Importance

Postoperative respiratory failure (PRF)—defined as unplanned intubation or prolonged ventilation—is considered to be the most serious of the postoperative respiratory complications because (1) it represents the "end stage" of several types of pulmonary complications (e.g., pneumonia, aspiration, pulmonary edema, adult respiratory distress syndrome [ARDS]) and non-pulmonary problems such as sepsis, oversedation, seizures, stroke, heart failure, pulmonary embolism, fluid overload and (2) often results in prolonged morbidity, longer length of stay, mortality, higher costs, and is associated with higher 30-day readmission rates (Sabate et al., 2014; Rosen et al., 2013; and Lawson et al., 2013). Healthcare facilities can decrease PRF rates by adopting and following guidelines for assessing perioperative pulmonary risk and implementing recommended preventive strategies for high-risk patients. Careful management of blood products and fluid resuscitation in the perioperative setting may reduce the risk of PRF due to ARDS.

Recent studies and current clinical practice guidelines for PRF have identified enhanced recovery pathways, prophylactic mucolytics, postoperative continuous positive airway pressure ventilation, lung protective intraoperative ventilation, prophylactic respiratory physiotherapy, epidural analgesia, and goal directed hemodynamic therapy as evidence-based interventions to reduce the incidence of PRF. Yet, progress in reducing the incidence of PRF has been stymied by lack of consensus regarding the definition of PRF, which patients are most at-risk, which risk factors are potentially modifiable, and which patients are more likely to benefit from targeted interventions of a health care system's limited resources. This measure would address this gap in data. See **Exhibit 1 below** for PRF logic model adapted from the American College of Physicians (ACP) 2006 clinical practice guidelines.

References:

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2. Sabate S., Mazo V., Canet J. (2014). Predicting postoperative pulmonary complications: implications for outcomes and costs. Case reports in anesthesiology. 27(2), 201-209.
3. Rosen, A. K., Loveland, S., Shin, M., Shwartz, M., Hanchate, A., Chen, Q., Kaafarani, H. M., & Borzecki, A. (2013). Examining the impact of the AHRQ Patient Safety Indicators (PSIs) on the Veterans Health Administration: the case of readmissions. Medical care, 51(1), 37–44.
4. Lawson E.H., Hall B.L., Louie R., et al. (2013). Association between occurrence of a postoperative complication and readmission: implications for quality improvement and cost savings. Annals of surgery, 258(1),10-18.

