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Hospital readmission after surgery: no place like home

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The benefits of concentrating surgery within a region into high-volume, so-called centres of excellence are well known, including improved outcomes and reduced costs. However, the potential downsides have received less attention. Concerns have been raised that regionalisation could potentially threaten patient outcomes by compromising continuity of care, especially when the patient travels far from home.[1] Although this concern is widely acknowledged, there has not previously been rigorous evidence to support it.

In *The Lancet*, Benjamin Brooke and colleagues[2] provide the first empirical evidence to suggest that travelling to a remote hospital for surgery could potentially be life threatening for patients. In a study of the US Medicare population, of patients who had surgery and were later readmitted to hospital because of complications, those who were readmitted to the same hospital where they had the procedure (ie, the index hospital) had a lower risk of 90 day mortality than did those readmitted to a different hospital. The investigators studied more than 9 million patients undergoing one of 12 complex surgical procedures. Patients who were readmitted to the same hospital where they had surgery were 26% less likely to die after surgery (odds ratio 0·74, 95% CI 0·66–0·83) than were those readmitted to other hospitals.

Brooke and colleagues' study[2] was observational, and susceptible to confounding. For example, patients readmitted to the index hospitals might have been different to those who were readmitted to other hospitals in some way that explains their improved outcomes—eg, because they were healthier, or more likely to seek care at the index hospital. Many observational studies simply use multivariate adjustment or propensity scores to adjust for potential confounding. However, these strategies often do not correct for potential confounding because they only account for measured variables. Any potential confounders that are not measured are not addressed, and can lead to biased results. However, Brooke and colleagues go beyond traditional approaches by using an instrumental variable approach.[3] Borrowed from economists, these methods rely on identification of an instrumental variable that roughly imitates random assignment and can therefore be used to generate unbiased estimates. Brooke and colleagues' instrumental variable analysis yields a more conservative estimate, with only an 8% reduction in risk of mortality for patients readmitted to an index hospital (odds ratio 0·92,

Scott Handcock/Rubberball/Corbis

95% CI 0·91–0·94). This result suggests that some, but not all, of the difference in outcomes between readmission to the index hospital versus other hospitals is caused by unmeasured differences in patients' characteristics.

Why would patients fare better when admitted to the hospital that performed their operation? We suggest that there are several possible reasons. First, the index hospitals might simply have better systems for effective management of complications than do non-index hospitals. Patients readmitted after surgery almost always have a postoperative complication, either medical or surgical.[4] The ability to treat patients effectively for complications is important to prevent death, and has been shown to be dependent on the procedure volume for the specific operation and hospital.[5,6] In this context, the procedure volume of the hospital is a proxy for the knowledge needed to manage patients with complex presentations and to treat them for life-threatening complications.

Second, the index-hospital staff might have more first-hand knowledge of the details of the specific patient—ie, they can provide superior continuity of care—which could include information about the patient's surgery and postoperative course before discharge. Often these details are tacit and not explicitly captured in the medical record (assuming other hospitals even have access to the hospital record for the index procedure). Brooke and colleagues' results suggest that this might be the case, since the beneficial effect of readmission to the index hospital was more pronounced for surgical complications than for medical complications. Optimum management of surgical complications might depend on specific details of the procedure known to the surgical team who did the operation.

A final reason could be the lower barriers for access to care at the index hospital than at a non-index hospital. Brooke and colleagues report that patients who were readmitted to the index hospital were admitted about 1 or 2 days earlier than were patients readmitted to non-index hospitals. Early presentation might lead to more timely management of surgical complications and improved outcomes. Patients could have difficulty accessing care at non-index hospitals, where they do not have a pre-existing relationship with a surgeon, thereby delaying presentation and treatment. Early intervention is a hallmark of effective rescue for most complications (eg, early empirical antibiotics for septic complications).[7] Moreover, the surgeon and other care providers at the index hospital who did the operation might have a stronger sense of duty towards the patient, which could lead to greater diligence in addressing the patient's complications and in helping them to access the necessary care.

These findings[2] have important implications for existing selective referral and centre of excellence programmes. In selective referral programmes in which patients need to travel long distances to receive care, every effort should be made to ensure that, after surgery, the patient is readmitted to the hospital where they had their operation. Such coordination would be helped if the patient remained near the hospital for some time after discharge. Alternatively, if the patient has already returned home, they should be transferred back to the index hospital if at all possible.

Such findings also have important implications for policy makers thinking about introducing selective referral programmes. The adverse outcomes of having surgery at distant hospitals need to be taken into account when these programmes are designed, which could simply mean inclusion of these outcomes in the calculation of potential benefits and harms before a decision is made to regionalise a specific procedure. Alternatively, Brooke and colleagues' findings[2] could be used to design initiatives more intelligently, for example, through creation of volume cutoffs that ensure a regional distribution that does not create insurmountable geographical barriers to readmission to the index hospital.

After many years of evidence to support the regionalisation of complex surgery, these new findings bring new understanding of the potential disadvantages of travelling to a remote hospital for surgery: when it comes to being readmitted to hospital after surgery, there is no place like home.

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Pain in the USA: states of suffering

BSIP/UIG

Worldwide, chronic pain afflicts more than 1·5 billion individuals.[1] In 2013, pain was in the top ten list of causes of years lived with disability (YLD) in 188 countries: low-back pain accounted for more than a mean of 72 million YLD, neck pain more than 34 million YLD, and migraine more than 28 million YLD.[2]

Despite being a universal problem, disparities exist—globally and nationally—in the management of pain. For example, Knaul and colleagues[3] noted that high-income countries, which represent less than 15% of the global population, accounted for 94% of morphine use. In the USA, physicians are more likely to underestimate the intensity of pain for patients from ethnic minorities than they are for non-Hispanic white patients, and they are more likely to overestimate pain for non-African-American patients than they are for those who are African-American.[4] Also, patients from ethnic minorities tend to under-report pain intensity to the physician and this is a factor in the inadequate or inequitable management of their pain.[4]

In the USA, the estimated financial cost of treatment and loss of productivity as a consequence of chronic pain is US$560–635 billion per year, but for many people pain treatment is not satisfactory.[5] Pain can only be quantified subjectively, and evidence from studies about management of pain is often equivocal. One of the US Institute of Medicine's recommendations, in its 2011 report about addressing pain in the US population, was for federal and state agencies and private organisations to improve the gathering and reporting of data on the incidence and prevalence of pain nationwide.[5] Other domains for which data were needed included interference of pain in activities of daily living and work, use of clinical and social services, costs, and the effectiveness of treatment in reducing pain and pain-related disability.[5]

Richard Nahin[6] recently estimated the prevalence of self-reported pain in the USA, using data from the 2012 National Health Interview Survey of 8781 individuals who completed the Functioning and Disability Supplement. According to the findings, an estimated 126·1 million (55·7%) adults had some pain in the 3 months before the survey. An estimated 14·4 million (6·3%) people had the highest severity of pain—ie, category 4 of four discrete categories with the approach developed by the Washington Group on Disability Statistics.[6] Nahin also reported that women, older people, and non-Hispanic individuals were more likely to report any pain, and Asian people were less likely to report pain.[6]

The findings from Nahin's study suggest that the assessment, prevention, and treatment of pain in the USA are neither adequate nor equitable. Further research into these issues is needed so that pain control can be improved and individualised, and extended for the benefit of people in low-income and middle-income countries.

