readmissions, being primarily for medical comorbidities, were associated with lower hospitalization cost and 1-year mortality than index readmissions, which were more commonly for aneurysm-related surgical issues. Similar findings were echoed by Pak et al.[14] and Saunders et al.[3] The latter also reported lower readmission costs among nonindex readmissions when the readmission indication was for medical reasons, but similar hospitalization costs for readmissions for surgical indications. However, there were also studies that observed no significant difference between index and nonindex readmissions in readmission length of stay,[9] hospitalization costs,[4,7,13] or subsequent readmission risk.[7]

The conflicting results regarding secondary outcomes between included studies may be attributable to failure to control for patient survival status during readmission in most studies. Hua et al.[11] noted a significant interaction effect between survival status and nonindex readmission. After stratification by survival status, they found that nonindex readmission length of stay was shorter than index readmissions for patients who died, but similar for patients who survived. Similarly, hospitalization costs were lower among nonindex readmission patients who died than index readmission patients, and costs were higher among nonindex readmissions than index readmissions if the patient had survived.

Risk of bias assessment

For all except 1 of the 17 studies[1] that evaluated the association between nonindex readmissions and readmission outcomes, moderate to high overall risk of bias was found by the reviewers (Table 2).

Confounding was the most prevalent bias category. Distance from patient residence to primary hospital, despite being reported as one of the most important risk factors for nonindex readmissions,[1,3,5,11,36,42] was not adjusted for by many studies. In addition, failure to adjust for readmission urgency, patient- or hospital-level confounders all predisposed studies to moderate or serious risk of bias.

Bias in selection of patients was considered high within studies that utilized an institutional case series,[8,41] narrow procedural categories,[3,7,8,13,14,28,37,41] or mixed surgical and nonsurgical admissions.[2,11] Most studies[1,4–14,28,37] did not provide information on the completeness of variables of interest and how missing data were managed. In addition, many studies did not describe how departures from intended exposures (ie, patients who transferred from nonindex to index hospitals) were categorized during analysis.[3,5,10–12,28,37]

Of note, major methodological concerns were found in all 4 studies that reported no significant association between nonindex readmission and mortality. Chappidi et al.[44] were not able to account for travel distance, and Stitzenberg et al.[4] failed to adjust for hospital-level variables for readmission facilities. Glebova et al.[8] utilized an institutional case series of only 33 patients, placing the study at high risk of type II error. The patient population in the study by Saunders et al.[3] were recently duplicated by a more extensive study,[45] leading to a significant association.

Discussion

Care fragmentation has been linked to patient dissatisfaction,[46] duplicate imaging exams,[47] redundant services,[48] and worsened clinical outcome[49–51] for many medical conditions. However, the relevant impact of care fragmentation on surgical patients in the immediate post-discharge period, a particularly vulnerable epoch, has not been well established.[52] Findings of the present systematic review and meta-analysis suggest that approximately 10.2%–37.4% of all 30-day readmissions after surgery occur at a different hospital from the one where surgery took place. Predictors of nonindex readmission, such as travel distance and patient's socioeconomic status, were mostly nonclinical and nonmodifiable. Furthermore, statistical synthesis demonstrated that the majority of studies reported elevated short-term mortality with nonindex readmissions after adjusting for other confounders.

Most identified patient-level risk factors for nonindex readmission appeared to be proxy markers for patients' access to healthcare that are not correctible, such as disadvantaged socioeconomic status and residency in rural areas. Distance from patient residence to surgery hospital has been reported by many included studies as the single most consistent factor predicting nonindex readmission,[3,10,11,45,53,54] whereas no hospital characteristic has been identified as consistently associated with index or nonindex readmission across studies. In support of this finding, Havens et al. found nonindex readmis-

