

Supplementary Digital Content Section A – Procedural codes to define study population

Procedure	CCI codes
<b>ORTHOPEDIC</b>	
Total hip replacement	1.VA.53.LA-PN ; 1.VA.53.PN-PN
Total knee replacement	1.VG.53
<b>VASCULAR</b>	
Carotid endarterectomy	1.JE.57 <u>without</u> 1.IJ.76 on the same date (exclude concurrent CABG surgery)
Endovascular Abdominal aortic aneurysm repair	1.KA.80.GQ-NRN or 1.KA.50.GS-BD or 1.KA.50.LA-BD or 1.KE.50.GQ-OA or 1.KE.51.GQ-GE [must have ICD-10 code I71.4 on the same admission]
Open Abdominal aortic aneurysm repair	1.KA.80.LA-XXN or 1.KA.76.NB-XXN or 1.KA.76.MZ-XXN [must have ICD-10 code I71.4 on the same admission]
Peripheral arterial bypass surgery	1.KG.76 ; 1.JM.76.MI ; 1.KT.76 ; 1.KG.80 or CCI code 1.KA.76 <u>without</u> ICD-10 codes I71.3 or I71.4 or I71.9 on the same admission.
<b>UROLOGIC</b>	
Partial or total nephrectomy	1.PC.87 ; 1.PC.89 ; 1.PC.91

Total cystectomy	1.PM.89 ; 1.PM.90 ; 1.PM.91 ; 1.PM.92
<b>INTRAPERITONEAL</b>	<b>DAD</b>
Large bowel and rectal surgery	1.NM.87 (all <u>except</u> 1.NM.87.BA) or 1.NM.89 ; 1.NM.91 ; 1.NQ.89 ; 1.NQ.90 or 1.NQ.87 (all <u>except</u> 1.NQ.87.BA)
Partial liver resection	1.OA.87
Pancreaticoduodenectomy	1.OK.87 ; 1.OK.89 ; 1.OK.91
Gastrectomy or esophagectomy	1.NF.87 ; 1.NF.89 ; 1.NF.90 ; 1.NF.91 ; 1.NF.92 ; 1.NA.88 ; 1.NA.89 ; 1.NA.90 ; 1.NA.91 ; 1.NA.92 ; 1.NA.87
<b>THORACIC</b>	
Pneumonectomy and lobectomy	1.GR.89 ; 1.GR.91 ; 1.GT.89 ; 1.GT.91 ; 1.GT.87

