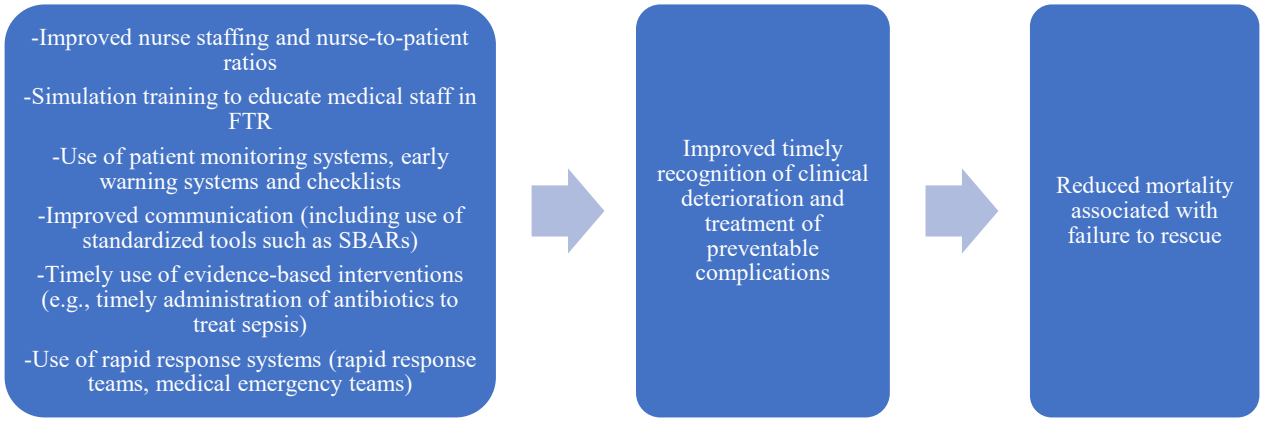
Importance

Attach a logic model and provide a description of the relationship between structures and processes and the desired outcome.

Failure to rescue (FTR) has been defined as the failure or delay to recognize and respond to complications from a disease process or medical intervention in a hospitalized patient (Hall, 2020a). According to the 2020 AHRQ publication *Making Healthcare Safer III*, FTR represents an important quality indicator since in-hospital complications can affect any patient regardless of the diagnosis or disease process (Hall, 2020). Various hospital characteristics, including higher nurse-to-bed ratios, more advanced nurse skill mix, greater hospital volume, a greater share of surgeons and anesthesiologists who are board certified and the presence of house staff have been shown to reduce failure to rescue rates (Aiken, 2011, 2014; Audet, 2018; Bourgon Labelle, 2019; Brooks-Carthon, 2012; Gonzalez et al., 2014; Kendall-Gallagher, 2011; Kutney-Lee, 2013, 2015; Liao, 2016; Ma, 2015; McHugh, 2012, 2013; Silber 1992, 1995, 2007; Twigg, 2019). Additionally, other processes of care – such as a hospitals use of technology-supported interventions (such as patient monitoring systems and rapid response teams), standardized communication tools, or simulation training – can improve timely recognition and response to clinical deterioration and reduce failure to rescue (Burke, 2022; Hall, 2020a; Hall, 2020b).

This logic model is adapted from Burke JR, Downey C, Almoudaris AM. Failure to Rescue Deteriorating Patients: A Systematic Review of Root Causes and Improvement Strategies. J Patient Saf. 2022;18(1):e140-e155. https://doi.org/10.1097/PTS.0000000000000720.

Exhibit 1. Failure to Rescue Logic Model



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If implemented, what is the measure's anticipated impact on important outcomes? *

Compared with the current CMS PSI 04 measure that is used for public reporting, the proposed measure has a much higher minimum volume threshold (25 versus 3), covers over 8 times more denominator patients, and captures about 2.1 times more numerator events (deaths). The numerator increase is largely due to the application of this measure to both Medicare Advantage and FFS enrollees, as well as the inclusion of deaths after hospital discharge but within 30 days of the index operative procedure.