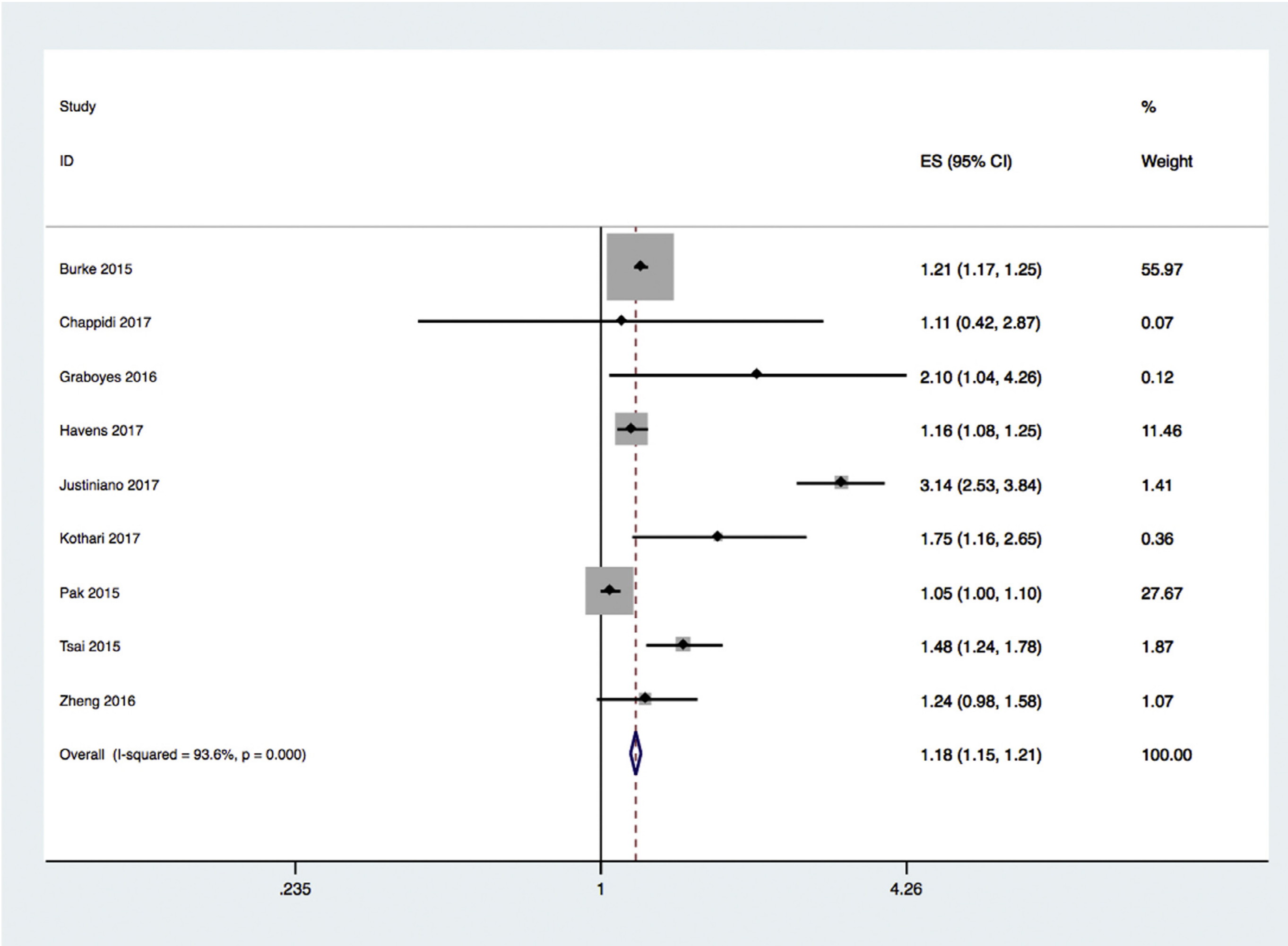

Fig. 3. Forest plot of pooled adjusted odds ratios for mortality associated with nonindex readmission. Results of our pooled analyses showed that nonindex readmission was associated with an odds ratio of 1.18 (95% confidence interval 1.15–1.21) for short-term mortality.