Supplementary Digital Content Section B – Frailty defining diagnoses

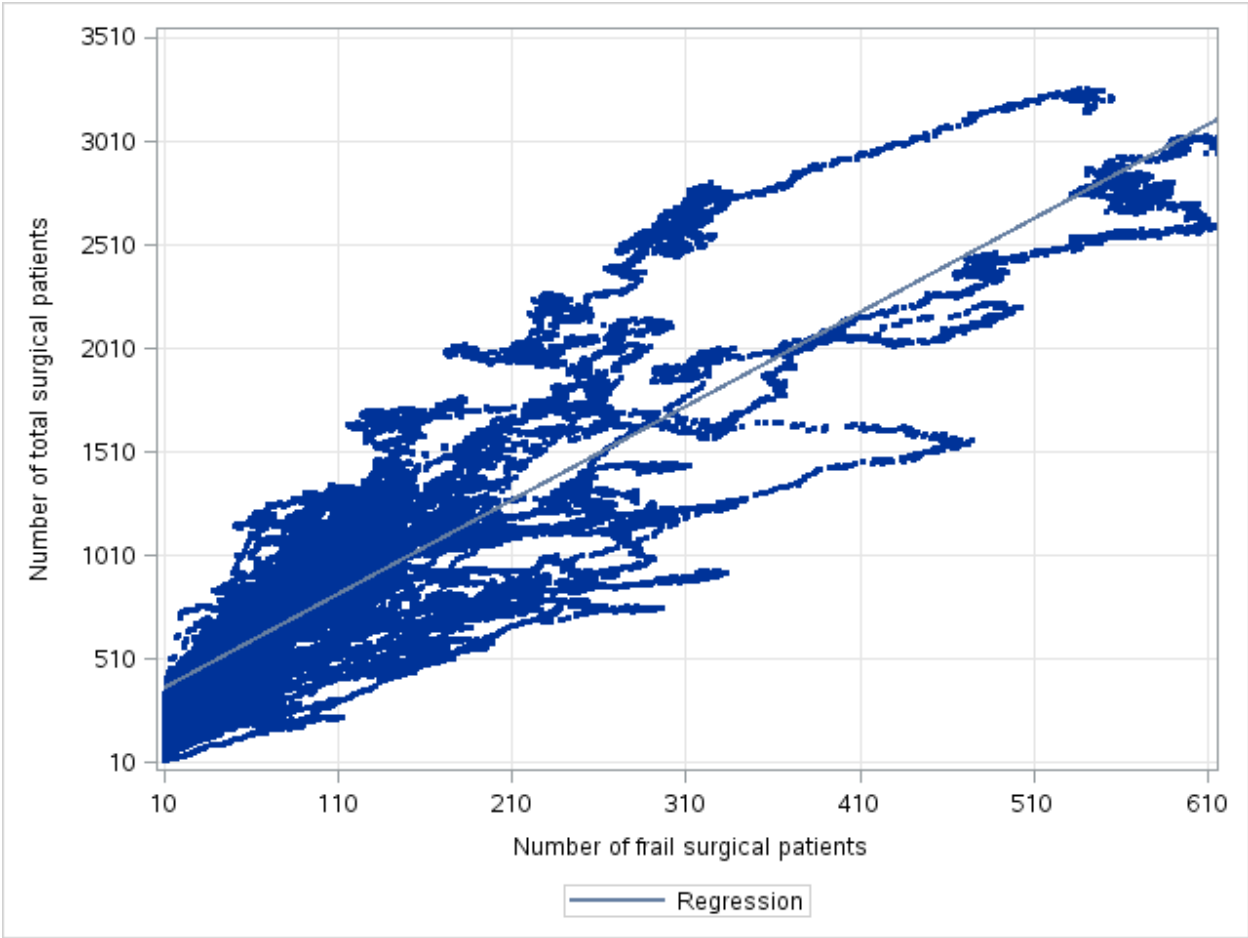
<b>Frailty Concept Diagnoses (Examples)</b>	
Malnutrition	Nutritional Marasmus Other severe protein-calorie malnutrition
Dementia	Senile dementia with delusional or depressive features Senile dementia with delirium
Impaired Vision	Profound impairment, both eyes Moderate or severe impairment, better eye/lesser eye: profound
Decubitus Ulcer	Decubitus Ulcer
Incontinence of Urine	Incontinence without sensory awareness Continuous leakage
Loss of Weight	Abnormal loss of weight and underweight Feeding difficulties and mismanagement Incontinence of Feces Incontinence of feces Obesity (morbid) Morbid obesity
Poverty	Lack Of Housing Inadequate Housing Inadequate material resources
Barriers to Access of Care	No Med Facility For Care No Med Facilities Necessary
Difficulty in Walking	Difficulty in walking Abnormality of gait
Fall	Fall On Stairs Or Steps Fall From Wheelchair

Supplementary Digital Content Section C – Complication codes

<b>Complication</b>	<b>Source</b>	<b>Definition or ICD-10 type 2 diagnostic code</b>
Postoperative mechanical ventilation	OHIP	G557, G405 after surgery
In hospital cardiac arrest	DAD	Flag for heart resuscitation
In hospital AKI	DAD	N17
In hospital MI	DAD	I21,I22,I20, I23.82, I24
In hospital atrial arrhythmia	DAD	I48, I495
In hospital ventricular arrhythmia	DAD	I490
In hospital heart failure	DAD	I50
In hospital ischemic stroke	DAD	I63 or I64
In hospital hemorrhagic stroke	DAD	I60, I61, I62
In hospital TIA	DAD	G45
In hospital pneumonia	DAD	J12, J13, J14, J15, J16, J17, J18, P23
In hospital pulmonary embolism	DAD	I26
In hospital DVT	DAD	I801; I802; I808; I822; I823; I828; I829
In hospital sepsis	DAD	R572, A41
Unplanned return to OR	DAD	Flag return to OR

