Supplementary Online Content

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This supplementary material has been provided by the authors to give readers additional information about their work.

eAppendix 1. Diagnosis and Procedure Codes Used in Analysis

CCS codes used to define cohort for practice-pattern analysis

Category	CCS Category Description
10, 11, 12	Thyroidectomy and other endocrine procedures
57	Creation; revision and removal of arteriovenous fistula or vessel-to-vessel cannula for dialysis
66	Procedures on spleen
67	Other therapeutic procedures; hemic and lymphatic system
70	Upper gastrointestinal endoscopy; biopsy
71, 72, 73	Other enterostomy procedures
74	Gastrectomy; partial and total
75	Small bowel resection
76, 77	Colonoscopy or proctoscopy and biopsy
78, 79	Colorectal resection; Local excision of large intestine lesion (not endoscopic)
80	Appendectomy
81	Hemorrhoid Procedures
84	Cholecystectomy and common duct exploration
85	Inguinal and femoral hernia repair
86	Other hernia repair
87	Laparoscopy (GI only)
89	Exploratory laparotomy
90	Excision; lysis peritoneal adhesions
94, 96, 99	Other OR gastrointestinal therapeutic procedures
165, 166, 167	Procedures on breast (mastectomy, lumpectomy, breast biopsy)
168	Incision and drainage; skin and subcutaneous tissue
169	Debridement of wound; infection or burn
170	Excision of skin lesion

ICD-9 CM codes used to define cohort for patient outcome analysis

Surgery Type	ICD-9 CM Codes	Complex (=1)
Groin hernia repair	53.01, 53.02, 53.03, 53.04, 53.05, 53.10, 53.11, 53.12, 53.13, 53.14, 53.15, 53.16, 53.17, 53.21, 53.29, 53.31, 53.39, 17.11, 17.12, 17.13, 17.21, 17.22, 17.23, 17.24	
Abdominal hernia repair-open	53.51, 53.59, 53.61, 53.69	
Abdominal hernia repair -lap	53.42, 53.43, 53.62, 53.63	
Umbilical hernia repair-open	53.41, 53.49	
Diaphragmatic hernia repair-open	53.72, 53.75	1
Diaphragmatic hernia repair-lap	53.71	1
Cholecystectomy-open	51.21, 51.22	
Cholecystectomy-lap	51.23, 51.24	
Hepatectomy	50.3, 50.22	1
Liver ablation-open	50.23	
Liver ablation-lap	50.25	
Pancreatectomy	52.6, 52.7, 52.51, 52.52, 52.53, 52.59	1
Splenectomy	41.5, 41.43	
Esophagomyotomy	42.7	1
Anti reflux surgery-lap	44.67	
Sleeve gastrectomy-lap	43.82, 44.68	1
Sleeve gastrectomy-open	43.89	1

Roux en Y gastric bypass-lap	44.38	1
Roux en Y gastric bypass-open	44.31, 44.39	1
Adjustable gastric band	44.95	1
Other bariatric	44.3, 44.96, 44.97, 44.99, 44.5, 44.51, 45.9	1
Gastrectomy	43.5, 43.6, 43.7, 43.81, 43.89, 43.91, 43.99	1
Vagotomy	44.00, 44.01, 44.02, 44.03	
Gastroenterostomy	44.38, 44.39	
Ulcer repair	44.40, 44.41, 44.42	
Enterectomy	45.61, 45.62	
Partial colectomy-lap	17.31, 17.32, 17.33, 17.34, 17.35, 17.36, 17.39	
Partial colectomy-open	45.71, 45.72, 45.73, 45.74, 45.75, 45.76, 45.79	
Total colectomy-lap	45.81	
Total colectomy-open	45.8, 45.82, 45.83	
Appendectomy	47.01, 47.09	
Ostomy revision	46.50, 46.51, 46.52, 46.40, 46.41, 46.43	
Ostomy creation	46.01, 46.03, 46.10, 46.11, 46.13, 46.20, 46.21, 46.22, 46.23, 46.39	
Abdominal-perineal resection	48.5, 48.50, 48.51, 48.52, 48.59	1
Low anterior resection	48.62, 48.63	1
Other proctectomy	48.40, 48.41, 48.42, 48.43, 48.49, 48.69	1
Lysis of adhesions-lap	54.51	
Lysis of adhesions -open	54.59	
Mastectomy	85.41, 85.42, 85.43, 85.44, 85.45, 85.46, 85.47, 85.48	
Adrenalectomy	07.21, 07.22, 07.29, 07.3	1
Parathyroidectomy	06.81, 06.89	
Partial thyroidectomy	06.2, 06.31, 06.39, 06.51	
Total thyroidectomy	06.4, 06.50, 06.52	