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Readmission destination and risk of mortality after major surgery: an observational cohort study

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Summary

Background **Hospital readmissions are common after major surgery, although it is unknown whether patients achieve improved outcomes when they are readmitted to, and receive care at, the index hospital where their surgical procedure was done. We examined the association between readmission destination and mortality risk in the USA in Medicare beneficiaries after a range of common operations.**

Methods **By use of claims data from Medicare beneficiaries in the USA between Jan 1, 2001, and Nov 15, 2011, we assessed patients who needed hospital readmission within 30 days after open abdominal aortic aneurysm repair, infrainguinal arterial bypass, aortobifemoral bypass, coronary artery bypass surgery, oesophagectomy, colectomy, pancreatectomy, cholecystectomy, ventral hernia repair, craniotomy, hip replacement, or knee replacement. We used logistic regression models incorporating inverse probability weighting and instrumental variable analysis to measure associations between readmission destination (index *vs* non-index hospital) and risk of 90 day mortality for patients who underwent surgery who needed hospital readmission.**

Findings **9 440 503 patients underwent one of 12 major operations, and the number of patients readmitted or transferred back to the index hospital where their operation was done varied from 186 336 (65·8%) of 283 131 patients who were readmitted after coronary artery bypass grafting, to 142 142 (83·2%) of 170 789 patients who were readmitted after colectomy. Readmission was more likely to be to the index hospital than to a non-index hospital if the readmission was for a surgical complication (189 384 [23%] of 834 070 patients readmitted to index hospital *vs* 36 792 [13%] of 276 976 patients readmitted non-index hospital, p<0·0001). Readmission to the index hospital was associated with a 26% lower risk of 90 day mortality than was readmission to a non-index hospital, with inverse probability weighting used to control for selection bias (odds ratio [OR] 0·74, 95% CI 0·66–0·83). This effect was significant (p<0·0001) for all procedures in inverse probability-weighted models, and was largest for patients who were readmitted after pancreatectomy (OR 0·56, 95% CI 0·45–0·69) and aortobifemoral bypass (OR 0·69, 95% CI 0·61–0·77). By use of hospital-level variation among regional index hospital readmission rates as an instrument, instrumental variable analysis showed that the patients with the highest probability of returning to the index hospital had 8% lower risk of mortality (OR 0·92 95% CI 0·91–0·94) than did patients who were less likely to be readmitted to the index hospital.**

Interpretation **In the USA, patients who are readmitted to hospital after various major operations consistently achieve improved survival if they return to the hospital where their surgery took place. These findings might have important implications for cost-effectiveness-driven regional centralisation of surgical care.**

Funding **None.**

Introduction

Identification of metrics for quality of surgical care has become a major priority for health-care providers, patients, those paying for health care, and policy makers in many countries. So far, the main focus has been on perioperative measures of surgical quality, including structural characteristics of hospitals where surgery takes place and measures of the perioperative process within hospitals that lead to the best postoperative outcomes.[1,2] Hospitals that provide high-quality surgical care are often labelled as so-called centres of excellence, and trends have emerged in support of cost-effectiveness-driven regional centralisation for complex and major surgery.[3,4] These changes were based on reports[5–9] showing that hospitals with certain characteristics—eg, high operative volume or specialty care pathways—are better able to manage patients undergoing complex surgery and resulting complications, leading to reduced rates of risk-adjusted mortality and readmission.

However, after patients have been discharged from hospital following major surgery, the factors that are associated with improved outcomes are unclear. This challenge is relevant in view of the fact that a substantial proportion of complications and deaths within 90 days after major surgery occur after patients have been discharged from hospital,[10] and up to 25% of patients will need readmission.[11,12] Because the need for hospital readmission after major surgery is associated with significantly increased risk of mortality,[13,14] metrics of quality for surgical readmission need to be defined.

Maintenance of continuity of care with the same health-care institutions and providers is an established metric of quality for patients treated for chronic medical conditions.[15,16] We postulated that this quality metric would also apply to patients who were readmitted to hospital after major surgery, who we suspected would achieve improved outcomes if they returned to the hospitals where their operation took place (ie, the index hospital). We aimed to assess readmission destination and risk-adjusted 90 day mortality estimates for fee-for-service Medicare beneficiaries in the USA who were readmitted to hospital within 30 days after 12 common operations across five surgical disciplines.

Methods

Data sources and study population

We used the Centers of Medicare and Medicaid Services Provider Analysis and Review database to study patients who were readmitted to hospital within 30 days after undergoing one of 12 major surgical procedures at acute care and critical access hospitals between Jan 1, 2001, and Nov 15, 2011. We used International Classification of Diseases 9th Revision (ICD-9) procedure codes to identify these procedures from the Part A Medicare claims dataset: open abdominal aortic aneurysm repair (38.34, 38.36, 38.44, 38.64, 39.25, and 39.52); aortobifemoral bypass (39.25); infrainguinal arterial bypass (39.29, 38.88, 38.48, and 38.38); coronary artery bypass grafting (36.10–36.19); cholecystectomy (51.21–51.24); colectomy (45.7–45.79, 45.8); pancreatectomy (52.70, 52.51–52.53, 52.59, 55.26); oesophagectomy (42.4, 42.40–42.42); craniotomy (01.20–01.28, 01.30–01.32, 01.39, 01.50–01.53, 01.59), ventral hernia repair (53.51, 53.61, 53.62); hip replacement (81.51); and knee replacement (81.54). In our analysis, we included all patients who made use of a fee-for-service, non-health maintenance organisation (HMO) payment model, who were aged younger than 99 years and underwent one of these 12 operations during the time period.

To be included in the cohort for analysis, all patients needed to be readmitted within 30 days of discharge after one of the 12 index surgical procedures. Only the first unplanned readmission during the first 30 postoperative days was examined. If patients were transferred to another institution during the postoperative period, the 30 day window started after discharge from the other institution.

Readmission destination

Our main exposure variable was readmission destination, defined by whether patients were readmitted to the index hospital where the surgery took place or a different, non-index, hospital. The exposure group included patients who were readmitted to outside hospitals but then transferred to the index hospital within 24 h. The reference group included all patients who were readmitted to, and cared for at, hospitals other than the index hospital. The definition of index versus non-index hospital admission was specific for each patient, which allowed for cross-classification of data. We used hospital identification numbers from the Centers of Medicare and Medicaid Services to categorise index and readmission hospitals.

Additionally, we assessed whether having the same surgical provider was associated with both index and readmission hospitalisations by use of Berenson-Eggers Type of Service (BETOS) codes. BETOS codes are associated with services that health-care providers perform for Medicare beneficiaries and submit for billing, including evaluation and management and medical procedures. We included billing claims from the operative surgeon, and nurse practitioners or physician assistants who might have been directly involved in patient care, and compared these claims with the provider billing claims for evaluation and management and medical procedures during the period of readmission.

Descriptive variables

We assessed differences in readmission destination by patient characteristics at several levels. Baseline demographic variables included age, sex, ethnic origin, disability, and Medicaid eligibility at the time of index hospital admission. We obtained data for education and median income from the American Community survey data (2006 to 2010) and used them to measure patient socioeconomic status. We assessed patients' comorbidities with a Charlson index (Romano adaptation)[17] score generated from the diagnosis at index hospital admission and procedure codes. We calibrated the Charlson index weights to a surgical hip fracture cohort that has previously been validated in various populations who had surgery.[12,18] We coded each

For the **American Community survey data** see http://www.census.gov/acs/www/data_documentation/data_main/

	Patients discharged after surgery	Patients readmitted to any hospital	Patients readmitted who were readmitted to index hospital
Vascular surgery			
Open abdominal aortic aneurysm repair	163 753	26 002 (15·9%)	18 220 (70·1%)
Aortobifemoral bypass	67 826	11 498 (17·0%)	8739 (76·0%)
Infrainguinal arterial bypass	448 296	90 596 (20·2%)	72 143 (79·6%)
Cardiothoracic surgery			
Coronary artery bypass surgery	1 502 815	283 131 (18·8%)	186 336 (65·8%)
Oesophagectomy	16 702	3665 (21·9%)	2447 (66·8%)
General surgery			
Cholecystectomy	1 435 157	183 494 (12·7%)	148 520 (80·9%)
Pancreatectomy	16 778	3582 (21·3%)	2670 (74·5%)
Colon resection	1 110 967	170 789 (15·4%)	142 142 (83·2%)
Ventral hernia repair	302 196	38 958 (12·9%)	32 248 (82·8%)
Neurosurgery			
Craniotomy	355 075	55 974 (15·8%)	39 195 (70·0%)
Orthopaedic surgery			
Hip replacement	1 272 419	89 154 (7·0%)	68 069 (76·3%)
Knee replacement	2 748 519	154 203 (5·6%)	113 335 (73·5%)