Supplementary Digital Content Section D - Plot of Total Surgical Volume vs. Frail Surgical volume

This plot shows the total number of surgical patients operated on in each hospital in the year before each index surgery on the Y-axis vs. the total number of frail surgical patients operated on in each hospital in the year before each index surgery on the x-axis. The grey-blue line represents the regression line fitted to the best linear relationship.



Supplementary Digital Content Section E – Outcome model specifications and relative associations for all covariates

Secondary outcome: Adverse events

<b>Covariate</b>		<b>OR</b>	<b>LCL</b>	<b>UCL</b>
Frailty volume quintile (reference)	1 (lowest-	1.00	1.00	1.00
	2	0.92	0.81	1.05
	3	0.90	0.78	1.04
	4	0.90	0.77	1.06
	5 (highest)	0.87	0.72	1.05
Total volume quintile 1 (lowest-reference)		1.00	1.00	1.00
	2	1.14	1.00	1.30
	3	1.12	0.97	1.29
	4	1.04	0.89	1.22
	5 (highest)	1.26	1.05	1.52
Year of surgery (3 knot restricted cubic spline)		1.03	1.01	1.04
Age (5 knot restricted spline)		1.16	1.12	1.20
		0.51	0.40	0.64
		2.64	1.60	4.33
Female ( vs male)		1.50	1.40	1.61
Rural (vs. not/none)		1.10	0.99	1.22
Neighborhood income quintile (reference)	1 (lowest-	1.00	1.00	1.00
	2	0.88	0.79	0.98
	3	0.89	0.80	0.99
	4	0.83	0.74	0.92
	5 (highest)	0.93	0.84	1.04
<b>Co-morbidities</b>				
ASA score (reference)	$\leq 2$	1.00	1.00	1.00
	3	0.93	0.86	1.00
	4	0.87	0.36	2.10
	5	4.63	3.24	6.64
		1.29	1.05	1.59
Alcohol abuse (vs. not/none)		0.50	0.43	0.57
Blood loss anemia (vs. not/none)		1.65	1.51	1.81
Cardiac valve disease (vs. not/none)		0.92	0.77	1.10
Coagulopathy (vs. not/none)		1.67	1.42	1.97
Chronic obstructive pulmonary disease		1.20	1.09	1.32
Cerebrovascular disease (vs. not/none)		1.06	0.91	1.24
Disease of pulmonary circulation (vs. not/none)		3.86	3.32	4.49