ICD9-CM codes used to define postoperative complications[a]

Description	ICD-9-CM Code
Pneumonia or other respiratory complication	480.x-486.x, 507-507.9, 518.4, 518.5x, 518.8-518.89, 997.3x
Myocardial infarction and other cardiac complications	410.00–410.91, 997.1
Nervous system complications	431.00-431.91, 433.00-433.91, 434.00-434.91, 436, 437.1, 997.0-997.09
Deep venous thrombosis/pulmonary embolism	415.11-415.19, 453.4x, 453.8x, 453.9x
Acute renal failure	584-584.9
Bleeding	998.1, 998.11, 998.12; 998.2 AND 99.0-99.09[b]
Postoperative infection	998.5, 998.51, 998.59, 996.64
Mechanical wound complication	998.13, 998.3-998.32
Septicemia	038-038.9, 790.7, 998.02
Return to operating room[b]	06.02, 34.03, 54.12, 54.61, 54.92
Other	998.8, 998.89, 998.9, E87.00[b]

[a] Diagnosis code only included if not present on admission
[b] Procedure codes

eAppendix 2. Complete Matching Algorithm

1) Match exactly for the following variables:
    (a) Hospital ID
2) Subject to (1), fine balance on the following variables:
    (a) Surgeon experience (years from training)
    (b) Primary surgical specialty
    (c) Secondary surgical specialty
3) Subject to (1) and (2), minimize distance between cases and controls for the following variables:
    (a) Age
    (b) Number of comorbidities
    (c) Median income (USD)
    (d) Income missing
    (e) Male
    (f) Hispanic
    (g) African-American
    (h) Other race
    (i) Elective admission
    (j) Emergency admission
    (k) Urgent admission
    (l) Medicare
    (m) Medicaid
    (n) Commercial insurance
    (o) Self insurance
    (p) Other type of payment
    (q) Surgeon age
    (r) Surgeon experience (years from training)
    (s) Total volume
    (t) Volume of complex operations
    (u) Volume of essential operations
    (v) Comorbidities
        1. Congestive Heart Failure
        2. Cardiac Arrhythmias
        3. Valvular Disease
        4. Pulmonary Circulation Disorders
        5. Peripheral Vascular Disorders
        6. Hypertension, Uncomplicated
        7. Hypertension, Complicated
        8. Paralysis
        9. Other Neurological Disorders
        10. Chronic Pulmonary Disease
        11. Diabetes, Uncomplicated
        12. Diabetes, Complicated
        13. Hypothyroidism
        14. Renal Failure
        15. Liver Disease
        16. Peptic Ulcer Disease Excluding Bleeding
        17. AIDS/HIV
        18. Lymphoma
        19. Metastatic Cancer
        20. Solid Tumor Without Metastasis
        21. Rheumatoid Arthritis/Collagen Vascular
        22. Coagulopathy
        23. Obesity
        24. Weight Loss
        25. Fluid and Electrolyte Disorders
        26. Blood Loss Anemia
        27. Deficiency Anemia

28. Alcohol Abuse
29. Drug Abuse
30. Psychoses
31. Depression

(w) Procedure Types
1. Groin hernia
2. Abdominal hernia (open)
3. Abdominal hernia (laparoscopic)
4. Umbilical hernia (open)
5. Diaphragmatic hernia (open)
6. Diaphragmatic hernia (laparoscopic)
7. Cholecystectomy (open)
8. Cholecystectomy (laparoscopic)
9. Hepatectomy
10. Liver ablation (open)
11. Liver ablation (laparoscopic)
12. Pancreatectomy
13. Splenectomy
14. Esophagectomy
15. Esophagomyotomy
16. Anti-reflux operations (laparoscopic)
17. Sleeve gastrectomy (laparoscopic)
18. Sleeve gastrectomy (open)
19. Roux en Y Gastric Bypass (laparoscopic)
20. Roux en Y Gastric Bypass (open)
21. Adjustable laparoscopic band placement
22. Other bariatric operations
23. Gastrectomy
24. Vagotomy
25. Gastroenterostomy
26. Operations for ulcers
27. Enterectomy
28. Partial colectomy (laparoscopic)
29. Partial colectomy (open)
30. Total colectomy (laparoscopic)
31. Total colectomy (open)
32. Appendectomy
33. Ostomy reversal or revision
34. Ostomy creation
35. Proctectomy (abdominal perineal resection)
36. Proctectomy (low anterior resection)
37. Proctectomy (other)
38. Lysis of Adhesions (laparoscopic)
39. Lysis of Adhesions (open)
40. Mastectomy
41. Adrenalectomy
42. Parathyroidectomy
43. Partial thyroidectomy
44. Total thyroidectomy