Table 1: **Patients readmitted after 12 major operations in five surgical specialties**

	Vascular surgery (n=128 096)				Cardiothoracic surgery (n=286 796)				General surgery (n=396 823)			
	Non-index	Index	Standardised difference	p value	Non-index	Index	Standardised difference	p value	Non-index	Index	Standardised difference	p value
Readmitted patients	28 994 (22·6%)	99 102 (77·4%)	··	··	98 007 (34·2%)	188 789 (65·8%)	··	··	71 243 (18·0%)	325 580 (82·0%)	··	··
Age at index surgery (years)	73·7 (10·5)	72·9 (10·0)	−0·069	<0·0001	73·6 (9·2%)	73·1 (7·9%)	−0·048	<0·0001	72·5 (12·8)	72·9 (12·1)	0·032	<0·0001
Black ethnic origin	3363 (11·6%)	15 559 (15·7%)	−0·025	<0·0001	4999 (5·1%)	12 861 (6·8%)	−0·089	<0·0001	71 239 (10·0%)	34 476 (10·6%)	−0·165	<0·0001
Female	12 467 (43·0%)	42 317 (42·7%)	−0·025	0·32	38 813 (39·6%)	72 715 (38·5%)	−0·089	<0·0001	39 532 (55·5%)	185 330 (56·9%)	−0·165	<0·0001
Using walker or wheelchair	1392 (4·8%)	5252 (5·3%)	−0·025	0·003	2252 (2·3%)	4592 (2·4%)	−0·089	0·28	2918 (4·1%)	12 447 (3·8%)	−0·165	<0·0001
Medicaid	7075 (24·4%)	24 280 (24·5%)	−0·025	24·4	24 014 (24·5%)	30 611 (16·2%)	−0·089	<0·0001	18 825 (26·4%)	79 109 (24·3%)	−0·165	<0·0001
College education	8640 (29·8%)	31 414 (31·7%)	0·116	<0·0001	29 202 (29·8%)	59 718 (31·6%)	0·098	<0·0001	21 458 (30·0%)	104 833 (32·2 %)	0·132	<0·0001
Home location	··	··	··	<0·0001	··	··	··	<0·0001	··	··	··	<0·0001
Large town	5074 (17·5%)	10 172 (10·3%)	··	··	22 052 (22·5%)	22 853 (12·1%)	··	··	9628 (13·5%)	37 482 (11·5%)	··	··
Small town	7162 (24·7%)	15 717 (15·9%)	··	··	24 696 (25·2%)	35 503 (18·8%)	··	··	20 799 (29·2%)	57 018 (17·5%)	··	··
Suburban	2696 (9·3%)	9593 (9·7%)	··	··	8330 (8·5%)	20 200 (10·7%)	··	··	6056 (8·5%)	32 232 (9·9%)	··	··
Urban	14 062 (48·5%)	63 620 (64·2%)	··	··	42 929 (43·8%)	110 275 (58·4%)	··	··	34 784 (48·8%)	199 010 (61·1%)	··	··
Charlson index	··	··	0·033	<0·0001	··	··	0·015	0·001	··	··	0·042	<0·0001
0–1	6687 (23·1%)	21 622 (21·8%)	··	··	35 084 (35·8%)	68 894 (36·5%)	··	··	26 548 (37·3%)	126 230 (38·8%)	··	··
2–4	10 867 (37·6%)	37 200 (37·5%)	··	··	37 538 (38·3%)	71 390 (37·8%)	··	··	21 921 (30·8%)	100 810 (31·0%)	··	··
>4	11 440 (39·5%)	40 280 (40·6%)	··	··	25 385 (25·9%)	48 505 (25·7%)	··	··	22 774 (32·0%)	98 540 (30·3%)	··	··
Discharge destination from index	··	··	0·095	<0·0001	··	··	0·091	<0·0001			0·203	<0·0001
Home	7674 (26·5%)	29 037 (29·3%)	··	··	34 303 (35·0%)	61 247 (32·4%)	··	··	33 485 (47·0%)	162 464 (49·9%)	··	··
SNF	8628 (29·8%)	24 478 (24·7%)	··	··	20 189 (20·6%)	38 772 (20·5%)	··	··	15 531 (21·8%)	73 256 (22·5%)	··	··
Rehabilitation facility	6170 (21·3%)	24 379 (24·6%)	··	··	7645 (7·8%)	17 829 (9·4%)	··	··	2422 (3·4%)	10 093 (3·1%)	··	··
Home care	3362 (11·6%)	13 082 (13·2%)	··	··	29 304 (29·9%)	60 410 (32·0	··	··	12 111 (17·0%)	62 186 (19·1%)	··	··
Other	3160 (10·9%)	8126 (8·2%)	··	··	6566 (6·7%)	10 531 (5·6%)	··	··	7694 (10·8%)	17 584 (5·4%)	··	··
Distance to index hospital (miles)	89·2 (257·3)	51·2 (194·2)	−0·144	<0·0001	103·3 (287·4)	81·8 (254·1)	−0·060	<0·0001	82·2 (244·1)	45·1 (191·8)	−0·152	<0·0001
Index hospital outside HRR	9597 (33·1%)	16 847 (17·0%)	0·095	<0·0001	33 809 (34·5%)	38 556 (20·4%)	0·091	<0·0001	21 174 (29·7%)	46 554 (14·3%)	0·203	<0·0001
Time to readmission (days)	12·9 (9·2)	12·7 (8·1)	−0·025	<0·0001	11·7 (9·1)	10·7 (7·6)	−0·089	<0·0001	12·6 (9·0)	11·0 (8·2)	−0·165	<0·0001

Data are n (%) or mean (SD) unless otherwise stated. SNF=skilled-nursing facility. HRR=hospital referral region. Vascular surgery=open abdominal aortic aneurysm repair, aortobifemoral bypass, infrainguinal arterial bypass. Cardiothoracic surgery=coronary artery bypass surgery, oesophagectomy. General surgery=cholecystectomy, pancreatectomy, colectomy, ventral hernia repair.

Table 2: **Characteristics of patients who were readmitted to hospital**

patient's ambulatory status with CPT codes within claims and carrier files for walkers, wheelchairs, and related accessories 2 years before and up to 30 days after the index surgery. Finally, we categorised the patient's discharge destination after their index hospital admission for surgery (home, skilled nursing facilities, rehabilitation facility, home with home-care services, or other).

We defined readmissions by whether they were elective, urgent, or emergent, and whether the