Dementia (vs. not/none)	0.85	0.69	1.04
Depression (vs. not/none)	1.20	1.03	1.40
Deficiency anemia (vs. not/none)	1.00	0.73	1.36
Diabetes mellitus without complications (vs. not/none)	0.81	0.74	0.90
Diabetes mellitus with complications (vs. not/none)	1.70	1.54	1.87
Dialysis (vs. not/none)	1.01	0.76	1.33
Drug abuse (vs. not/none)	1.11	0.75	1.65
Heart failure (vs. not/none)	5.25	4.77	5.77
Hemiplegia (vs. not/none)	1.32	0.97	1.80
Hypertension with complications (vs. not/none)	1.50	1.23	1.83
Hypertension without complications (vs. not/none)	1.35	1.25	1.45
Liver disease (vs. not/none)	0.93	0.68	1.29
Malignancy (vs. not/none)	0.98	0.87	1.10
Metastases (vs. not/none)	1.32	1.03	1.69
Obesity (vs. not/none)	0.84	0.76	0.93
Peptic ulcer disease (vs. not/none)	0.70	0.53	0.94
Peripheral vascular disease (vs. not/none)	0.98	0.84	1.14
Psychoses (vs. not/none)	1.71	1.24	2.36
Renal disease (vs. not/none)	0.81	0.68	0.98
Rheumatic disease (vs. not/none)	0.88	0.66	1.17
Venous thromboembolism (vs. not/none)	0.77	0.57	1.02
Weight loss (vs. not/none)	1.17	0.96	1.41
<b>One-year mortality risk</b>			
HOMR score (per 1 unit increase)	1.04	1.03	1.05
<b>Healthcare resource use</b>			
Acute hospitalization in year prior to index admission (vs. not/none)	0.79	0.72	0.86
Emergency department visit in year prior to index admission (vs. not/none)	0.80	0.73	0.87
<b>Procedure</b>			
Total hip replacement (reference)	1.00	1.00	1.00
Total knee replacement (vs. not/none)	0.95	0.85	1.05
Carotid endarterectomy (vs. not/none)	1.30	1.01	1.68
Endovascular AAA repair repair (vs. not/none)	1.27	0.90	1.81
Open AAA repair (vs. not/none)	4.82	4.00	5.82
Peripheral arterial bypass (vs. not/none)	1.99	1.68	2.35
Nephrectomy (vs. not/none)	2.44	2.01	2.97
Cystectomy (vs. not/none)	4.63	3.66	5.87
Large bowel surgery (vs. not/none)	2.47	2.21	2.76
Liver resection (vs. not/none)	3.71	2.70	5.10
Pancreaticoduodenectomy (vs. not/none)	4.39	3.13	6.16
Gastrectomy or esophagectomy (vs. not/none)	5.34	4.43	6.43
Lobectomy or pneumonectomy (vs. not/none)	3.55	2.91	4.34

AAA: Abdominal aortic aneurysm; ASA: American Society of Anesthesiologists; HOMR: Hospital One Year Mortality Risk; LCL: Lower Confidence Level (95%) OR: Odds Ratio; UCL: Upper Confidence Level (95%)

Secondary outcome: Failure to rescue

<b>Covariate</b>		<b>OR</b>	<b>LCL</b>	<b>UCL</b>
Frailty volume quintile (reference)	1 (lowest-			
	2	0.95	0.64	1.40
	3	0.62	0.39	0.98
	4	0.60	0.36	0.99
	5 (highest)	0.40	0.21	0.76
Total volume quintile 1 (lowest-reference)	2	1.66	1.11	2.49
	3	1.79	1.11	2.86
	4	1.62	0.96	2.73
	5 (highest)	2.40	1.27	4.53
	Year of surgery (3 knot restricted cubic spline)	1.01	0.97	1.06
Age (5 knot restricted spline)		1.14	1.01	1.28
		0.59	0.26	1.33
		1.72	0.31	9.41
Female ( vs male)		1.21	0.95	1.53
Rural (vs. not/none)		0.73	0.54	1.00
Neighborhood income quintile (reference)	1 (lowest-	1.00	1.00	1.00
	2	1.15	0.82	1.61
	3	1.21	0.85	1.71
	4	0.81	0.55	1.18
	5 (highest)	1.28	0.91	1.82
<b>Co-morbidities</b>				
ASA score (reference)	$\leq 2$	1.00	1.00	1.00
	3	0.66	0.52	0.84
	4	1.57	1.14	1.96
	5	3.47	1.95	6.19
	Alcohol abuse (vs. not/none)	1.58	0.91	2.73
Atrial arrhythmia (vs. not/none)	1.86	1.35	2.56	
Blood loss anemia (vs. not/none)	1.29	1.00	1.66	
Cardiac valve disease (vs. not/none)	1.33	0.87	2.04	
Coagulopathy (vs. not/none)	0.70	0.44	1.12	
Chronic obstructive pulmonary disease	1.21	0.93	1.59	
Cerebrovascular disease (vs. not/none)	1.33	0.88	2.03	
Disease of pulmonary circulation (vs. not/none)	0.62	0.39	1.00	
Dementia (vs. not/none)	1.91	1.18	3.10	
Depression (vs. not/none)	0.80	0.50	1.30	
Deficiency anemia (vs. not/none)	1.81	0.90	3.63	
Diabetes mellitus without complications (vs. not/none)	1.08	0.80	1.46	
Diabetes mellitus with complications (vs. not/none)	1.01	0.76	1.34	
Dialysis (vs. not/none)	1.49	0.82	2.70	
Drug abuse (vs. not/none)	0.68	0.15	3.05	
Heart failure (vs. not/none)	0.88	0.68	1.14	
Hemiplegia (vs. not/none)	0.74	0.30	1.83	
Hypertension with complications (vs. not/none)	1.01	0.62	1.66	
Hypertension without complications (vs. not/none)	0.74	0.59	0.94	
Liver disease (vs. not/none)	1.81	0.83	3.94	
Malignancy (vs. not/none)	1.13	0.82	1.56	