Exhibit 1: PRF Logic Model

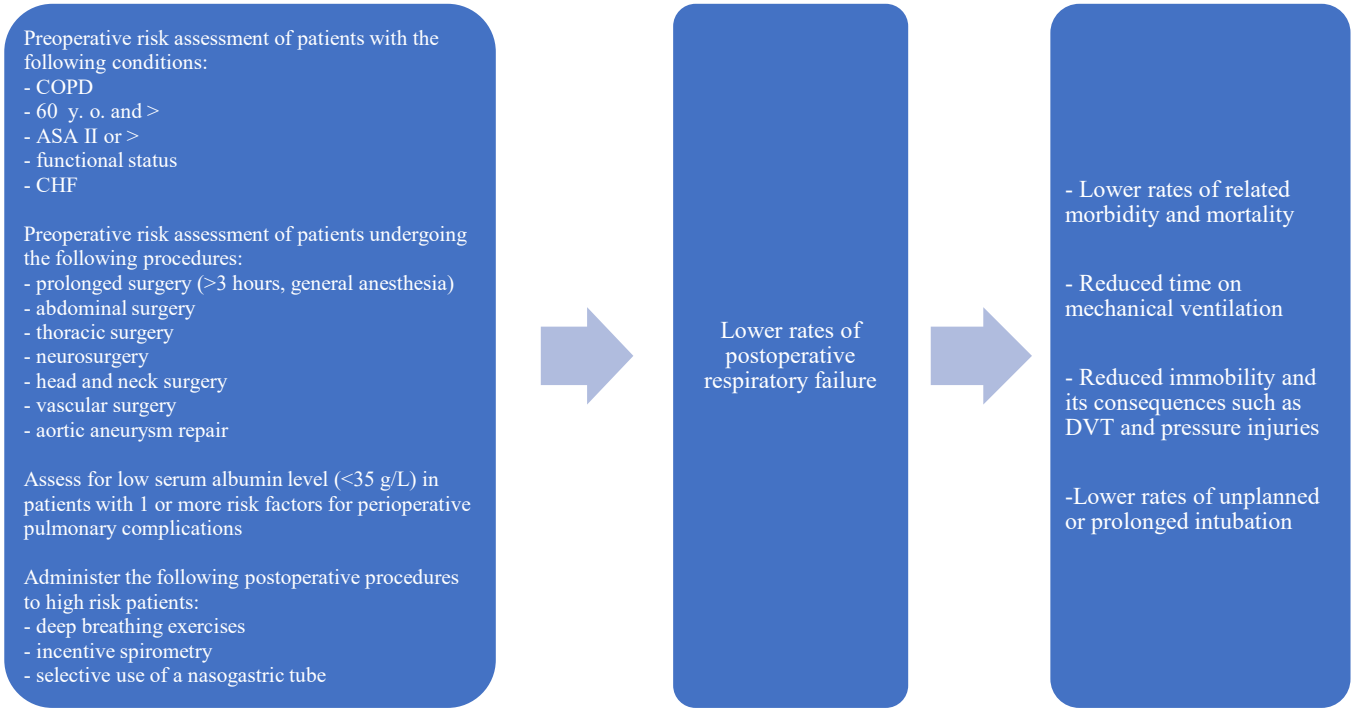
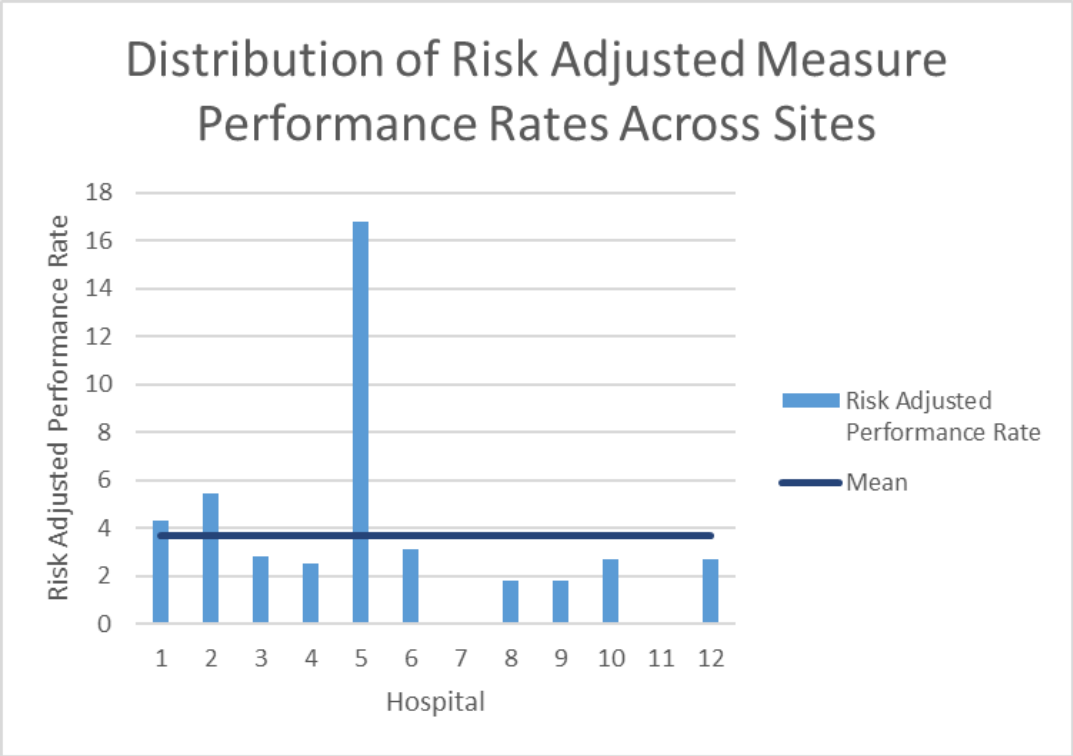


Table 1: Performance Results, By Site (Observed, Predicted, and Risk Adjusted Rates)

Hospital	Observed Rate (per 1000 encounters)	Predicted Rate (per 1000 encounters)	Risk Adjusted (performance) rate	RA rate lower 95% CI	RA rate upper 95% CI	*
1	18.634	12.840	4.346	0.901	7.791	
2	3.165	1.739	5.451	0.117	10.785	
3	1.192	1.274	2.802	1.280	4.324	
4	4.234	4.996	2.538	1.428	3.648	
5	6.270	1.118	16.793	0.388	33.199	MAXIMUM
6	6.174	5.958	3.103	2.048	4.159	
7	0.000	2.958	0.000	0.000	0.000	MINIMUM
8	1.175	1.967	1.789	0.000	5.295	
9	1.155	1.881	1.838	0.000	5.439	
10	1.513	1.678	2.701	0.056	5.347	
11	0.000	1.376	0.000	0.000	0.000	
12	2.846	3.163	2.694	0.336	5.053	MEDIAN

Note: * Cells intentionally left blank.