eAppendix 3. Sensitivity Analysis

In an observational study, one concern is that bias from a hidden covariate can give the impression that a treatment effect exists when in fact no effect is present. Bias from hidden confounders can also mask an actual treatment effect leaving the analyst to conclude there is no effect when in fact such an effect exists. We explored this possibility using a test of equivalence and a sensitivity analysis. For the sensitivity analysis, we conducted a test of equivalence to test the hypotheses that τ is not small. Under a test of equivalence, we test the following null hypothesis $H_0^{(\delta)}: |\tau| > \delta$. Rejecting $H_0^{(\delta)}$ provides a basis for asserting with confidence that $|\tau| < \delta$. $H_0^{(\delta)}$ is the union of two exclusive hypotheses: $\overleftarrow{H}_0^{(\delta)}: \tau \le -\delta$ and $\overrightarrow{H}_0^{(\delta)}: \tau \ge \delta$, and $H_0^{(\delta)}$ is rejected if both $\overleftarrow{H}_0^{(\delta)}$ and $\overrightarrow{H}_0^{(\delta)}$ are rejected. We can apply the two tests without correction for multiple testing since we test two mutually exclusive hypotheses. Thus, we can test whether the estimate from our study is different from other possible treatment effects which are represented by δ.

With a test of equivalence, it is not possible to demonstrate a total absence of effect, but if this were a randomized trial we could safely test that our estimated effect is not as large as δ. That is, we may be able to reject $H_0^{(\delta)}: |\tau| > \delta$. In an observational study, however, there are additional complications. Since the treatment was not randomly assigned, it may be the case that we reject the null hypothesis of equivalence due to hidden confounding. However, using a sensitivity analysis we may find evidence that the test of equivalence is insensitive to biases from nonrandom treatment assignment.
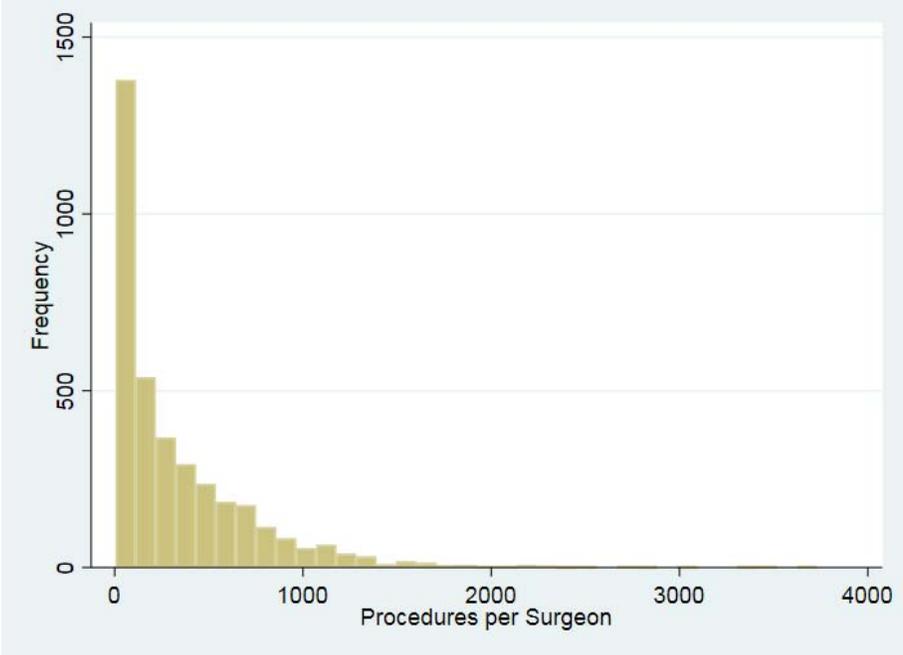
eTable 1. Complete Results of Match