	Neurosurgery (n=55 974)				Orthopaedic surgery (n=243 357)			
	Non-index	Index	Standardised difference	p value	Non-index	Index	Standardised difference	p value
Readmitted patients	16 779 (30·0%)	39 195 (70·0%)	..	..	61 953 (25·5%)	181 404 (74·5%)	..	..
Age at index surgery (years)	74·1 (11·7)	73·3 (11·5)	–0·055	<0·0001	74·5 (9·6)	74·5 (9·1)	0·001	0·79
Black ethnic origin	1728 (10·3%)	4350 (11·1%)	–0·169	0·004	4151 (6·7%)	14 331 (7·9%)	–0·164	<0·0001
Female	7404 (44·1%)	16 667 (42·5%)	–0·169	<0·0001	37 537 (60·6%)	112 511 (62·0%)	–0·164	<0·0001
Using walker or wheelchair	957 (5·7%)	2126 (5·4%)	–0·169	0·10	3544 (5·7%)	10 217 (5·6%)	–0·164	0·91
Medicaid	3488 (20·8%)	7455 (19·0%)	–0·169	<0·0001	9065 (14·6%)	26 302 (14·5%)	–0·164	0·33
College education	5440 (32·4%)	13 561 (34·6%)	0·117	<0·0001	9870 (15·9%)	26 892 (14·8%)	0·097	<0·0001
Home location	..	..	..	<0·0001	..	..	..	<0·0001
Large town	2629 (15·7%)	3724 (9·5%)	..	..	8116 (13·1%)	19 954 (11·0%)	..	..
Small town	3389 (20·2%)	5648 (14·4%)	..	..	16 981 (27·4%)	30 660 (16·9%)	..	..
Suburban	1532 (9·1%)	3684 (9·4%)	..	..	5576 (9·0%)	18 140 (10·0%)	..	..
Urban	9249 (55·1%)	26139 (66·7%)	..	..	31 280 (50·5%)	112 650 (62·1%)	..	..
Charlson index			0·023	0·25	..	..	0·015	<0·0001
0–1	6124 (36·5%)	14 580 (37·2%)	..	..	40 704 (65·7%)	119 001 (65·6%)	..	..
2–4	5201 (31·0%)	12 229 (31·2%)	..	..	15 550 (25·1%)	46 077 (25·4%)	..	..
>4	5454 (32·5%)	12 386 (31·6%)	..	..	5699 (9·2%)	16 326 (9·0%)	..	..
Discharge destination from index	..	..	0·163	<0·0001	..	..	0·165	<0·0001
Home	4443 (26·5%)	11 484 (29·3%)	..	..	10 525 (17·0%)	24 490 (13·5%)	..	..
SNF	5003 (29·8%)	9681 (24·7%)	..	..	18 496 (29·9%)	66 394 (36·6%)	..	..
Rehabilitation facility	3570 (21·3%)	9642 (24·6%)	..	..	12 010 (19·4%)	35 011 (19·3%)	..	..
Home care	1940 (11·6%)	5174 (13·2%)	..	..	14 792 (23·9%)	41 360 (22·8%)	..	..
Other	1823 (10·9%)	3214 (8·2%)	..	..	6130 (9·9%)	14 149 (7·8%)	..	..
Distance to index hospital (miles)	112·9 (315·7)	77·1 (254·5)	–0·102	<0·0001	62·5 (201·0)	47·1 (191·4)	–0·066	<0·0001
Index hospital outside HRR	6661 (39·7%)	9219 (23·5%)	0·163	<0·0001	18 593 (30·0%)	28 462 (15·7%)	0·165	<0·0001
Time to readmission (days)	13·5 (9·1)	11·7 (8·3)	–0·169	<0·0001	13·1 (9·3)	11·3 (8·4)	–0·164	<0·0001

Data are n (%) or mean (SD) unless otherwise stated. SNF=skilled-nursing facility. HRR=hospital referral region. Neurosurgery=craniotomy. Orthopaedic surgery=hip replacement, knee replacement.

***Table 3:* Characteristics of patients who were readmitted to hospital**

readmission was to manage a medical complication (eg, heart failure or peneumonia) or a surgical complication (ie, a complication requiring a procedure at the time of readmission such as wound debridement). We based this distinction on the medical and surgical diagnosis-related groups assigned to patients at the time of readmission. We categorised the source of admission to the hospital at the time of readmission as being from an emergency department, outpatient clinic, transfer from another hospital facility, or another source.

We characterised the hospitals patients were readmitted to in several ways. We assessed overall hospital volume of admissions and procedure-specific volumes by hospital. We measured admission volumes across all years combined and with biannual values smoothed by a moving average. For all 12 procedures, the top 10% of hospitals ranked by volume accounted for roughly 50% of operations, and we used this cutoff point to define hospitals with the highest volumes of procedures. We categorised the teaching status of hospitals (non-teaching, minor teaching, and major teaching) based on the ratio of junior doctors to beds, as identified by the 2010 American Hospital Association files, and whether hospitals were members of the Council of Teaching Hospitals. Additionally, we assessed the number of hospital beds, intensive-care unit beds, physician staffing (full-time equivalents), and nurse-to-patient ratios using the year-specific American Hospital Association files. We assessed hospital compliance with established process measures derived from the Surgical Care Improvement Program (SCIP), using the 2012 Hospital Compare website. We chose SCIP-9 (compliance with removal of urinary catheters by postoperative day 2) because this measure had the most variability and discriminatory potential between hospitals in the USA.

For the **Hospital Compare website** see http://www.medicare.gov/hospitalcompare/search.html

	Vascular surgery (n=128 096)				Cardiothoracic surgery (n=286 796)				General surgery (n=396 823)			
	Non-index	Index	Standardised difference	p value	Non-index	Index	Standardised difference	p value	Non-index	Index	Standardised difference	p value
Hospital characteristics												
Teaching status	..	..	..	<0·0001	..	..	..	<0·0001	..	..	..	<0·0001
Non-teaching	10 701 (36·9%)	42 438 (42·8%)	−0·440	..	31 256 (32·4%)	78 354 (41·5%)	−0·579	..	34 832 (48·9%)	176 480 (54·2%)	−0.148	..
Minor teaching	6422 (22·1%)	25 324 (25·5%)	0·044	..	20 849 (21·2%)	48 610 (25·7%)	0·037	..	15 635 (21·9%)	79 546 (24·4%)	0·052	..
Major teaching	651 (2·2%)	2620 (2·6%)	0·053	..	2003 (2·0%)	5001 (2·6%)	0·076	..	1759 (2·0%)	7264 (2·2%)	0·009	..
COTH non-integrated	4565 (15·7%)	15 395 (15·5%)	0·289	..	21 903 (22·3%)	33 320 (17·6%)	0·462	..	8440 (11·8%)	35 299 (10·8%)	0·105	..
COTH integrated	6655 (22·9%)	13 325 (13·4%)	0·358	..	21 509 (21·9%)	23 504 (12·4%)	0·447	..	10 577 (14·8%)	26 991 (8·3%)	0·074	..
Number of beds	511·0 (443)	457·6 (360)	0·567	<0·0001	560·7 (552)	494·7 (397)	0·789	<0·0001	401·4 (382)	370·7 (329)	0·214	<0·0001
Number of intensive care unit beds	33·9 (40)	29·3 (31)	0·442	<0·0001	36·2 (46)	31·6 (33)	0·629	<0·0001	26·4 (32·7)	23·8 (27·1)	0·180	<0·0001
Number of staff	4489·5 (17 636)	3569·7 (13 847)	0·121	<0·0001	4908·0 (7195)	3702·1 (4462)	0·111	<0·0001	3396·4 (14 858)	2765·2 (10 411)	0·035	<0·0001
SCIP-9 compliance	27 892 (96·2%)	95 235 (96·1%)	−0·022	<0·0001	94 292 (96·2%)	181 502 (96·1%)	−0·027	<0·0001	68 243 (95·8%)	311 899 (95·8%)	0·003	0·36
Patient characteristics												
Household income (US$)	68 817 (42 964)	67 117 (36 032)	0·086	<0·0001	68 443 (54 862)	66 183 (40 817)	0·055	<0·0001	65 780 (36 913)	65 749 (33 180)	0·098	0·81
Readmission for surgical DRG	6381 (22·0%)	42 121 (42·5%)	0·496	<0·0001	8332 (8·5%)	35 532 (18·8%)	0·340	<0·0001	10 704 (15·0%)	51 110 (15·7%)	0·042	<0·0001
Emergent or urgent readmission	24 919 (85·9%)	77 116 (77·8%)	−0·261	<0·0001	87 344 (89·1%)	164 269 (87·0%)	−0·243	<0·0001	61 208 (85·9%)	285 573 (87·7%)	0·097	<0·0001
Source of readmission	..	..	..	<0·0001	..	..	..	<0·0001	..	..	..	<0·0001
Emergency department	14 745 (50·9%)	40 218 (40·6%)	0·075	..	55 623 (56·8%)	92 883 (49·2%)	0·244	..	34 049 (47·8%)	172 558 (53·0%)	−0·105	..
Clinic	9993 (34·5%)	45 689 (46·1	−0·261	..	28 814 (29·4%)	63 056 (33·4%)	−0·243	..	24 622 (34·6%)	111 999 (34·4%)	0·097	..
Transfer	2516 (8·7%)	9614 (9·7%)	0·270	..	6439 (6·6%)	22 466 (11·9%)	0·142	..	7387 (10·4%)	21 814 (6·7%)	−0·006	..
Other	1740 (6·0%)	3581 (3·6%)	−0·104	..	7131 (7·3%)	10 384 (5·5%)	−0·059	..	5185 (7·3%)	19 209 (5·9%)	−0·065	..
In-hospital mortality	1685 (5·8%)	4672 (4·7%)	−0·037	<0·0001	3336 (3·4%)	6844 (3·6%)	0·017	0·06	4118 (5·8%)	16 028 (4·9%)	−0·032	<0·0001
90 day mortality	5397 (18·6%)	15 474 (15·6%)	−0·076	<0·0001	9519 (9·7%)	16 063 (8·5%)	−0·028	<0·0001	13 320 (18·7%)	50 891 (15·6%)	−0·032	<0·0001
Readmission length of stay (days)	6·7%	8·2	0·177	<0·0001	5·6	7·1	0·164	<0·0001	6·5	7·1	0·084	<0·0001
Any complication	12 354 (42·6%)	43 345 (43·7%)	0·019	<0·0001	50 602 (51·6%)	100 079 (53·0%)	0·017	<0·0001	25 205 (35·4%)	129 952 (39·9%)	0·092	<0·0001