Exhibit 2: Distribution of Risk-Adjusted Performance Rates Across Sites



Feasibility

Table 2. Feasibility Scores (All Sites)

Data Element	Data Availability	Data Accuracy	Data Standards	Workflow
Encounter, Performed: Elective Hospitalizations	100%	100%	100%	100%
Encounter, Performed: Observation Services	100%	100%	100%	100%
Encounter, Performed: Outpatient Surgery Service	100%	100%	100%	100%
Assessment, Performed: Non-Invasive Oxygen Therapy	100%	100%	100%	100%
Laboratory Test, Performed: Carbon dioxide [Partial pressure] in Arterial blood	100%	100%	100%	100%
Laboratory Test, Performed: Oxygen [Partial pressure] in Arterial blood" using "Oxygen [Partial pressure] in Arterial blood"	100%	100%	100%	100%
Laboratory Test, Performed: pH of Arterial blood" using "pH of Arterial blood"	100%	100%	100%	100%
Procedure, Performed: General and Neuraxial Anesthesia	100%	100%	100%	100%
Procedure, Performed: Head and Neck Surgeries with High Risk Airway Compromise	100%	100%	100%	100%
Procedure, Performed: Intubation	100%	100%	100%	92%
Procedure, Performed: Mechanical Ventilation	100%	100%	100%	100%
Procedure, Performed: Oxygen Therapy by Nasal Cannula or Mask	100%	100%	100%	100%
Procedure, Performed: Tracheostomy Procedures Operating Room/Suite	100%	100%	100%	100%

Data Element	Data Availability	Data Accuracy	Data Standards	Workflow
Removal of endotracheal tube (procedure)	100%	100%	100%	85%
Diagnosis: Acute Respiratory Failure	100%	100%	100%	100%
Diagnosis: Neuromuscular Disorder	100%	100%	100%	100%
Diagnosis: Obstetrics and VTE Obstetrics	100%	100%	100%	100%
Diagnosis attribute: Present on Admission or Clinically Undetermined	100%	100%	100%	100%
Procedural Hospital Locations	100%	100%	100%	100%
Tracheostomy Diagnoses	100%	100%	100%	100%
Procedure, Performed: Tracheostomy Procedures	100%	100%	100%	100%
Procedure, Performed: Non Invasive Oxygen Therapy by Nasal Cannula or Mask	100%	100%	100%	100%
Physical Exam, Performed: Body mass index (BMI) [Ratio]	100%	100%	100%	100%
Assessment, Performed: Tobacco smoking status	100%	100%	100%	100%
Assessment, Performed: American society of anesthesiologists morbidity state)	100%	100%	100%	100%
Laboratory Test, Performed: Bicarbonate	100%	100%	100%	100%
Laboratory Test, Performed: Blood urea nitrogen lab test	100%	100%	100%	100%
Laboratory Test, Performed: Creatinine	100%	100%	100%	100%
Laboratory Test, Performed: Hemoglobin	100%	100%	100%	100%
Laboratory Test, Performed: Hematocrit	100%	100%	100%	100%
Laboratory Test, Performed: Sodium	100%	100%	100%	100%
Date of birth	100%	100%	100%	100%
Ethnicity	100%	100%	100%	100%
Payer	100%	100%	100%	100%
Race	100%	100%	100%	100%
ONC Administrative Sex	100%	100%	100%	100%
Encounter, Performed: Emergency Department	100%	100%	100%	100%
Assessment, Performed: Non Invasive Oxygen Therapy	100%	100%	100%	100%
Laboratory Test, Performed: Aspartate transaminase lab test	100%	100%	100%	100%
Laboratory Test, Performed: Albumin lab test	100%	100%	100%	100%
Laboratory Test, Performed: Aspartate transaminase lab test	100%	100%	100%	100%
Laboratory Test, Performed: Bilirubin lab test	100%	100%	100%	100%
Laboratory Test, Performed: Leukocyte count lab test	100%	100%	100%	100%
Laboratory Test, Performed: Platelet count lab test	100%	100%	100%	100%
Laboratory Test, Performed: White blood cells count lab test	100%	100%	100%	100%
Physical Exam, Performed: Body mass index (BMI) [Ratio]	100%	100%	100%	100%
Physical Exam, Performed: Body temperature	100%	100%	100%	100%
Physical Exam, Performed: Heart rate	100%	100%	100%	100%
Physical Exam, Performed: Respiratory rate	100%	100%	100%	100%
Physical Exam, Performed: Systolic blood pressure	100%	100%	100%	100%