sions to occur most frequently in the Midwest and least frequently in the Northeast, likely explained by the respective concentration of tertiary medical centers in the Midwest and the Northeast.[10,53] Patients with more comorbidities, residing in more rural areas and having lower income, were all found to experience nonindex readmissions more commonly. In addition, some studies, such as that by Havens et al, have suggested that nonindex readmissions occur more frequently after surgery at low-resource safety-net hospitals. Seeking care at a safety-net hospital is likely a marker for a patient population with compromised healthcare accessibility. When these patients encounter complications requiring urgent medical attention, the difficulty in bringing them back to the original hospital reflects access disparity that is likely difficult to correct by patient education or changes in hospital compensation structure alone, as suggested by some researchers.[10]

One other key difference between index and nonindex readmission in the present study was the readmission diagnosis. Patients with index readmissions were more commonly coded as carrying a diagnosis of "surgical complications," and patients with nonindex readmissions experienced more "medical complications." Two potential explanations exist: (1) Patients with compromised healthcare access may prefer to receive care under a local setting, except when local expertise for managing the specific problem is deemed lacking and return to the original hospital deemed necessary, such as when a hepatobiliary complication occurred after pancreatoduodenectomy.[43] (2) Index hospitals, with better access to patient's previous care records, may be better able to recognize and link the patient's condition on readmission to their prior procedure, thus making the diagnosis of a surgical complication. Although general admission diagnoses were available, it was almost impossible to quantify the urgency and severity of the patient's condition from studies utilizing administrative databases. These may be the real driving factors behind the patient's choice of index or nonindex readmission destination and remain to be explored by future researchers.

Most studies and our meta-analysis have concluded nonindex readmissions to be associated with worse short-term mortality after surgery. This finding has been largely consistent across procedure types, including complex high-risk surgeries[35,45] and common general surgery procedures.[10,11] It is difficult to speculate on the reasons for this association because of a lack of information on processes of care from available data. Previous research on care transitions has described inadequate health information transfer, leading to delays in diagnosis and delivery of appropriate therapy,[55,56] inaccurate medication reconciliation,[57,58] and dysfunctional care co-ordination across sites,[59] which could all offer plausible mechanisms responsible for this association.

Substantial inconsistencies were observed regarding secondary outcomes, such as length of stay, hospitalization cost, and repeat readmission risks between studies. This is likely the result of most

Table 2
Risk of bias assessment for studies reporting readmission outcomes.

Study	Domains							Overall risk of bias judgment
	Bias due to confounding	Bias in selection of participants	Bias in measurement of exposure (nonindex readmission)	Bias due to departures from intended exposures	Bias owing to missing data	Bias in measurement of outcomes (mortality)	Bias in selection of reported results	
Brooke et al.[1]	Low	Low	Low	Low	No information	Low	Low	Low
Burke et al.[2]	Serious	High	Low	Low	Low	Low	Low	High
Chappidi et al.[7]	Serious	High	Low	Low	No information	Low	Low	High
Glebova et al.[8]	Moderate	Serious	High	Low	No Information	Low	Low	High
Gore et al.[28]	Serious	High	Low	No information	No information	Low	Low	High
Graboyes et al.[9]	Serious	High	Low	Low	No information	Low	Low	High
Havens et al.[10]	Moderate	Low	Low	No information	No information	Low	Low	Moderate
Hua et al.[11]	Moderate	High	Low	No information	No information	Low	Low	Moderate
Justiniano et al.[12]	Moderate	Moderate	Low	No information	No information	Low	Low	Moderate
Justiniano et al.[34]	Moderate	Moderate	Low	Low	Low	Low	Low	Moderate
Kothari et al.[13]	Serious	Moderate	Low	Low	No information	Low	Low	High
Pak et al.[14]	Serious	Moderate	Low	Low	No information	Low	Low	High
Ryoo et al.[37]	Serious	Moderate	Low	No information	No information	No information	No information	High
Saunders et al.[3]	Moderate	Moderate	Low	No information	Low	Low	Low	Moderate
Stitzenberg et al.[4]	Moderate	Low	Low	Low	No information	Low	Low	Moderate
Tsai et al.[5]	Moderate	Low	Low	No information	No information	Low	Low	Moderate
Zheng et al.[6]	Serious	Low	Low	Low	No information	Low	Low	High