	NUBR Surgeons		UBR Surgeons		Unmatched	Matched
	Unmatched	Matched	Matched	Unmatched		
Surgeon-level variables	Mean				Std.Diff[a]	Std.Diff
Surgeon age, y	52.63	52.43	52.86	53.27	-0.07	-0.05
Surgeon experience, y	16.10	15.84	16.09	16.42	-0.03	-0.02
All procedures, No.	145.23	144.12	147.5	133.92	0.09	-0.03
Complex, No.	30.94	31.01	31.58	33.29	-0.03	-0.01
Essential, No.	121.96	120.77	123.21	109.52	0.12	-0.02
	Proportion of surgeons				Std.Diff	Std.Diff
Surgeon sex, female	0.19	0.20	0.19	0.19	-0.01	0.04
Patient-level variables	Mean				Std.Diff	Std.Diff
Age, years	56.43	56.35	56.35	56.07	0.05	0
Comorbidities, number	2.12	2.16	2.17	2.24	-0.17	-0.01
Median Income, USD	52449	53115	53228	53550	-0.09	-0.01
	Mean proportion of patients per surgeon				Std.Diff	Std.Diff
Sex-Male	0.40	0.40	0.40	0.40	0.01	-0.01
Ethnicity-Hispanic	0.12	0.10	0.11	0.10	0.1	-0.01
Race-White	0.79	0.77	0.76	0.74	0.21	0.04
Race-African-American	0.11	0.12	0.12	0.12	-0.09	-0.04
Race-Other	0.10	0.11	0.11	0.14	-0.21	-0.03
Admission-Emergent	0.49	0.48	0.48	0.44	0.14	0.01
Admission-Urgent	0.09	0.09	0.09	0.08	0.06	0.01
Admission-Elective	0.42	0.43	0.43	0.47	-0.17	-0.01
Insurance-Medicare	0.38	0.38	0.37	0.37	0.06	0.03
Insurance-Medicaid	0.11	0.10	0.11	0.10	0.1	-0.05
Insurance-Commercial	0.42	0.43	0.43	0.45	-0.18	-0.01
Insurance-Self	0.05	0.05	0.05	0.05	0.03	-0.01
Insurance-Other	0.04	0.04	0.03	0.03	0.18	0.03
Income Missing	0.04	0.04	0.04	0.05	-0.09	0.03
Comorbidities	Mean proportion of patients per surgeon				Std.Diff	Std.Diff
Congestive Heart Failure	0.05	0.05	0.05	0.05	-0.05	0.02
Cardiac Arrhythmias	0.11	0.11	0.11	0.12	-0.13	0.01
Valvular Disease	0.03	0.04	0.04	0.04	-0.11	-0.02
Pulmonary Circulation Disorders	0.01	0.02	0.01	0.02	-0.12	0.05
Peripheral Vascular Disorders	0.03	0.04	0.03	0.04	-0.07	0.06
Hypertension, Uncomplicated	0.40	0.40	0.40	0.39	0.04	-0.08
Hypertension, Complicated	0.06	0.06	0.06	0.06	-0.01	0.04
Paralysis	0.01	0.01	0.01	0.01	-0.04	-0.05
Other Neurological Disorders	0.03	0.03	0.03	0.03	-0.01	0.04
Chronic Pulmonary Disease	0.15	0.16	0.16	0.16	-0.06	-0.02
Diabetes,	0.12	0.12	0.13	0.13	-0.1	-0.07