Note: * cell intentionally left blank

Scientific Acceptability

Table 3. Hospital Test Site Characteristics

Health System	Hospital Test Site	EHR System	Region	Bed Size	Teaching Status^	Urban/Rural
A	1	Cerner	Southeast	200-499	Community Teaching	Urban
B	2	Epic	Southeast	200-499	Community Teaching	Urban
C	3	Epic	West	>499	Major Teaching	Urban
D	4	Epic	Northeast	>499	Community Teaching	Urban
D	5	Epic	Northeast	100-199	Community Teaching	Urban
D	6	Epic	Northeast	>499	Major Teaching	Urban
D	7	Epic	Northeast	200-299	Major Teaching	Urban
D	8	Epic	Northeast	100-199	Community Teaching	Urban
D	9	Epic	Northeast	200-299	Community Teaching	Urban
D	10	Epic	Northeast	200-499	Major Teaching	Urban
D	11	Epic	Northeast	100-199	Non-Teaching	Urban
D	12	Epic	Northeast	>499	Major Teaching	Urban
E*	13	Meditech	Southeast	100-199	Non-Teaching	Urban

Note: *Hospital 13 only participated in alpha (feasibility) testing.
Note: ^ Teaching intensity is often measured by the ratio of interns and residents to beds. In this report, major teaching hospitals are those with an intern- and resident-to-bed ratio (IRB) of 0.25 (one resident for every four beds) or above and at least 50 beds, while community teaching hospitals include hospitals with an IRB of less than 0.25 or teaching hospitals with fewer than 50 beds.

Table 4. Measure Denominator Population Characteristics (Sites 1-6)

Measure Denominator Population Characteristics	Site 1	Site 1	Site 2	Site 2	Site 3	Site 3	Site 4	Site 4	Site 5	Site 5	Site 6	Site 6
*	n	%	n	%	n	%	n	%	n	%	n	%
Number of encounters	322	1.1	1,264	4.2	10,909	36.0	4,724	15.6	638	2.1	5,345	17.6
Number of PRF events	6	1.9	4	0.3	13	0.1	20	0.4	4	0.6	33	0.6
Age (Mean)	70.4	9.3	55.4	16.1	57.2	17.1	58.3	16.9	52.4	12.8	59.7	16.5
Sex	*	*	*	*	*	*	*	*	*	*	*	*
Male	167	51.9	872	69.0	5,821	53.4	2,455	52.0	316	49.5	2,953	55.3
Race	*	*	*	*	*	*	*	*	*	*	*	*
White	233	72.4	699	55.3	7,050	64.7	2,427	51.4	123	19.3	2,696	50.4
Black or African American	83	25.8	513	40.6	602	5.5	496	10.5	187	29.3	643	12.0
Other	4	1.2	44	3.5	2,589	23.7	764	16.2	252	39.5	1,539	28.8
Unknown	2	0.6	8	0.6	668	6.1	1,037	21.9	76	11.9	467	8.8
Ethnicity	*	*	*	*	*	*	*	*	*	*	*	*
Hispanic or Latino	1	0.3	15	1.2	1,330	12.2	402	8.5	165	25.9	1,273	23.8
Non-Hispanic	313	97.2	1,236	97.8	8,911	81.7	3,116	66.0	361	56.6	3,536	66.2
Missing	8	2.5	13	1.0	668	6.1	1,206	25.5	112	17.5	536	10.0
(Primary) Payer	*	*	*	*	*	*	*	*	*	*	*	*
Medicaid	38	11.8	64	5.1	1,674	15.4	844	17.9	118	18.5	1,479	27.7
Non-Medicaid	284	88.2	1,200	94.9	9,235	84.6	3,880	82.1	520	81.5	3,866	72.3
Surgical Procedure	321	99.7	1,251	99.0	2,340	21.5	0	0.0	0	0.0	0	0.0
ASA Category	*	*	*	*	*	*	*	*	*	*	*	*
1 or 2	77	23.9	512	40.5	5,249	48.1	2,162	45.8	482	75.6	2,061	38.6
3	164	50.9	729	57.7	5,321	48.8	2,173	46.0	156	24.4	2,773	51.9
4 or 5	81	25.2	23	1.8	339	3.1	389	8.2	0	0.0	511	9.5
White Blood Cell Category	*	*	*	*	*	*	*	*	*	*	*	*
<20,000	321	99.7	1,264	100.0	10,836	99.3	4,609	97.6	629	98.6	5,208	97.4
≥20,000	1	0.3	0	0.0	73	0.7	115	2.4	9	1.4	137	2.6
Albumin Category	*	*	*	*	*	*	*	*	*	*	*	*
≥2.5	321	99.7	1,263	99.9	10,888	99.8	4,641	98.2	636	99.7	5,294	99.1
<2.5	1	0.3	1	0.1	21	0.2	83	1.8	2	0.3	51	0.9
Bilirubin Category	*	*	*	*	*	*	*	*	*	*	*	*
<2.0	322	100.0	1,264	100.0	10,895	99.9	4,680	99.1	638	100.0	5,234	97.9
≥2.0	0	0.0	0	0.0	14	0.1	44	0.9	0	0.0	111	2.1
BUN Category	*	*	*	*	*	*	*	*	*	*	*	*
<14.4	152	47.2	1,136	90.0	9,183	84.2	2,584	54.7	506	79.3	3,113	58.2