studies' failure to account for survival bias. If readmission length of stay is cut short by mortality, then the hospitalization cost is no longer comparable and readmission risks are also biased because of an altered denominator. In fact, researchers of only one included study[11] have stratified their analyses by readmission survival status. They corroborated that nonindex hospitalization length of stay and costs were lower among those who died during and increased for those that survived.

Despite our finding, care fragmentation was only one of many potential explanations for the observed association between nonindex readmission and mortality. Almost all included studies were at moderate to high risk for residual bias, stemming from systemic differences of patients or healthcare systems between the two comparison groups. In fact, a multitude of unmeasured confounding variables were not accounted for by any of the studies, such as means of transportation, availability of surgical subspecialists on staff, acuity of readmission diagnosis, aggressiveness of care and end-of-life decision. Furthermore, the retrospective and observational nature of our research question precluded the use of many standardized risk-of-bias assessment tools. For example, it is nearly impossible to characterize the degree of missing data or discern selective outcome reporting from studies using secondary data. Because of the cross-institutional nature of the research questions, most studies utilized administrative databases, which are inherently limited in their ability to make causal inferences. Furthermore, none of the studies are truly representative of the readmission pattern on a national level, either because of restriction to particular surgical procedures or constraints of the database. This may explain why the Medicare population consistently incurs higher overall readmissions compared with the general population. It is worth noting, however, that many of these limitations are inherent in our retrospective research question rather than because of any methodology deficiency of the respective studies. Despite the heterogenous population, procedure type, and data source represented among our included studies, what is perhaps more remarkable is that nearly all studies have reported worse outcomes after nonindex readmissions.

In view of our finding that most risk factors for care fragmentation are likely not modifiable, we recommend enhancing care continuity through interhospital health information exchange (HIE)[60] systems. Nonindex readmission only represents one link in the entire spectrum of potential care fragmentation during a surgery patient's recovery course. Previous studies have shown that other than the hospital, discontinuity in surgeon,[34] nursing staff,[61] house staff,[62] and emergency department[63] were all associated with various degrees of worsened outcome. In fact, care fragmentation appeared to be both a hallmark and a symptom of the modern healthcare environment. It is neither feasible nor desired to reverse the global trend of surgery center regionalization or build a 24-hour care team for each individual patient. Continuity of care consisted of personnel continuity (an ongoing relationship between a patient and a healthcare provider) and information continuity (availability of documentation of earlier transpired events for subsequent patient encounters).[64] Current HIE systems, where discharge summaries were routinely completed in a delayed fashion, and interhospital information sharing, frequently relying on a stack of illegible papers, leave much to be desired.[55] We believe that enhancing information continuity through the use of information technology and optimizing hand-off channels may be the solution to the mounting problem of care fragmentation. Future studies may provide important insight to this issue by comparing the impact of nonindex readmissions among health systems without and with integrated HIE, such as the Veteran Affairs health administration or Kaiser Permanente.

In conclusion, the findings of the current study suggest that nonindex readmission is a common phenomenon after surgery and is associated with worse short-term mortality. Most factors that predispose patients to nonreadmissions are related to patient care access issues and may not be modifiable. Hence, efforts to reverse regionalization or enforcing continuity of care may not be efficacious in resolving care fragmentation. Future studies are required to explore whether enhancing information continuity via electronic medical record sharing and better care planning can mitigate the adverse consequences of care fragmentation.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.surg.2018.08.021.

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