Metastases (vs. not/none)	0.98	0.48	1.99
Obesity (vs. not/none)	1.53	1.10	2.13
Peptic ulcer disease (vs. not/none)	1.79	0.91	3.55
Peripheral vascular disease (vs. not/none)	1.20	0.82	1.76
Psychoses (vs. not/none)	0.75	0.25	2.24
Renal disease (vs. not/none)	1.34	0.86	2.08
Rheumatic disease (vs. not/none)	0.68	0.23	1.99
Venous thromboembolism (vs. not/none)	2.04	1.03	4.05
Weight loss (vs. not/none)	0.83	0.48	1.43
<b>One-year mortality risk</b>			
HOMR score (per 1 unit increase)	1.04	1.01	1.06
<b>Healthcare resource use</b>			
Acute hospitalization in year prior to index admission (vs. not/none)	1.03	0.77	1.37
Emergency department visit in year prior to index admission (vs. not/none)	1.00	0.75	1.33
<b>Procedure</b>			
Total hip replacement (reference)	1.00	1.00	1.00
Total knee replacement (vs. not/none)	0.68	0.43	1.07
Carotid endarterectomy (vs. not/none)	0.66	0.24	1.82
Endovascular AAA repair repair (vs. not/none)	1.32	0.47	3.69
Open AAA repair (vs. not/none)	1.19	0.66	2.13
Peripheral arterial bypass (vs. not/none)	2.18	1.36	3.50
Nephrectomy (vs. not/none)	1.42	0.75	2.69
Cystectomy (vs. not/none)	1.85	0.95	3.62
Large bowel surgery (vs. not/none)	1.88	1.30	2.72
Liver resection (vs. not/none)	3.50	1.53	7.99
Pancreaticoduodenectomy (vs. not/none)	0.82	0.19	3.58
Gastrectomy or esophagectomy (vs. not/none)	1.53	0.86	2.74
Lobectomy or pneumonectomy (vs. not/none)	1.41	0.73	2.72

AAA: Abdominal aortic aneurysm; ASA: American Society of Anesthesiologists; HOMR: Hospital One Year Mortality Risk; LCL: Lower Confidence Level (95%) OR: Odds Ratio; UCL: Upper Confidence Level (95%)

## Secondary outcome: In-hospital costs

Covariate		IRR	LCL	UCL
Frailty volume quintile reference)	1 (lowest-	1.00	1.00	1.00
	2	1.00	0.99	1.02
	3	1.02	1.00	1.04
	4	1.00	0.98	1.02
	5 (highest)	0.98	0.96	1.00
	Total volume quintile 1 (lowest-reference)		1.00	1.00
	2	0.94	0.93	0.95
	3	0.98	0.97	0.99
	4	0.98	0.98	0.99
	5 (highest)	1.03	1.02	1.03