Measure Denominator Population Characteristics	Site 1	Site 1	Site 2	Site 2	Site 3	Site 3	Site 4	Site 4	Site 5	Site 5	Site 6	Site 6
*	n	%	n	%	n	%	n	%	n	%	n	%
≥14.4	170	52.8	128	10.0	1,726	15.8	2,140	45.3	132	20.7	2,232	41.8
Creatinine Category	*	*	*	*	*	*	*	*	*	*	*	*
<1.5	278	86.3	1,243	98.3	10,610	97.3	4,384	92.8	630	98.7	4,963	92.8
≥1.5	44	13.7	21	1.7	299	2.7	340	7.2	8	1.3	382	7.2
Hematocrit Category	*	*	*	*	*	*	*	*	*	*	*	*
≥30.0	307	95.3	1,253	99.1	10,416	95.5	4,323	91.5	584	91.5	4,538	84.9
<30.0	15	4.7	11	1.9	493	4.5	401	8.5	54	8.5	807	15.1
Temperature Category	*	*	*	*	*	*	*	*	*	*	*	*
≥36.0	321	99.7	1,263	99.9	10,878	99.7	4,686	99.2	638	100.0	5,317	99.5
<36.0	1	0.3	1	0.1	31	0.3	38	0.8	0	0.0	28	0.5
Heart Rate Category	*	*	*	*	*	*	*	*	*	*	*	*
<110	320	99.4	1,234	97.6	10,774	98.8	4,584	97.0	634	99.4	5,240	98.0
≥110	2	0.6	30	2.4	135	1.2	140	3.0	4	0.6	105	2.0
pH ABG Category	*	*	*	*	*	*	*	*	*	*	*	*
7.25-7.49	316	98.1	1,259	99.6	10,888	99.8	4,685	99.2	637	99.8	5,278	98.8
<7.25 or >7.49	6	1.9	5	0.4	21	0.2	39	0.8	1	0.2	67	1.2
pAO2 Category	*	*	*	*	*	*	*	*	*	*	*	*
≥80	290	90.1	1,256	99.4	10,863	99.6	4,663	98.7	636	99.7	5,279	98.8
<80	32	9.9	8	0.6	46	0.4	61	1.3	2	0.3	66	1.2
Sodium Category	*	*	*	*	*	*	*	*	*	*	*	*
130-149	322	100.0	1,264	100.0	10,663	97.7	4,701	99.5	638	100.0	5,305	99.8
<130 or >149	0	0.0	0	0.0	246	2.3	23	0.5	0	0.0	40	0.2
Acquired immune deficiency syndrome	2	0.6	10	0.8	3	0.0	52	1.1	9	1.4	50	0.9
Alcohol abuse	6	1.9	10	0.8	42	0.4	31	0.7	8	1.3	44	0.8
Deficiency anemias	58	18.0	142	11.2	202	1.9	483	10.2	25	3.9	447	8.4
Autoimmune conditions	24	7.5	42	3.3	216	2.0	179	3.8	9	1.4	169	3.2
Chronic blood loss anemia	0	0.0	20	1.6	5	0.1	24	0.5	4	0.6	27	0.5
Leukemia	2	0.6	1	0.1	20	0.2	22	0.5	0	0.0	22	0.4
Lymphoma	1	0.3	1	0.1	17	0.2	15	0.3	0	0.0	23	0.4
Metastatic cancer	4	1.2	41	3.2	240	2.2	155	3.3	4	0.6	173	3.2
Solid tumor without metastasis, in situ	0	0.0	0	0.0	22	0.2	8	0.2	0	0.0	13	0.2
Solid tumor without metastasis, malignant	7	2.2	34	2.7	183	1.7	103	2.2	4	0.6	159	3.0