Data are n (%) or mean (SD) unless otherwise stated. COTH=Council of Teaching Hospitals. SCIP=Surgical Care Improvement Program. DRG=diagnosis-related group. Vascular surgery=open abdominal aortic aneurysm repair, aortobifemoral bypass, infrainguinal arterial bypass. Cardiothoracic surgery=coronary artery bypass surgery, oesophagectomy. General surgery=cholecystectomy, pancreatectomy, colectomy, ventral hernia repair.

Table 4: **Readmission characteristics and outcomes**

We used the University of Washington Rural-Urban Commuting Area (RUCA) Version 2 codes to categorise the locations of hospitals and patients' homes with zip codes, aggregated to four levels: urban, suburban, large town, or rural. We calculated the distance from the patient's home to the hospital as a straight-line distance measured in miles. Finally, we assessed whether patients underwent their index surgical procedure within the US hospital referral region associated with their home address.

Outcomes

The main outcome measure was 90 day all-cause mortality, beginning from the day of hospital readmission. We obtained dates of death from the Medicare Vital Status file.

	Neurosurgery (n=55 974)				Orthopaedic surgery (n=243 357)			
	Non-index	Index	Standardised difference	p value	Non-index	Index	Standardised difference	p value
Hospital characteristics								
Teaching status	..	..	..	<0·0001	..	..	..	<0·0001
Non-teaching	4678 (27·9%)	13 287 (33·9%)	–0·556	..	33 660 (54·3%)	98 347 (54·2%)	–0·215	..
Minor teaching	2493 (17·5%)	8270 (21·1%)	–0·085	..	15 385 (24·8%)	47 060 (25·9%)	0·060	..
Major teaching	442 (2·6%)	1071 (2·7%)	0·023	..	1680 (2·7%)	5299 (2·9%)	0·083	..
COTH non-integrated	3296 (19·6%)	7574 (19·3%)	0·363	..	7126 (11·5%)	19 993 (11·0%)	0·165	..
COTH integrated	5420 (32·3%)	8993 (22·9%)	0·535	..	4102 (6·6%)	10 705 (5·9%)	0·093	..
Number of beds	578·2 (455)	546·6 (405)	0·688	<0·0001	337·0 (361)	358·1 (316)	0·266	<0·0001
Number of intensive care unit beds	39·7 (42)	36·2 (36·3)	0·566	<0·0001	20·9 (30)	22·4 (25)	0·210	<0·0001
Number of staff	5040·4 (14 311)	4389·0 (7922)	0·156	<0·0001	2714·4 (13 464)	2524·6 (9268)	0·030	<0·0001
SCIP-9 compliance	16 130 (96·1%)	37 677 (96·1%)	–0·001	0·82	98 911 (96·4%)	174 327 (96·1%)	–0·067	<0·0001
Patient characteristics								
Household income ($)	67 953 (47 358)	68 522 (42 377)	0·079	0·09	74 029 (49 752)	68 120 (36 375)	0·049	<0·0001
Readmission for surgical DRG	2869 (17·1%)	12 511 (31·9%)	0·377	<0·0001	8506 (13·7%)	48 110 (26·5%)	0·362	<0·0001
Emergent or urgent readmission	14 534 (86·6%)	32 841 (83·8%)	–0·169	<0·0001	53 430 (86·2%)	104 100 (77·2%)	–0·126	<0·0001
Source of readmission	..	..	..	<0·0001	..	..	..	<0·0001
Emergency department	8372 (49·9%)	17 011 (43·4%)	0·155	..	27 168 (43·9%)	70 748 (39·0%)	0·062	..
Clinic	5084 (30·3%)	13 522 (34·5%)	–0·169	..	20 360 (32·9%)	73 469 (40·5%)	–0·126	..
Transfer	2316 (13·8%)	7094 (18·1%)	0·105	..	7305 (11·8%)	23 220 (12·8%)	0·173	..
Other	1007 (6·0%)	1568 (4·0%)	–0·092		7120 (11·5%)	13 967 (7·7%)	–0·138	..
In-hospital mortality	1328 (7·9%)	2595 (6·6%)	–0·049	<0·0001	1321 (2·1%)	3120 (1·7%)	–0·026	<0·0001
90 day mortality	5235 (31·2%)	10151 (25·9%)	–0·111	<0·0001	3428 (5·5%)	8704 (4·8%)	–0·027	<0·0001
Readmission length of stay (days)	6·4	7·4%)	0·123	<0·0001	3043 (4·9%)	10 006 (5·5%)	0·106	<0·0001
Any complication	3121 (18·6%)	7503 (19·1%)	0·007	0·14	14 615 (23·6%)	46 601 (25·7%)	0·048	<0·0001

Data are n (%) or mean (SD) unless otherwise stated. COTH=Council of Teaching Hospitals. SCIP=Surgical Care Improvement Program. DRG=diagnosis-related group. Neurosurgery=craniotomy. Orthopedic surgery=hip replacement, knee replacement.

Table 5: **Readmission characteristics and outcomes**

We also assessed in-hospital mortality during the period of hospital readmission.

Statistical analysis

We used two methods to assess the primary outcome measure: inverse probability weighting and an instrumental variable analysis.[19] We did all analyses with SAS version 9.3.

To address confounding by measured covariates, we used logistic regression incorporating inverse probability weighting, a type of propensity score analysis.[20] We first calculated descriptive statistics for the predictor variables measured within cohorts of patients undergoing each operation using bivariate comparisons (χ^2 and ANOVA). We then used multiple logistic regression to calculate the probability of a patient being readmitted to the index hospital based on 74 covariates (appendix). The weights for each patient were defined as the inverse of the estimated probabilities for being readmitted to the index hospital. After we weighted patients, we ran logistic regression models for each of the 12 surgical procedures clustered by hospital size (ie, small, medium, and large) to estimate odds ratios (ORs) for mortality. Model convergence was not possible when we attempted clustering at the level of individual hospitals because many US hospitals had few patients in each procedure group. We also did risk adjustment for all 12 procedures using logistic regression models without inverse probability weighting and without clustering.

We calculated p values for comparisons between index and non-index hospitals using *t* tests for means and χ^2 tests for proportions. We made categorical comparisons with χ^2 tests or ANOVA, as appropriate.