Table 1. Comparison of Observed Distribution Across Hospitals (PSI 04 as Currently Specified versus Proposed 30-day Mortality Measure)

Label	Min	5th %	10th%	25th %	Med	75th %	90th %	95th %	Max
Proposed measure denominator	25	77	91	141	293	628	1264	1731	8099
Current CMS PSI 04 denominator	3	4	5	11	29	68	128	*	617
Proposed measure numerator (deaths in 30 days)	0	0	3	5	13	32	56	77	195
Current CMS PSI 04 numerator (in-hospital deaths)	0	0	0	1	4	11	23	*	97
Proposed measure, observed rate per 1000 discharges	0	0	6.2	26.3	44.1	65.2	90.9	108.2	222.2
Current CMS PSI 04, observed rate per 1000 discharges	0	0	0	84.7	149.5	206.9	266.7	*	666.7
Proposed measure, risk standardized rate per 1000 discharges	0	0	8.38	29.33	43.48	60.95	80.75	91.01	341.71
Current CMS PSI 04, risk standardized rate per 1000 discharges	0	0	0	103.36	159.94	209.52	261.01	*	1000.0

Note: N=2,055 hospitals with at least 25 denominator-qualifying Medicare discharges from IPPS hospitals (7/1/2020-6/30/2022) using ICD-10-CM/PCS processed with CMS+VA v13.0 software.
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Scientific Acceptability

Please provide descriptive characteristics of measured entities included in the analysis (e.g., size, location, type). *

Table 2. Descriptive Characteristics of the Hospitals with 25 or More Discharges (Medicare FFS, 1/1/2021-6/30/2022)

Hospital Characteristic	Hospitals (N)	% of Hospitals
Hospital Size	*	*
Missing	8	0.4%
Small: Certified beds <100	268	13.0%
Medium: Certified beds 100-250	753	36.6%
Large: Certified beds >250	1,026	49.9%
Hospital Teaching	*	*
Missing	8	0.4%
Nonteaching: Resident FTE/bed ratio = 0	1,492	72.6%
Community teaching: Resident FTE/bed ratio (0 - 0.25)	388	18.9%
Major teaching: Resident FTE/bed ratio ≥0.25	167	8.1%
Hospital Nursing	*	*
Missing	46	2.2%
Nurse skill mix <0.85	277	13.5%
Nurse skill mix 0.85-0.975	923	44.9%
Nurse skill mix >0.975	809	39.4%
Hospital Location	*	*
Missing	8	0.4%
Rural	260	12.7%
Urban	1,787	87.0%
Hospital Category	*	*
Missing	14	0.7%
Investor Owned <100 beds	86	4.2%
Investor Owned >=100 beds	306	14.9%
Not-for-Profit (Rural); <100 beds	64	3.1%
Not-for-Profit (Rural); >=100 beds	160	7.8%
Not-for-Profit (Urban); <100 beds	116	5.6%
Not-for-Profit (Urban); 100-299 beds	598	29.1%
Not-for-Profit (Urban); >=300 beds	711	34.6%
Total	**2055**	**100%**

Note: N=2,055 hospitals with at least 25 denominator-qualifying Medicare FFS discharges from IPPS hospitals (1/1/2021-6/30/2022) using ICD-10-CM/PCS processed with CMS+VA v13.0 software.
*Cells left intentionally blank

Table 3. Descriptive Characteristics of the Medicare FFS Population (1/1/2021-6/30/2022)