Measure Denominator Population Characteristics	Site 1	Site 1	Site 2	Site 2	Site 3	Site 3	Site 4	Site 4	Site 5	Site 5	Site 6	Site 6
*	n	%	n	%	n	%	n	%	n	%	n	%
Cerebrovascular disease	18	5.6	23	1.8	71	0.7	77	1.6	2	0.3	138	2.6
Coagulopathy	9	2.8	25	2.0	72	0.7	109	2.3	9	1.4	214	4.0
Dementia	2	0.6	1	0.1	1	0.0	3	0.1	1	0.2	9	0.2
Depression	37	11.5	212	16.8	711	6.5	490	10.4	48	7.5	523	9.8
Diabetes with chronic complications	55	17.1	140	11.1	500	4.6	333	7.1	21	3.3	483	9.0
Diabetes without chronic complications	54	16.8	134	10.6	832	7.6	510	10.8	92	14.4	687	12.9
Drug abuse	1	0.3	10	0.8	43	0.4	22	0.5	14	2.2	37	0.7
Congestive heart failure	70	21.7	55	4.4	159	1.5	434	9.2	8	1.3	462	8.6
Hypertension, complicated	111	34.5	150	11.9	683	6.3	682	14.4	17	2.7	870	16.3
Hypertension, uncomplicated	163	50.6	597	47.2	2,770	25.4	1,694	35.9	267	41.9	2,317	43.4
Liver disease, mild	3	0.9	48	3.8	131	1.2	180	3.8	17	2.7	416	7.8
Liver disease, moderate to severe	1	0.3	4	0.3	8	0.1	27	0.6	1	0.2	82	1.5
Chronic pulmonary disease	85	26.4	272	21.5	1,174	10.8	790	16.7	114	17.9	941	17.6
Neurological disorders affecting movement	10	3.1	16	1.3	49	0.5	37	0.8	1	0.2	56	1.1
Other neurological disorders	3	0.9	12	1.0	84	0.8	181	3.8	2	0.3	184	3.4
Seizures and epilepsy	5	1.6	11	0.9	59	0.5	100	2.1	12	1.9	127	2.4
Obesity	85	26.4	736	58.2	835	7.7	1,361	28.8	263	41.2	1,339	25.1
Paralysis	4	1.2	15	1.2	66	0.6	52	1.1	2	0.3	69	1.3
Peripheral vascular disease	58	18.0	90	7.1	174	1.6	318	6.7	6	0.9	370	6.9
Psychoses	2	0.6	34	2.7	76	0.7	68	1.4	7	1.1	89	1.7
Pulmonary circulation disease	27	8.4	22	1.7	29	0.3	166	3.5	4	0.6	232	4.3
Renal failure, moderate	37	11.5	95	7.5	148	1.4	184	3.9	6	0.9	407	7.6
Renal failure, severe	23	7.1	16	1.3	220	2.0	215	4.6	1	0.2	197	3.7
Hypothyroidism	64	19.9	146	11.6	678	6.2	541	11.5	44	6.9	659	12.3
Other thyroid disorders	0	0.0	31	2.5	138	1.3	172	3.6	16	2.5	126	2.4
Peptic ulcer with bleeding	0	0.0	4	0.3	2	0.0	12	0.3	3	0.5	26	0.5
Valvular disease	47	14.6	35	2.8	129	1.2	534	11.3	14	2.2	579	10.8
Weight loss	8	2.5	17	1.3	67	0.6	152	3.2	8	1.3	373	7.0

Note: * Cells intentionally left blank.

Table 5. Measure Denominator Population Characteristics (Sites 8-12)