Year of surgery (3 knot restricted cubic spline)		0.98	0.98	0.98
Age (5 knot restricted spline)		1.03	1.03	1.03
		0.90	0.87	0.92
		1.14	1.08	1.22
Female ( vs male)		1.04	1.03	1.04
Rural (vs. not/none)		1.06	1.05	1.07
Neighborhood income quintile	1 (lowest-reference)	1.00	1.00	1.00
	2	0.99	0.98	1.00
	3	0.97	0.96	0.98
	4	0.97	0.96	0.98
	5 (highest)	0.98	0.97	0.99
<b>Co-morbidities</b>		1.00	1.00	1.00
ASA score	$\leq 2$	1.00	1.00	1.00
(reference)	3	0.98	0.97	0.99
	4	0.97	0.88	1.06
	5	2.12	1.95	2.30
Alcohol abuse (vs. not/none)		1.11	1.08	1.15
Atrial arrhythmia (vs. not/none)		0.98	0.96	0.99
Blood loss anemia (vs. not/none)		1.22	1.20	1.24
Cardiac valve disease (vs. not/none)		1.01	0.98	1.04
Coagulopathy (vs. not/none)		1.21	1.18	1.24
Chronic obstructive pulmonary disease		1.08	1.06	1.09
Cerebrovascular disease (vs. not/none)		1.03	1.00	1.05
Disease of pulmonary circulation (vs. not/none)		1.29	1.25	1.33
Dementia (vs. not/none)		0.98	0.95	1.01
Depression (vs. not/none)		1.18	1.15	1.20
Deficiency anemia (vs. not/none)		0.97	0.92	1.02
Diabetes mellitus without complications (vs. not/none)		1.01	1.00	1.03
Diabetes mellitus with complications (vs. not/none)		1.18	1.16	1.20
Dialysis (vs. not/none)		1.44	1.37	1.51
Drug abuse (vs. not/none)		1.09	1.04	1.15
Heart failure (vs. not/none)		1.26	1.24	1.28
Hemiplegia (vs. not/none)		1.14	1.09	1.20
Hypertension with complications (vs. not/none)		1.07	1.04	1.11
Hypertension without complications (vs. not/none)		1.02	1.02	1.03
Liver disease (vs. not/none)		1.05	1.00	1.10
Malignancy (vs. not/none)		1.09	1.07	1.11
Metastases (vs. not/none)		1.21	1.16	1.26
Obesity (vs. not/none)		0.88	0.87	0.89
Peptic ulcer disease (vs. not/none)		0.95	0.91	0.99
Peripheral vascular disease (vs. not/none)		0.99	0.97	1.02
Psychoses (vs. not/none)		1.29	1.23	1.36
Renal disease (vs. not/none)		1.02	0.99	1.05
Rheumatic disease (vs. not/none)		1.22	1.18	1.26
Venous thromboembolism (vs. not/none)		1.08	1.03	1.13
Weight loss (vs. not/none)		1.13	1.10	1.17
<b>One-year mortality risk</b>		1.00	1.00	1.00
HOMR score (per 1 unit increase)		1.01	1.01	1.01

<b>Healthcare resource use</b>	1.00	1.00	1.00
Acute hospitalization in year prior to index admission (vs. not/none)	0.97	0.96	0.98
Emergency department visit in year prior to index admission (vs. not/none)	0.95	0.95	0.96
<b>Procedure</b>	1.00	1.00	1.00
Total hip replacement (reference)	1.00	1.00	1.00
Total knee replacement (vs. not/none)	0.85	0.84	0.86
Carotid endarterectomy (vs. not/none)	0.67	0.65	0.69
Endovascular AAA repair repair (vs. not/none)	1.17	1.11	1.22
Open AAA repair (vs. not/none)	1.56	1.51	1.62
Peripheral arterial bypass (vs. not/none)	1.35	1.31	1.38
Nephrectomy (vs. not/none)	0.98	0.96	1.01
Cystectomy (vs. not/none)	2.06	1.97	2.15
Large bowel surgery (vs. not/none)	1.29	1.27	1.31
Liver resection (vs. not/none)	1.48	1.40	1.56
Pancreaticoduodenectomy (vs. not/none)	2.16	2.04	2.30
Gastrectomy or esophagectomy (vs. not/none)	2.07	2.01	2.14
Lobectomy or pneumonectomy (vs. not/none)	1.51	1.47	1.56

AAA: Abdominal aortic aneurysm; ASA: American Society of Anesthesiologists; HOMR: Hospital One Year Mortality Risk; LCL: Lower Confidence Level (95%) OR: Odds Ratio; UCL: Upper Confidence Level (95%)