Measure Denominator Population Characteristics	N	%
Total number of encounters	417,054	100.0
Total number of deaths	18,152	4.4
Age (Mean/Std.Dev)	72.8	9.5
CMR_Index_Mortality (Mean/Std.Dev)	6.4	13.4
Age Category	*	*
Age≤40	4,093	1.0
40<Age≤50	7,337	1.7
50<Age≤60	20,833	5.0
60<Age≤70	116,336	27.9
70<Age≤80	156,378	37.5
Age>80	112,077	26.9
Sex	*	*
Male	192,616	46.2
Female	224,438	53.8
Race	*	*
White	354,161	84.9
Black	34,489	8.3
Other	5,570	1.3
Asian	5,472	1.3
Hispanic	6,544	1.6
Native/Unknown	10,818	2.6
COVID Diagnosis POA (Yes)	7,592	1.8
Comorbidity-Elixhauser AHRQ	*	*
Acquired immune deficiency syndrome	1,399	0.3
Alcohol abuse	11,539	2.8
Deficiency anemias	78,674	18.9
Autoimmune conditions	24,544	5.9
Chronic blood loss anemia	2,363	0.6
Leukemia	3,131	0.8
Lymphoma	4,060	1.0
Metastatic cancer	14,051	3.4
Solid tumor without metastasis, in situ	157	0.04
Solid tumor without metastasis, malignant	12,416	3.0
Cerebrovascular disease	20,915	5.0
Coagulopathy	29,468	7.1
Dementia	26,714	6.4
Depression	64,878	15.6
Diabetes with chronic complications	101,531	24.3
Diabetes without chronic complications	36,786	8.8
Drug abuse	7,458	1.8
Congestive heart failure	112,160	26.9
Hypertension, complicated	157,155	37.7
Hypertension, uncomplicated	170,225	40.8
Liver disease, mild	17,153	4.1
Liver disease, moderate to severe	4,943	1.2
Chronic pulmonary disease	99,717	23.9
Neurological disorders affecting movement	17,429	4.2
Other neurological disorders	14,044	3.4
Seizures and epilepsy	11,704	2.8

Measure Denominator Population Characteristics	N	%
Obesity	95,069	22.8
Paralysis	14,304	3.4
Peripheral vascular disease	65,261	15.7
Psychoses	13,591	3.3
Pulmonary circulation disease	27,060	6.5
Renal failure, moderate	69,781	16.7
Renal failure, severe	36,682	8.8
Hypothyroidism	82,486	19.8
Other thyroid disorders	6,727	1.6
Peptic ulcer with bleeding	4,592	1.1
Valvular disease	57,308	13.7
Weight loss	37,248	8.9
TRNSFER (from another hospital)	36,498	8.8
FTR-Complication categories after POA or Dx1 exclusions	*	*
Cardiac event complication	104,894	25.2
Congestive heart failure	107,022	25.7
Hypotension/Shock/Hypovolemia	30,735	7.4
Pulmonary embolus/Deep vein thrombosis/Phlebitis	11,278	2.7
Cerebrovascular accident	1,814	0.4
Coma	822	0.2
Seizure	1,631	0.4
Delirium/Psychosis	2,231	0.5
Nervous system complications	63	0.02
Pneumonia/Pneumonitis	8,751	2.1
Pneumothorax	524	0.1
Respiratory compromise/Bronchospasm	16,441	3.9
Internal organ damage/Perforation	2,078	0.5
Peritonitis	10,960	2.6
GI bleed and blood loss	18,251	4.4
Sepsis	10,560	2.5
Deep wound infection/Wound complication	2,354	0.6
Renal dysfunction	43,481	10.4
Gangrene/Amputation	17,448	4.2
Intestinal obstruction/Ischemia	19,894	4.8
Foreign body	31	0.01
Pressure injury	9,744	2.3
Orthopedic complication	32,385	7.8
Hepatitis/Jaundice	4,178	1.0
Pancreatitis	2,513	0.6
Necrosis of bone (Thermal or Aseptic)	2,498	0.6
Osteomyelitis	10,517	2.5
Disseminated intravascular coagulation	311	0.1
Pyelonephritis	1,115	0.3
Postprocedural/Transfusion complication	3,500	0.8
Major Diagnostic Categories (MDCs)	*	*
MDC 05: Diseases and disorders of the circulatory system	130,978	31.4
MDC 06: Diseases and disorders of the digestive system	68,406	16.4
MDC 07: Diseases and disorders of the hepatobiliary system and pancreas	16,487	4.0
MDC 08: Diseases and disorders of the musculoskeletal system and connective tissue	187,720	45.0
MDC 09: Diseases and disorders of the skin, subcutaneous tissue and breast	5,279	1.3
MDC 10: Endocrine, nutritional and metabolic diseases and disorders	8,184	2.0