To address potential unmeasured bias, we did instrumental variable analysis with hospital-level variation in regional index hospital 30 day readmission rates as an

See Online for appendix

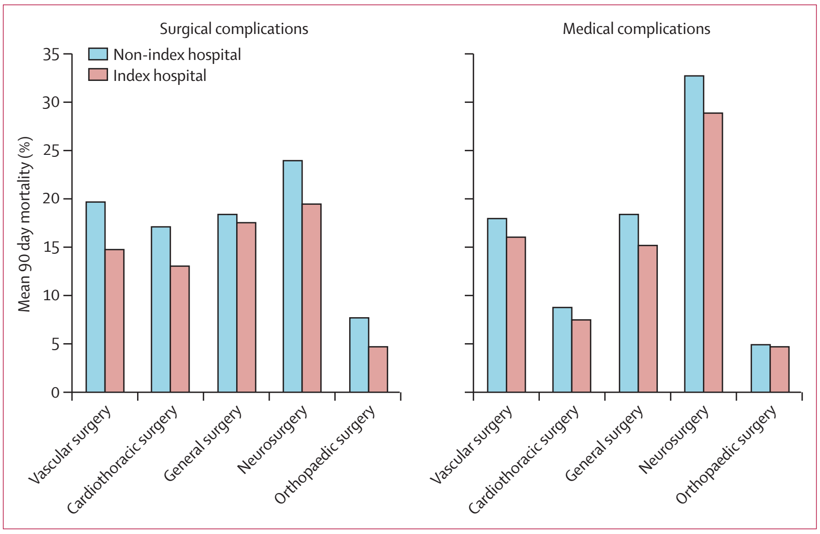

Figure 1: **Crude 90 day mortality**
Cardiothoracic surgery=coronary artery bypass surgery, oesophagectomy. General surgery=cholecystectomy, pancreatectomy, colectomy, ventral hernia repair. Neurosurgery=craniotomy. Orthopaedic surgery=hip replacement, knee replacement.

instrument. Hospitals within each hospital referral region were divided into quartiles based on index readmission rates after each operation, and we then compared groups of patients at hospitals that differed in terms of high and low probability of being readmitted to the index hospital (appendix). This type of geographic instrumental variable behaves like a natural random assignment of patients who underwent surgery to regional exposure groups that differ in likelihood of returning to the index hospital at the time of readmission.[19] We estimated risk-adjusted ORs for 90 day mortality for all 12 procedures with comparisons between hospitals at low and high risk of index readmission compared with non-index readmission.

To investigate whether having the same surgical providers during both index hospital admission and readmission was associated with a survival benefit, we calculated adjusted in-hospital and 90 day mortality based on whether patients were readmitted to non-index hospitals, index hospitals with different providers, or index hospitals with the same providers. We did incremental R^2 analysis to calculate the fraction of the variance accounted for in the model when surgical provider information was added, compared with only the variable for hospital of readmission.

We also did several sensitivity analyses to evaluate the effect of hospital destination on mortality under various conditions. This analysis included stratification by emergency department admissions, hospital teaching status, hospital procedure volume level (low *vs* high), and distance to the index hospital greater than 50 miles. We selected 50 miles as a cutoff because it represented roughly 1 h of travel time to the hospital. Dartmouth Human Investigation Committee deemed this study to be exempt from review.

Role of the funding source

There was no funding source for this study. BSB and PPG had full access to all the data in the study and BSB, PPG, and SRGF had final responsibility for the decision to submit for publication.

Results

We identified 9 440 503 patients during the study period who underwent one of 12 major operations within five surgical specialties (table 1). Across all procedures, prevalence of 30 day readmission ranged between 154 203 (5·6%) of 2 748 519 patients for knee replacement and 3665 (21·9%) of 16 702 patients for oesophagectomy.

In patients who needed to be readmitted to hospital within 30 days after major surgery, the number who were readmitted or transferred to the index hospital varied between procedures, from 186 336 (65·8%) of 283 131 patients who were readmitted after coronary artery bypass grafting, to 142 142 (83·2%) of 170 789 patients who were readmitted after colectomy (table 1). We calculated hospital-level index readmission prevalence within hospital referral regions for all 12 procedures, stratified by quartiles (appendix). The demographics and discharge destinations of patients who returned to the index hospital varied with the type of surgery (tables 2, 3). Patients who were readmitted to the index hospital were significantly more likely to live in urban areas and to have travelled fewer miles to have their operation at a hospital within their same hospital referral region than were those who were admitted to a different hospital (tables 2, 3). Additionally, patients returning to index hospitals were readmitted within fewer days than were those who went to other hospitals.

We compared the characteristics of the hospitals that patients were readmitted to, stratified by whether these hospitals were the index hospital or non-index hospitals (tables 4, 5). Generally, the index hospitals were smaller, with fewer staff and beds than were non-index hospitals (tables 4, 5). Moreover, index hospitals were more likely than non-index hospitals to be non-teaching hospitals, have lower SCIP-9 compliance, and be located in regions with lower mean incomes for the most surgical specialties (tables 4, 5).

The likelihood of patients being readmitted to the index hospital was increased when the readmission was to manage surgical complications compared with medical complications (tables 4, 5). Of the readmissions for medical complications, cardiac and infectious complications were most common overall. However, readmissions for medical or surgical complications were less likely to be for urgent or emergent indications if the patient returned to the index hospital than if they went to a non-index hospital (tables 4, 5).

We collected crude 90 day mortality data for patients who were readmitted to index and non-index hospitals for medical and surgical causes (appendix). For all types of surgery, unadjusted 90 day mortality was significantly