	NUBR Surgeons		UBR Surgeons		Unmatched	Matched
	Unmatched	Matched	Matched	Unmatched		
Uncomplicated						
Diabetes, Complicated	0.01	0.01	0.01	0.02	-0.11	-0.05
Hypothyroidism	0.11	0.11	0.11	0.10	0.02	0.02
Renal Failure	0.06	0.07	0.07	0.07	-0.08	0.01
Liver Disease	0.05	0.05	0.05	0.05	-0.08	-0.03
Peptic Ulcer Disease Excluding Bleeding	0.01	0.01	0.01	0.01	-0.05	-0.06
AIDS/HIV	0.00	0.00	0.00	0.00	-0.12	-0.11
Lymphoma	0.01	0.01	0.01	0.01	-0.02	0.07
Metastatic Cancer	0.07	0.07	0.08	0.09	-0.2	-0.06
Solid Tumor Without Metastasis	0.19	0.20	0.20	0.23	-0.17	-0.01
Rheumatoid Arthritis/ Collagen Vascular	0.02	0.02	0.02	0.02	-0.05	-0.04
Coagulopathy	0.03	0.03	0.03	0.04	-0.14	0.02
Obesity	0.14	0.13	0.13	0.13	0.02	0.01
Weight Loss	0.06	0.06	0.06	0.07	-0.14	-0.04
Fluid and Electrolyte Disorders	0.20	0.21	0.20	0.19	0.06	0.04
Blood Loss Anemia	0.01	0.01	0.01	0.01	0.08	-0.06
Deficiency Anemia	0.02	0.02	0.01	0.01	0.12	0.10
Alcohol Abuse	0.02	0.02	0.02	0.02	-0.03	0.01
Drug Abuse	0.01	0.01	0.01	0.01	-0.03	0.04
Psychoses	0.01	0.01	0.01	0.01	-0.02	0.02
Depression	0.10	0.10	0.09	0.10	0.02	0.07
Operations	Mean proportion of operations per surgeon				Std.Diff	Std.Diff
Groin hernia repair	0.02	0.02	0.02	0.02	0.07	-0.03
Abdominal hernia repair-open	0.05	0.04	0.04	0.07	-0.16	-0.03
Abdominal hernia repair -lap	0.01	0.01	0.01	0.01	0.01	0.03
Umbilical hernia repair-open	0.01	0.01	0.01	0.01	-0.08	-0.05
Diaphragmatic hernia repair-open	0.00	0.00	0.00	0.00	-0.07	-0.05
Diaphragmatic hernia repair-lap	0.01	0.01	0.01	0.01	-0.03	0.05
Cholecystectomy-open	0.03	0.03	0.03	0.03	-0.07	0.02
Cholecystectomy-lap	0.20	0.30	0.28	0.16	0.26	0.06
Hepatectomy	0.01	0.00	0.01	0.01	-0.17	-0.02
Liver ablation-open	0.00	0.00	0.00	0.00	-0.04	0.00
Liver ablation-lap	0.00	0.00	0.00	0.00	0.00	0.00
Pancreatectomy	0.01	0.00	0.01	0.02	-0.18	-0.03
Splenectomy	0.01	0.01	0.01	0.01	-0.06	0.10
Esophagectomy	0.00	0.00	0.00	0.01	-0.17	-0.07
Esophagomyotomy	0.00	0.01	0.00	0.01	-0.13	0.1
Anti reflux surgery-lap	0.01	0.01	0.00	0.02	-0.10	0.11
Sleeve gastrectomy-lap	0.02	0.00	0.00	0.02	0.00	0.00
Sleeve gastrectomy-open	0.00	0.00	0.00	0.00	0.05	0.00

	NUBR Surgeons		UBR Surgeons		Unmatched	Matched
	Unmatched	Matched	Matched	Unmatched		
Roux en Y gastric bypass-lap	0.02	0.00	0.00	0.01	0.05	0.00
Roux en Y gastric bypass-open	0.00	0.00	0.00	0.00	-0.03	0.00
Adjustable gastric band	0.00	0.00	0.00	0.00	-0.03	0.00
Other bariatric	0.00	0.00	0.00	0.00	0.00	0.00
Gastrectomy	0.01	0.00	0.01	0.02	-0.2	-0.11
Vagotomy	0.00	0.00	0.00	0.00	-0.03	0.10
Gastroenterostomy	0.01	0.00	0.01	0.01	0.08	-0.14
Ulcer repair	0.01	0.00	0.00	0.01	0.12	0.03
Enterectomy	0.05	0.08	0.06	0.05	-0.03	0.06
Partial colectomy-lap	0.06	0.03	0.07	0.04	0.19	-0.14
Partial colectomy-open	0.09	0.09	0.08	0.07	0.24	0.04
Total colectomy-lap	0.00	0.00	0.00	0.00	0.04	
Total colectomy-open	0.00	0.01	0.01	0.00	-0.02	-0.03
Appendectomy	0.13	0.17	0.13	0.11	0.11	0.10
Ostomy revision	0.02	0.03	0.01	0.02	0.17	0.12
Ostomy creation	0.02	0.01	0.02	0.02	-0.06	-0.07
Abdominal-perineal resection	0.01	0.00	0.00	0.00	0.11	-0.02
Low anterior resection	0.02	0.01	0.02	0.01	0.17	-0.08
Other proctectomy	0.01	0.00	0.01	0.01	0.17	-0.02
Lysis of adhesions-lap	0.01	0.00	0.01	0.01	-0.11	-0.02
Lysis of adhesions-open	0.03	0.03	0.02	0.03	-0.08	0.03
Mastectomy	0.09	0.07	0.05	0.11	-0.09	0.08
Adrenalectomy	0.00	0.00	0.00	0.00	-0.12	-0.08
Parathyroidectomy	0.01	0.00	0.02	0.01	-0.08	-0.30
Partial thyroidectomy	0.01	0.00	0.01	0.01	-0.08	-0.09
Total thyroidectomy	0.01	0.00	0.02	0.02	-0.06	-0.17

[a] Std.Diff – standardized difference, in units of standard deviation

eFigure 1. Distribution of Procedures per Surgeon in Practice Pattern Analysis

eFigure 2. Distribution of Procedures per Surgeon in Outcomes Analysis