Measure Denominator Population Characteristics	N	%
Modified Medicare Severity Diagnosis-Related Groups (MDRG; combining levels with and without complications and comorbidities)	*	*
MDRG 502: Percutaneous cardiovascular procedures with non-drug-eluting stent or 4+ arteries or stents	347	0.1
MDRG 503: Cardiac valve and other major cardiothoracic procedures without cardiac catheterization	36,577	8.8
MDRG 505: Other cardiothoracic procedures	4,350	1.0
MDRG 509: Amputation for circulatory system disorders except upper limb and toe	6,574	1.6
MDRG 511: Percutaneous cardiovascular procedures with drug-eluting stent	19,946	4.8
MDRG 513: Percutaneous cardiovascular procedures without coronary artery stent	1,448	0.4
MDRG 514: Other vascular procedures	16,180	3.9
MDRG 515: Upper limb and toe amputation for circulatory system disorders	563	0.1
MDRG 518: Vein ligation and stripping	64	0.02
MDRG 519: Other circulatory system O.R. procedures	2,244	0.5
MDRG 540: Endovascular cardiac valve replacement and supplement procedures	15,706	3.8
MDRG 541: Aortic and heart assist procedures except pulsation balloon	5,367	1.3
MDRG 542: Other major cardiovascular procedures	15,253	3.7
MDRG 543: Percutaneous and other intracardiac procedures	3,971	1.0
MDRG 601: Stomach, esophageal and duodenal procedures	10,489	2.5
MDRG 602: Major small and large bowel procedures	40,626	9.7
MDRG 603: Rectal resection	280	0.1
MDRG 604: Peritoneal adhesiolysis	5,123	1.2
MDRG 605: Appendectomy with complicated principal diagnosis	1,079	0.3
MDRG 606: Appendectomy without complicated principal diagnosis	659	0.2
MDRG 607: Minor small and large bowel procedures	756	0.2
MDRG 608: Anal and stomal procedures	555	0.1
MDRG 609: Inguinal and femoral hernia procedures	1,174	0.3
MDRG 610: Hernia procedures except inguinal and femoral	2,785	0.7
MDRG 611: Other digestive system O.R. procedures	4,077	1.0
MDRG 701: Pancreas, liver and shunt procedures	5,482	1.3
MDRG 702: Biliary tract procedures except only cholecystectomy with or without C.D.E.	647	0.2
MDRG 703: Cholecystectomy with C.D.E.	122	0.03
MDRG 704: Cholecystectomy except by laparoscope without C.D.E.	1,563	0.4
MDRG 705: Laparoscopic cholecystectomy without C.D.E.	7,232	1.7
MDRG 706: Hepatobiliary diagnostic procedures	466	0.1
MDRG 707: Other hepatobiliary or pancreas O.R. procedures	787	0.2
MDRG 801: Combined anterior and posterior spinal fusion	21,794	5.2
MDRG 802: Spinal fusion except cervical with spinal curvature, malignancy, infection or extensive fusions	4,132	1.0
MDRG 803: Spinal fusion except cervical	14,446	3.5
MDRG 804: Bilateral or multiple major joint procedures of lower extremity	1,325	0.3
MDRG 805: Wound debridement and skin graft except hand for musculoskeletal and connective tissue disorders	5,487	1.3
MDRG 806: Revision of hip or knee replacement	15,837	3.8
MDRG 807: Major hip and knee joint replacement or reattachment of lower extremity	34,480	8.3
MDRG 808: Cervical spinal fusion	4,692	1.1
MDRG 809: Amputation for musculoskeletal system and connective tissue disorders	2,501	0.6
MDRG 810: Biopsies of musculoskeletal system and connective tissue	1,580	0.4
MDRG 811: Hip and femur procedures except major joint	51,595	12.4
MDRG 812: Major joint or limb reattachment procedures of upper extremities	4,698	1.1
MDRG 813: Knee procedures with principal diagnosis of infection	1,585	0.4
MDRG 814: Knee procedures without principal diagnosis of infection	749	0.2