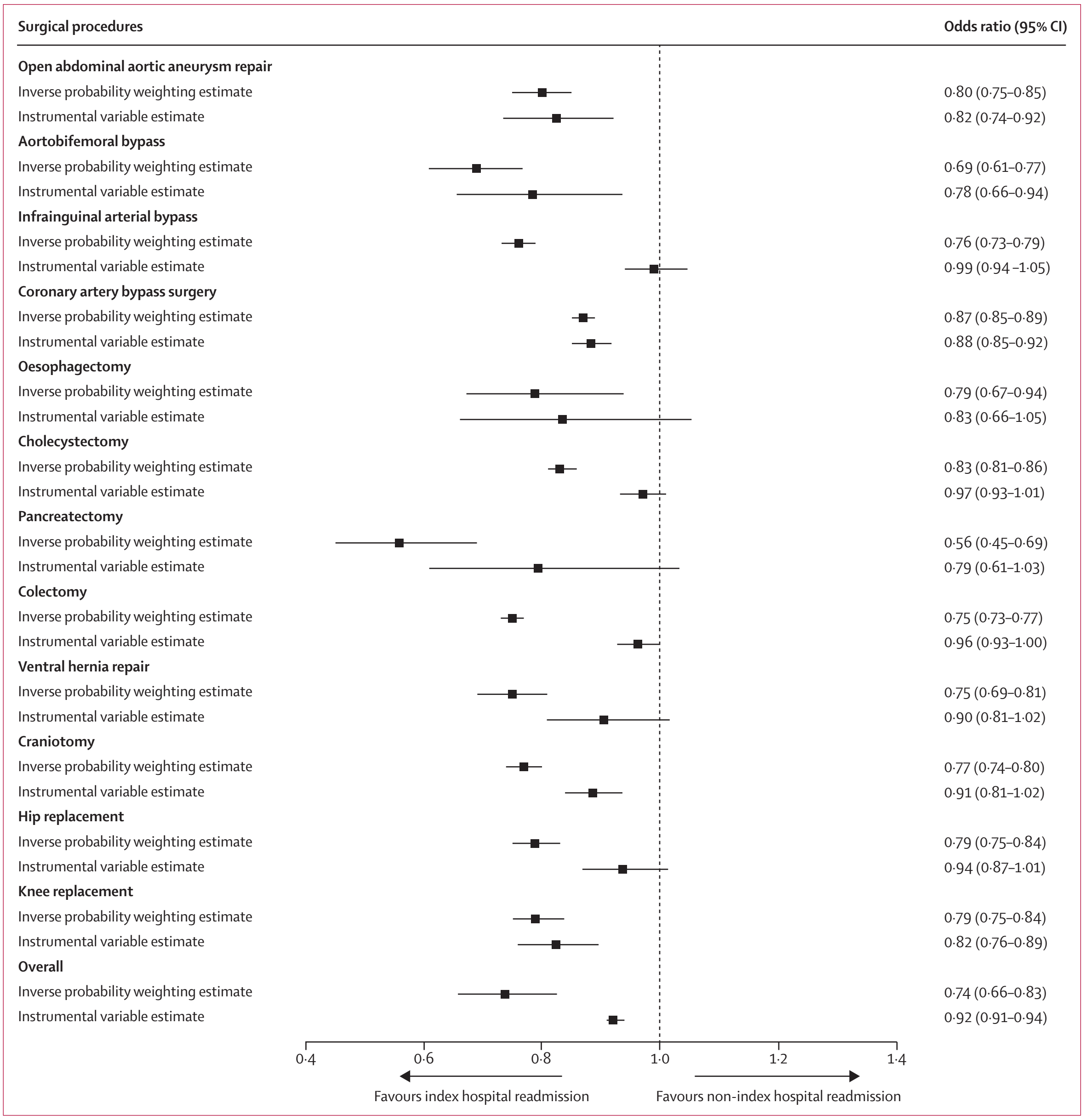

Figure 2: **Inverse probability weighting and instrumental variable analyses of 90 day mortality**

lower for patients who were readmitted to the index hospital where surgery occurred than for patients readmitted to other hospitals (tables 4, 5, figure 1). These findings were supported by risk-adjusted, inverse probability weighted models for all 12 surgical procedures (index hospital readmission *vs* non-index hospital readmission, overall OR 0·74, 95% CI 0·66–0·83; figure 2). For all surgical procedures, 90 day mortality was reduced for patients readmitted to index hospitals compared with those admitted to non-index hospitals, and the effect was largest for those who underwent pancreatectomy (0·56, 0·45–0·69), aortobifemoral bypass (0·69, 0·61–0·77), colectomy (0·75, 0·73–0·77), and ventral hernia repair (0·75, 0·69–0·81, figure 2). Furthermore, readmission to the index hospital was the most consistent predictor of survival relative to the 74 other covariates in the model (appendix). We also identified similar results using logistic regression models without inverse probability weighting (data not shown).

In our instrumental variable analysis, we identified a similar, but attenuated, reduction in mortality for patients readmitted to the index hospital compared with those readmitted to non-index hospitals (figure 2). Patients with a higher probability of being readmitted to the index hospital instead of a non-index hospital after surgery had

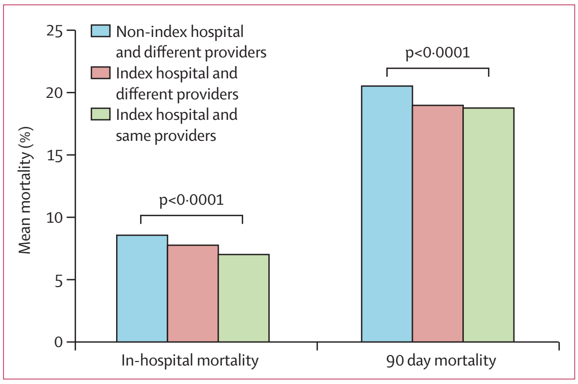

Figure 3: **Effects of continuity of care on in-hospital mortality and 90 day mortality**
Data stratified by whether patients returned to the index hospital where surgery occurred and whether they were managed by the same or different providers during index and readmission hospital stays.

an 8% lower risk of 90 day mortality (overall OR 0·92, 95% CI 0·91–0·94) than did patients with a lower probability of index hospital readmission. For all 12 procedures assessed with instrumental variable analyses, ORs for risk-adjusted mortality favoured patients who returned to the index hospital, but this difference was significant for only six of 12 surgical procedures (figure 2).

Compared with readmission to non-index hospitals, the reduction in mortality was greatest when patients were readmitted to the index hospital for surgical complications (adjusted OR 0·75, 95% CI 0·74–0·77), and this effect existed for all surgical specialties (figure 1). Furthermore, patients who needed management for a surgical complication at the time of readmission had a significant reduction in 90 day mortality in all comparisons if the same surgeon was involved in both the index and readmission treatment (figure 3). Knowledge of whether patients received care from the same surgical providers during readmission to the index hospital increased the R^2 value by 2·9% relative to models with hospital of readmission alone, supporting an incremental benefit for maintenance of continuity with respect to treatment providers. Patients who were readmitted to the index hospital for medical complications also had significantly reduced risk of 90-day mortality (adjusted OR 0·84, 95% CI 0·83–0·85) compared with those readmitted to different hospitals, although this effect was reduced in comparisons of readmissions for surgical complications.

To determine whether the effect seen at 90 days existed earlier in the readmission process, we also examined in-hospital mortality during the readmission period for medical and surgical complications (appendix). We noted that in-hospital mortality was also significantly reduced for patients readmitted to index hospitals after all surgical procedures except for cardiothoracic operations (tables 4, 5). These results were supported by risk-adjusted weighted models: the only patients not to have a lower risk of in-hospital mortality associated with readmission to the index hospital were those readmitted after coronary artery bypass grafting (appendix). Additionally, we detected a

	Odds ratio	95% CI	p value
Major teaching hospital			
Open abdominal aortic aneurysm repair	0·68	0·58–0·80	<0·0001
Aortobifemoral bypass	0·31	0·23–0·42	<0·0001
Infrainguinal arterial bypass	0·64	0·58–0·71	<0·0001
Coronary artery bypass surgery	0·59	0·56–0·63	<0·0001
Cholecystectomy	0·73	0·67–0·79	<0·0001
Colectomy	0·68	0·63–0·73	<0·0001
Ventral hernia repair	0·52	0·42–0·65	<0·0001
Craniotomy	0·79	0·73–0·86	<0·0001
Hip replacement	0·64	0·56–0·73	<0·0001
Non-teaching hospital			
Open abdominal aortic aneurysm repair	0·85	0·72–0·85	<0·0001
Aortobifemoral bypass	0·68	0·59–0·78	<0·0001
Infrainguinal arterial bypass	0·79	0·76–0·83	<0·0001
Coronary artery bypass surgery	0·87	0·84–0·89	<0·0001
Cholecystectomy	0·84	0·81–0·87	<0·0001
Colectomy	0·76	0·74–0·79	<0·0001
Ventral hernia repair	0·75	0·68–0·82	<0·0001
Craniotomy	0·78	0·74–0·81	<0·0001
Hip replacement	0·80	0·75–0·85	<0·0001
Distance <50 miles to index hospital			
Open abdominal aortic aneurysm repair	0·76	0·71–0·83	<0·0001
Aortobifemoral bypass	0·65	0·57–0·75	<0·0001
Infrainguinal arterial bypass	0·80	0·77–0·84	<0·0001
Coronary artery bypass surgery	0·81	0·79–0·83	<0·0001
Cholecystectomy	0·82	0·79–0·84	<0·0001
Colectomy	0·73	0·70–0·75	<0·0001
Ventral hernia repair	0·70	0·64–0·76	<0·0001
Craniotomy	0·77	0·74–0·81	<0·0001
Hip replacement	0·81	0·76–0·85	<0·0001
Distance ≥50 miles to index hospital			
Open abdominal aortic aneurysm repair	0·93	0·83–1·05	0·26
Aortobifemoral bypass	0·68	0·54–0·86	0·002
Infrainguinal arterial bypass	0·72	0·65–0·78	<0·0001
Coronary artery bypass surgery	1·05	1·01–1·09	0·03
Cholecystectomy	0·88	0·82–0·94	<0·0001
Colectomy	0·86	0·81–0·92	<0·0001
Ventral hernia repair	0·87	0·72–1·04	0·12
Craniotomy	0·73	0·68–0·78	<0·0001
Hip replacement	0·77	0·67–0·88	<0·0001

Risk-adjusted odds ratio of 90 day mortality for readmission to same hospital stratified by teaching status (major teaching *vs* non-teaching) and distance to index hospital (<50 miles *vs* ≥50 miles). The reference group for all sensitivity analyses is readmission to other hospitals than where surgery occurred. We only included data for the nine procedures for which stratified regression models were able to converge.