Measure Denominator Population Characteristics	Site 7	Site 7	Site 8	Site 8	Site 9	Site 9	Site 10	Site 10	Site 11	Site 11	Site 12	Site 12
*	n	%	n	%	n	%	n	%	n	%	n	%
Number of encounters	73	0.2	851	2.8	866	2.9	2,643	8.7	995	3.3	1,757	5.8
Number of outcomes	0	0.0	1	0.1	1	0.1	4	0.2	0	0.0	5	0.3
Age (Mean)	19.9	1.8	60.3	15.6	57.9	17.5	63.1	13.9	55.4	16.2	59.7	15.3
Sex	*	*	*	*	*	*	*	*	*	*	*	*
Male	41	56.2	432	50.8	599	69.2	1,597	60.4	684	68.7	1,118	63.6
Race	*	*	*	*	*	*	*	*	*	*	*	*
White	34	46.6	566	66.5	373	43.0	623	23.6	620	62.3	423	24.1
Black or African American	4	5.4	58	6.8	187	22.6	365	13.8	176	17.7	649	36.9
Other	25	34.3	148	17.4	223	25.8	1,549	58.6	160	16.1	367	20.9
Unknown	10	13.7	79	9.3	83	9.6	106	4.0	39	3.9	318	18.1
Ethnicity	*	*	*	*	*	*	*	*	*	*	*	*
Hispanic or Latino	24	32.9	97	11.4	193	22.3	591	22.4	109	11.0	121	6.9
Non-Hispanic	42	57.5	649	76.3	559	64.6	1,827	69.1	837	84.1	1,121	63.8
Missing	7	9.6	105	12.3	114	13.1	225	8.5	49	4.9	515	29.3
(Primary) Payer	*	*	*	*	*	*	*	*	*	*	*	*
Medicaid	33	45.2	94	11.1	205	24.0	1,237	53.2	129	13.0	701	40.0
Non-Medicaid	40	54.8	757	89.0	661	76.0	1,406	46.8	866	87.0	1,056	60.0
Surgical Procedure	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
ASA Category	*	*	*	*	*	*	*	*	*	*	*	*
1 or 2	36	49.3	454	53.4	445	51.4	1,245	47.1	445	44.7	603	34.3
3	32	43.8	392	46.1	405	46.8	1,308	49.5	532	53.5	1,073	61.1
4 or 5	5	6.9	5	0.5	16	1.8	90	3.4	18	1.8	81	4.6
White Blood Cell Category	*	*	*	*	*	*	*	*	*	*	*	*
<20,000	70	95.9	828	97.3	857	99.0	2,604	98.5	977	98.2	1,719	97.8
≥20,000	3	4.1	23	2.7	9	1.0	39	1.5	18	1.8	38	2.2
Albumin Category	*	*	*	*	*	*	*	*	*	*	*	*
≥2.5	72	98.6	850	99.9	865	99.9	2,639	99.8	992	99.7	1,734	98.7
<2.5	1	1.4	1	0.1	1	0.1	4	0.2	3	0.3	23	1.3
Bilirubin Category	*	*	*	*	*	*	*	*	*	*	*	*
<2.0	69	94.5	848	99.7	863	99.7	2,641	99.9	994	99.9	1,743	99.2
≥2.0	4	5.5	3	0.3	3	0.3	2	0.1	1	0.1	14	0.8
BUN Category	*	*	*	*	*	*	*	*	*	*	*	*
<14.4	68	93.2	464	54.5	557	64.3	1,475	55.8	659	66.2	1,026	58.4

Measure Denominator Population Characteristics	Site 7	Site 7	Site 8	Site 8	Site 9	Site 9	Site 10	Site 10	Site 11	Site 11	Site 12	Site 12
*	n	%	n	%	n	%	n	%	n	%	n	%
≥14.4	5	6.8	387	45.5	309	35.6	1,168	44.2	336	33.8	731	41.6
Creatinine Category	*	*	*	*	*	*	*	*	*	*	*	*
<1.5	72	98.6	832	97.8	818	94.5	2,542	96.2	974	97.9	1,686	96.0
≥1.5	1	1.4	19	2.2	48	5.5	101	3.8	21	2.1	71	4.0
Hematocrit Category	*	*	*	*	*	*	*	*	*	*	*	*
≥30.0	67	91.8	785	92.2	756	87.3	2,397	90.7	937	94.2	1,537	87.5
<30.0	6	8.2	66	7.8	110	12.7	346	9.3	58	5.8	220	12.5
Temperature Category	*	*	*	*	*	*	*	*	*	*	*	*
≥36.0	73	100.0	847	99.5	866	100.0	2,562	96.9	967	97.2	1,752	99.7
<36.0	0	0.0	4	0.5	0	0.0	81	3.1	28	2.8	5	0.3
Heart Rate Category	*	*	*	*	*	*	*	*	*	*	*	*
<110	65	89.0	847	99.5	855	98.7	2,617	99.0	985	99.0	1,733	98.6
≥110	8	11.0	4	0.5	11	1.3	26	1.0	10	1.0	24	1.4
pH ABG Category	*	*	*	*	*	*	*	*	*	*	*	*
7.25-7.49	72	98.6	844	99.2	866	100.0	2,638	99.8	995	100.0	1,750	99.6
<7.25 or >7.49	1	1.4	7	0.8	0	0.0	5	0.2	0	0.0	7	0.4
pAO2 Category	*	*	*	*	*	*	*	*	*	*	*	*
≥80	71	97.3	845	99.3	865	99.9	2,629	99.5	993	99.8	1,740	99.0
<80	2	2.7	6	0.7	1	0.1	14	0.5	0	0.2	17	1.0
Sodium Category	*	*	*	*	*	*	*	*	*	*	*	*
130-149	73	100.0	849	99.8	849	98.0	2,626	99.4	974	97.9	1,753	99.8
<130 or >149	0	0.0	2	0.2	17	2.0	17	0.6	21	2.1	4	0.2
Acquired immune deficiency syndrome	0	0.0	6	0.7	4	0.5	19	0.7	6	0.6	18	1.0
Alcohol abuse	0	0.0	8	0.9	9	1.0	11	0.4	9	0.9	10	0.6
Deficiency anemias	1	1.4	48	5.6	76	8.8	210	8.0	55	5.5	153	8.7
Autoimmune conditions	1	1.4	51	6.0	34	3.9	80	3.0	37	3.7	57	3.2
Chronic blood loss anemia	0	0.0	2	0.2	10	1.2	7	0.3	3	0.3	12	0.7
Leukemia	2	2.7	2	0.2	3	0.4	5	0.2	4	0.4	1	0.1
Lymphoma	0	0.0	2	0.2	0	0.0	3	0.1	0	0.0	3	0.2
Metastatic cancer	1	1.4	1	0.1	4	0.5	77	2.9	8	0.8	79	4.5
Solid tumor without metastasis, in situ	0	0.0	0	0.0	3	0.4	4	0.2	2	0.2	3	0.2
Solid tumor without metastasis, malignant	0	0.0	5	0.6	17	2.0	57	2.2	13	1.3	21	1.2