Measure Denominator Population Characteristics	N	%
MDRG 815: Back and neck procedures except spinal fusion or disc device or neurostimulator	4,370	1.1
MDRG 816: Lower extremity and humerus procedures except hip, foot and femur	9,310	2.2
MDRG 817: Local excision and removal of internal fixation devices except hip and femur	753	0.2
MDRG 818: Local excision and removal of internal fixation devices of hip and femur	364	0.1
MDRG 819: Soft tissue procedures	1,641	0.4
MDRG 820: Foot procedures	547	0.1
MDRG 821: Major thumb or joint procedures	33	0.01
MDRG 822: Major shoulder or elbow joint procedures	88	0.02
MDRG 823: Arthroscopy	4	0.0
MDRG 824: Shoulder, elbow or forearm procedures, except major joint procedures	861	0.2
MDRG 825: Hand or wrist procedures, except major thumb or joint procedures	209	0.1
MDRG 826: Other musculoskeletal system and connective tissue O.R. procedures	4,001	1.0
MDRG 901: Skin graft for skin ulcer or cellulitis	491	0.1
MDRG 902: Skin graft except for skin ulcer or cellulitis	755	0.2
MDRG 903: Other skin, subcutaneous tissue and breast procedures	2,133	0.5
MDRG 904: Mastectomy for malignancy	157	0.04
MDRG 905: Breast biopsy, local excision and other breast procedures	230	0.1
MDRG 913: Skin debridement	1,473	0.4
MDRG 1001: Adrenal and pituitary procedures	709	0.2
MDRG 1002: Amputation of lower limb for endocrine, nutritional and metabolic disorders	3,144	0.8
MDRG 1003: O.R. procedures for obesity	898	0.2
MDRG 1004: Skin grafts and wound debridement for endocrine, nutritional and metabolic disorders	1,257	0.3
MDRG 1005: Thyroid, parathyroid and thyroglossal procedures	531	0.1
MDRG 1006: Other endocrine, nutritional and metabolic O.R. procedures	1,553	0.4
MDRG 7799: Tracheostomy for face, mouth and neck diagnoses or laryngectomy	4,149	1.0

Dx1=principal diagnosis; MDC=Major Diagnostic Category; MDRG= Modified Medicare Severity Diagnosis-Related Group; POA=present on admission;
Note: N=2,055 hospitals with at least 25 denominator-qualifying Medicare FFS discharges from IPPS hospitals (1/1/2021-6/30/2022) using ICD-10-CM/PCS processed with CMS+VA v13.0 software.
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Reliability

For each level of reliability testing conducted, describe the method of reliability testing and what it tests. *

We applied split-half and test-retest approaches to estimate the reliability of this risk-adjusted measure at the accountable entity (hospital) level, using the intracluster correlation coefficient (ICC) as an estimator.

For hospital h in subsample t where each hospital subsample is based on summarizing performance across a varying number of denominator-eligible patient-days (n_{ht}), we assumed that the smoothed and risk-adjusted performance measure for hospital h and subsample t (Y_{ht}) follows a simple two-level model: $Y_{ht} = \mu + \alpha_h + \varepsilon_{ht}$

where the hospital effects (α_h) are sampled from a normal distribution with mean 0 and variance of hospital effects (σ_b^2) and the residual errors (ε_{ht}) are independently sampled from a normal distribution with mean 0 and variance: σ_e^2/n_{ht}^6

The subsamples here could come from different calendar periods or from randomly generated subsamples (e.g., split-halves) of patients, stratified by hospital. In the split-half approach, we set T=2 without replacement, resulting in two records per hospital based on all-inclusive and mutually exclusive subsamples. Note that the specification of the residual error variance assumes that, conditional on hospital random effects, the variance is inversely proportional to the sample size used to form the hospital-subsample estimate.