Table 6: **Sensitivity analysis**

similar in-hospital mortality benefit for patients who were readmitted under the care of the same provider for the management of surgical complications as for the index surgery (figure 3).

We did sensitivity analyses to examine the effect of hospital teaching status, distance greater than 50 miles to the index hospital, readmission through the emergency department, and volume of procedures at the hospital on risk-adjusted 90 day mortality models. The mortality benefit associated with readmission to the index hospital remained significant for all surgical procedures in these models, except for two procedures (open abdominal aortic aneurysm repair and ventral hernia repair) in patients who lived more than 50 miles from the index hospital (table 6).

Discussion

Patients undergoing major surgical procedures are often readmitted to hospitals to manage various medical and surgical complications, which are known to increase their risk of mortality.[11] However, the best destination for these high-risk readmissions has not been established. Our results describe a consistent reduction in 90 day mortality for patients who were readmitted to the same hospital as where their surgery was done, for 12 diverse and common high-risk surgical procedures. In our inverse probability-weighted analysis, readmission to the index hospital was associated with a 26% reduction in risk of 90 day mortality compared with readmission to non-index hospitals. These results were supported by the hospital-level instrumental variable analysis, in which patients with the highest probability of index hospital readmission had an 8% lower risk of 90 day mortality than did patients with a lower likelihood of returning to the index hospital. This decrease in mortality risk was greatest for patients who were readmitted for surgical complications, rather than medical complications, especially when these patients were managed by the same surgical providers who did the index surgery. Together, these results suggest that patients who need readmission for complications after major surgery will have the best outcomes when managed by providers who maintain continuity of care throughout the patient's postoperative course.

Hospital readmissions after surgery have become a high-profile metric of health-care quality worldwide.[8] Financial penalties for unplanned readmissions are now being enforced in the USA and the UK, with hospitals taking responsibility for readmissions, irrespective of whether patients return to the same hospital where the surgery was done or to another hospital.[21–23] However, the association between readmission destination after surgery and patient outcomes has not been studied closely. A study[24] that used a sample of 5% of Medicare claims for open and endovascular abdominal aortic aneurysm repair between 2005 and 2009 identified no benefit for 30 day mortality when patients returned to the same hospital where surgery was performed.[24] These results contrast with those of our study, which used 100% of Part A and B claims over a longer time period, and showed consistent reductions in in-hospital and 90 day mortality outcomes for 12 surgical procedures, including open abdominal aortic aneurysm repair. Furthermore, our main effect remained unchanged, even when our models controlled for established measures of surgical quality, such as hospital size, teaching status, and volume of procedures. The mortality reduction associated with index hospital readmission has face validity, which was further supported by our finding that this effect was most evident when the same surgical providers were involved in management of surgical complications (figure 3).

These findings raise important questions about the sustainability of worldwide health policies that aim to concentrate major or complex surgical procedures into specialised hospitals at the regional level. Patients increasingly travel long distances to have their operations done at hospitals that are recognised as providing high-quality care or because of a financial incentive for health insurers.[25] This strategy has been adopted by several large corporations in the USA as a way to control spending on major surgical procedures by sending employees to hospitals that specialise in complex surgical care and accept

Panel: **Research in context**

Systematic review

Before we did this study, we searched PubMed and the Cochrane Library databases for all articles published between Jan 1, 1990, and Feb 1, 2014, that were relevant to hospital readmission destination after major surgery. We used the search terms "post-discharge", "continuity of patient care", "patient readmission", "operative procedures" and "surgery". Using these search criteria, we identified no prospective or retrospective studies that were applicable to this subject.

While the data for this study were being analysed, two relevant observational studies were published with some conflicting results. The first study assessed readmission destination after abdominal aortic aneurysm repair in a 5% sample of US Medicare beneficiaries from 2005 to 2009, but detected no significant mortality benefit associated with readmission to the index hospital.[23] By contrast, another study that used 100% of Medicare claims for patients undergoing a composite of abdominal aortic aneurysm repair and four other procedures between 2009 and 2011 identified increased risk of 30 day mortality when patients were readmitted to hospitals other than where their surgery was performed.[29] Although individual procedures or post-discharge complications were not assessed in this study, the results support an association between maintenance of continuity of post-discharge surgical care and improved survival.

Interpretation

Our data suggest that, when complications occur after major surgical procedures, patients who return to the index hospital and receive care from their original surgical team achieve significantly better 90 day survival than do patients whose readmission is to a non-index hospital. These data were consistent across a range of surgical procedures in models designed to control for measured and unmeasured confounding. Maintenance of continuity of post-discharge care within institutions where providers are familiar with a patient's surgical history should be regarded as a measure of surgical quality, and be considered carefully when patients select a hospital in which to undergo major surgery.

bundled payments.[26] Additionally, the Centers of Excellence programme, established by Centers of Medicare and Medicaid Services, will only pay for some high-risk surgical procedures that are done in approved facilities.[27] These programmes make many patients travel to high-volume hospitals for their operations. When patients need readmission for complications, the assumption is that patients can seek care at local hospitals without a significant penalty in surgical outcomes. Our results challenge this theory, and we argue that continuity of surgical care needs to be treated as a competing metric of quality in choices of hospital in which to undergo major surgery.

Maintenance of continuity of care after hospital discharge has been shown to be a plausible and effective strategy to improve outcomes in a range of patients with high-risk medical disorders.[15,16,28–30] For example, integrated post-hospital care delivery has been shown to reduce readmissions for patients with acute and chronic medical conditions, such as pneumonia, urinary tract infections, heart failure, and chronic obstructive pulmonary disease.[15,16] Moreover, continuity of care has been reported to reduce complications and reduce overall health-care costs for patients with chronic diseases.[15] This benefit is maintained when patients are cared for by teams within the same health-care setting, regardless of whether the same providers are involved with every episode of care.[28] Although continuity of care in the management of patients undergoing surgery has not been thoroughly investigated, some studies[12,29,30] suggest that patients returning to the same hospital and maintaining frequent contact with the surgical and primary care teams in the period following hospital discharge after high-risk surgery might have reduced risk of readmission and death. Our data further support the importance of continuity in surgical care, showing a dose-dependent reduction in mortality after readmission as the degree of continuity increased at the hospital level and provider level (figure 3). Moreover, our results suggest that continuity of care during readmission is a more consistent predictor of survival for patients who have undergone surgery after discharge from hospital than are other established quality measures such as hospital procedure volume.

Our study has several limitations. First, because our study was retrospective, readmission destination for patients was subject to selection bias and unmeasured confounding. This might include factors that determine severity of illness, time to presentation, and access to health care. Second, in our use of administrative billing data, we could not capture the full extent of the patient care continuity or conditions that determine medical complexity. Patients with the resources to return to the hospital where surgery was done might have clinical characteristics give a survival advantage. The findings from our instrumental variable analysis, however, reduce the likelihood that the effects seen for mortality result solely from unmeasured confounding. Third, our large, national study focused on Medicare patients and therefore our findings might not be generalisable to younger patient populations undergoing high-risk surgery or populations outside the USA.

Our results suggest that maintenance of continuity of surgical care is an important marker of quality, and should be taken into consideration in assessments of the advantages and potential unintended consequences of cost-effectiveness-driven regional centralisation of surgical care.

Contributors

BSB, PPG, MHS, and SRGF conceived and designed the study. DJG did the analyses and, with BSB, PPG, LWK, MHS, and SRGF assisted with the study design and analysis. BSB drafted the report and revised it with contributions from all authors.

Declaration of interests

We declare no competing interests.

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