We used SAS PROC NLMIXED to analyze the dataset where the units of analysis are hospital subsample estimates. This allowed us to specify a two-level random effects model (hospital subsamples nested within hospital) to properly account for the between-observation variation in denominator sizes, so that we could obtain maximum likelihood estimates of the variance components, including the between hospital variance component (σ_b^2) and the error variance component (σ_e^2). These estimates were then used in a "plug-in" estimator of the classical intracluster correlation coefficient (ICC): $ICC(n) = \sigma_b^2/[(\sigma_b^2 + (\sigma_e^2/n)] = nR/(nR + 1)$ where $R = \sigma_b^2/\sigma_e^2$, which is the ratio of the between-hospital variance component (σ_b^2) over the error variance component (σ_e^2), and n is a hospital's denominator-eligible sample size.

By design, hospital-level risk-adjusted outcome measures are centered around a global mean with an approximately normal distribution (allowing for the fact that the tails of the distribution may be augmented with hospitals that are true quality outliers). Because this ICC depends only on the ratio of between-hospital to within-hospital estimated variance components, and the relevant denominator for each hospital, we can estimate reliability as a function of the hospital's denominator size, using an application of the Spearman-Brown prophecy formula. We applied this methodology to hospital subsamples that were formed by randomly dividing the available year of patient data from each hospital into two, then executing the measure code separately on each split-half, to yield two estimates per hospital.

The higher the ICC, the greater the statistical reliability of the measure, and the greater the proportion of variation that can be attributed to systematic differences in performance across hospitals (i.e., signal as opposed to noise). We used the rubric established by Landis and Koch (1977) to interpret ICCs, while also acknowledging the former Consensus Based Entity's draft acceptable reliability threshold of 0.5:

0 – 0.2: slight agreement

0.21 – 0.39: fair agreement

0.4 – 0.59: moderate agreement

0.6 – 0.79: substantial agreement

0.8 – 0.99: almost perfect agreement

1: perfect agreement

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Validity

Provide the statistical results from validity testing for each level of validity testing conducted*

Table 4. Convergent Validity of Failure-to-Rescue Measures (CMS PSI 04 as Currently Specified versus Proposed 30-day Failure to Rescue Measure) with Other Outcome Measures, Spearman Rank Correlation Coefficients

Hospital Compare Measures	CMS PSI 04 In-Hospital Mortality (Observed)	Proposed CMS 30-Day Failure to Rescue (Observed)
30-d readmission: Acute Myocardial Infarction	0.024	0.106
30-d readmission: Coronary Artery Bypass	0.012	0.183
30-d readmission: COPD	0.044	0.103
30-d readmission: Heart Failure	0.029	0.143
30-d readmission: Hip and Knee	-0.002	0.140
30-d readmission: Hospital-wide	0.139	0.229
30-d readmission: Pneumonia	0.104	0.140
30-d mortality: Acute Myocardial Infarction	0.107	0.175
30-d mortality: Coronary Artery Bypass	0.102	0.239
30-d mortality: COPD	0.081	0.171
30-d mortality: Heart Failure	0.007	0.106
30-d mortality: Pneumonia	0.120	0.213
30-d mortality: Stroke	0.134	0.085
Hip/knee Complication Rate	-0.015	0.093

Note: N=2,055 hospitals with at least 25 denominator-qualifying Medicare discharges from IPPS hospitals (1/1/2021-6/30/2022) using ICD-10-CM/PCS processed with CMS+VA v13.0 software.

Table 5. Known Groups Validity for Failure-to-Rescue Measures (PSI 04 as Currently Specified Versus Proposed 30-day Mortality Measure)

Hospital Characteristic	Hospitals	CMS PSI 04 In-Hospital Mortality (Observed/1000)	Proposed CMS 30-Day Failure to Rescue (Observed/1000)
Hospital Teaching	*	*	*
Resident FTE/bed ratio = 0	1684	42.2	79.6
Resident FTE/bed ratio (0 - 0.25)	404	48.1	81.4
Resident FTE/bed ratio ≥0.25	172	53.5 (1.27x non-teaching)	76.6 (0.96x non-teaching)
Hospital Nursing	*	*	*
Nurse skill mix <0.85	328	46.2	85.2
Nurse skill mix 0.85-0.975	1017	48.5	85.8
Nurse skill mix >0.975	872	38.1 (0.82x lowest skill mix)	70.3 (0.83x lowest skill mix)
Nurse-bed ratio <1	496	45.2	83.2
Nurse-bed ratio 1-2	1266	45.5	81.8
Nurse-bed ratio >2	445	38.8 (0.86x lowest ratio)	69.6 (0.84x lowest ratio)
Hospital Location	*	*	*
Rural	354	37.8	78.5
Urban	1906	45.3 (1.20x rural)	79.9 (1.01x rural)
Hospital Size	*	*	*
<100 beds	358	23.7	53.3

Hospital Characteristic	Hospitals	CMS PSI 04 In-Hospital Mortality (Observed/1000)	Proposed CMS 30-Day Failure to Rescue (Observed/1000)
100-250 beds	850	42.7	83.5
>250 beds	1052	52.2	85.6

Note: N=2,055 hospitals with at least 25 denominator-qualifying Medicare discharges from IPPS hospitals (1/1/2021-6/30/2022) using ICD-10-CM/PCS processed with CMS+VA v13.0 software.
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Risk Adjustment

Explain the rationale for the model.

Table 6. Risk Adjustment Variables used in Published Studies

Reference	Initial Adjustments (OR)	Additional Adjustments (AOR)
Abe, 2020	• Patient characteristics (age, sex), trauma characteristics (mechanism of injury, injury severity scale (ISS), Glascow coma scale, systolic blood pressure, heart rate)	*
Abreu, 2023	• Patient characteristics (age, sex, race/ethnicity, median household income, Charlson comorbidity index score), insurance payer, type of surgical procedure, hospital characteristics (size, location, teaching status	• Patient age, race/ethnicity, hospital location, hospital teaching status, insurance payer, type of surgical procedure
Ahmed, 2014	• Patient characteristics (demographics, comorbidities), admission type	*
Aiken, 2002	• Patient characteristics (age, sex, surgery type, comorbidities, and significant interactions between these terms)	• Hospital size (≤100 beds, 101-250 beds, or ≥251 beds) • Hospital teaching status (nonteaching, ≤1:4 trainee: bed ratio, or >1:4 trainee: bed ratio) • Hospital technology level (high technology hospitals had facilities for open heart surgery and/or major transplants)
Aiken, 2003	*	• Patient characteristics (age, sex, transfer status, emergency admission, surgery type, comorbidities, and significant interactions between these terms) • Hospital size (≤100 beds, 101-250 beds, or ≥251 beds) • Hospital teaching status (nonteaching, ≤1:4 trainee:bed ratio, or >1:4 trainee:bed ratio) • Hospital technology level (high technology hospitals had facilities for open heart surgery and/or major transplants) • Estimated AOR jointly for nurse education level, nurse staffing, nurse experience and board-certification status of surgeon
Bell, 2023	*	• Patient characteristics (age, sex, race/ethnicity, insurance status, comorbidities, methanism of injury, injury severity scale (ISS), motor Glasgow Coma scale, hypotension)
Buettner, 2016	• Patient characteristics (age, sex, race/ethnicity, household income, insurance payer) admission type, operation, hospital characteristics (volume, region)	• Hospital volume, surgeon volume, insurance payer, operation type
Diers, 2022	• Patient characteristics (sex, frailty, tumor location, comorbidities), admission type, hospital caseload	*
Friese, 2010	• Patient characteristics (demographics, comorbidities, cancer information)	• Estimated AOR jointly for six hospital characteristics: teaching intensity, hospital size, National Cancer Institute-designation, Commission on Cancer-designation, technology level, and procedure volume
Friese, 2015	• Patient characteristics (age, sex race/ethnicity, comorbidities), operation performed, hospital characteristics	• Patient characteristics, teaching program, transplant program, adjusted nurse hours/patient day
Glance, 2011	• Death rate used to stratify hospitals adjusted for	*

	patient characteristics (age, sex, mechanism of injury, transfer status, Glasgow Coma Scale motor component, and systolic blood pressure) • FTR adjusted for patient age, sex, transfer status, physiology, mechanism of trauma, injury severity, and comorbidities	
Gleeson, 2019	• Patient characteristics (age, sex), preoperative risk factors (e.g., hypertension, creatinine, dyspnea, weight loss, functional status, disseminated cancer), type of postoperative complications	• Albumin <3.5g/dL, age ≥65, septic shock, acute renal failure, unplanned intubation
Kaestner, 2010	• Year, admission type, patient characteristics (severity adjustment), hospital characteristics (technology level, bed size, nurse-to-bed ratio, nurse mix), decedents' ICU days as an instrumental variable (including non-ICU hospital days as a covariate)	
Karamchandani, 2023	• Patient characteristics (age, sex, race/ethnicity, BMI, functional status), preoperative risk factors (e.g., ASA physical status, dyspnea, smoking status), comorbidities	• Age, sex, ASA physical status, presence of preoperative ascites, disseminated cancer, bleeding disorders, elevated creatinine, low prealbumin values
Kendall-Gallagher, 2011	*	• Patient characteristics (comorbidities, demographics, admission type, surgery type), hospital size, teaching status, technology level, state
Kutney-Lee, 2015	• Patient characteristics (age, sex, surgical diagnosis related group, emergency admission, transfer status, comorbidities)	*
Massarweh, 2016	• Patient characteristics (age, sex, ASA classification), emergency procedure, comorbidities, preoperative functional status, preoperative weight loss, operation speciality/complexity	*
Rosero, 2017	*	• Patient characteristics (demographics, comorbidities), hospital characteristics
Sheetz, 2014	• Risk adjustment at the hospital level for patient characteristics (age, sex, race, BMI, comorbidities, smoking status, alcohol use, DNR status, preoperative functional status, ASA classification, operative duration, surgeon specialty, work relative value units, intraoperative transfusion status)	*
Silber, 2007	• Patient comorbidities	• Partial model adjusted for all patient and hospital characteristics simultaneously
Silber, 2009	• Patient characteristics (age, sex, comorbidities and interactions between terms)	• AOR1 used a random effects model with individual hospital indicators (Note: adding median income of patient's zip code to this model yielded similar outcomes)
Silber, 2010	• Aggressiveness measures adjusted for patient age and sex • Base FTR model adjusted for procedure type	• AOR1 adjusted for procedure type and patient characteristics (age, sex, comorbidities and interactions between terms) • AOR2 adjusted for procedure type, patient characteristics, and hospital characteristics (resident-to-bed ratio, nurse mix, nurse-to-bed ratio, high technology, number of beds) • AOR3 adjusted for procedure type, patient characteristics, hospital characteristics, and geographic region (fixed effects) AOR4 adjusted for procedure type, patient characteristics, hospital characteristics, region, and hospital (random effects model in which each hospital has its own effect)

Silber, 2014a	• Compared hospitals by matching to a template of patients that were close to the overall population	
Silber, 2014b	• Compared hospitals by matching to a hospital-specific template of patients	
Spolverato, 2014	• Patient characteristics, clinicopathological, operative and hospital characteristics	• Patient characteristics, operative and hospital characteristics
Stonko, 2021	• Patient characteristics (age, sex, mechanism of injury, injury severity score, heart rate, Glascow coma score, existence of any complication)	*
Warnack, 2019	• Patient characteristics (age, sex, Charlson comorbidity index, injury severity scale (ISS), need for surgery), physician attributed errors (diagnostic error or delay, treatment delay), nature of injury	*
Wright, 2012	• Patient characteristics (age, year of surgery, race, urgency of operation, performance of extended cytoreduction, Charlson comorbidity index) • Hospital teaching characteristics	*
Yan 2023	• Patient sex, frailty, preoperative acute serious conditions, complications, operative severity score	• Preoperative acute serious conditions, complications, operative severity score, frailty, complications

AOR = adjusted odds ratio; ASA = American Society of Anesthesiologists; BMI = body mass index; DNR = do not resuscitate; OR = odds ratio
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