Measure Denominator Population Characteristics	Site 7	Site 7	Site 8	Site 8	Site 9	Site 9	Site 10	Site 10	Site 11	Site 11	Site 12	Site 12
*	n	%	n	%	n	%	n	%	n	%	n	%
Cerebrovascular disease	0	0.0	11	1.3	15	1.7	26	1.0	10	1.0	21	1.2
Coagulopathy	2	2.7	23	2.7	14	16	28	1.1	10	1.0	32	1.8
Dementia	0	0.0	1	0.1	2	0.2	3	0.1	1	0.1	1	0.1
Depression	10	13.7	189	22.2	93	10.7	207	7.8	79	7.9	98	5.6
Diabetes with chronic complications	0	0.0	47	5.5	74	8.6	160	6.1	28	2.8	122	6.9
Diabetes without chronic complications	3	4.1	101	11.9	82	9.5	571	21.6	145	14.6	343	19.5
Drug abuse	0	0.0	15	1.8	8	0.9	17	0.6	15	1.5	14	0.8
Congestive heart failure	2	2.7	22	2.6	37	4.3	74	2.8	24	2.4	96	5.5
Hypertension, complicated	0	0.0	69	8.1	75	8.7	208	7.9	47	4.7	188	10.7
Hypertension, uncomplicated	2	2.7	383	45.0	392	45.3	1,530	57.9	472	47.4	945	53.8
Liver disease, mild	8	11.0	29	3.4	37	4.3	118	4.5	371	37.3	127	7.2
Liver disease, moderate to severe	1	1.4	1	0.1	0	0.0	3	0.1	1	0.1	1	0.1
Chronic pulmonary disease	16	21.9	194	22.8	203	23.4	404	15.3	214	21.5	315	17.9
Neurological disorders affecting movement	0	0.0	26	3.1	4	0.5	17	0.6	13	1.3	8	0.5
Other neurological disorders	3	4.1	26	3.1	5	0.6	30	1.1	8	0.8	28	1.6
Seizures and epilepsy	2	2.7	15	1.8	10	1.2	30	1.1	4	0.4	24	1.4
Obesity	10	13.7	197	23.2	423	48.9	940	35.6	617	62.0	755	43.0
Paralysis	1	1.4	17	2.0	5	0.6	22	0.8	4	0.4	19	1.1
Peripheral vascular disease	1	1.4	32	3.8	63	7.3	78	3.0	28	2.8	69	3.9
Psychoses	0	0.0	27	3.2	16	1.9	24	0.9	11	1.1	21	1.2
Pulmonary circulation disease	1	1.4	8	0.9	10	1.2	14	0.5	9	0.9	30	1.7
Renal failure, moderate	0	0.0	46	5.4	33	3.8	93	3.5	13	1.3	59	3.4
Renal failure, severe	1	1.4	3	0.4	20	2.3	25	1.0	7	0.7	19	1.1
Hypothyroidism	2	2.7	127	14.9	91	10.5	314	11.9	127	12.8	168	9.6
Other thyroid disorders	0	0.0	23	2.7	17	2.0	42	1.6	24	2.4	46	2.6
Peptic ulcer with bleeding	0	0.0	4	0.5	3	0.4	10	0.4	0	0.0	8	0.5
Valvular disease	8	11.0	57	6.7	29	3.4	67	2.5	30	3.0	75	4.3
Weight loss	6	8.2	9	1.1	16	1.9	47	1.8	6	0.6	53	3.0

Note: * Cells intentionally left blank. Site 13 only participated in alpha testing (not beta) and therefore is not included in the table above.

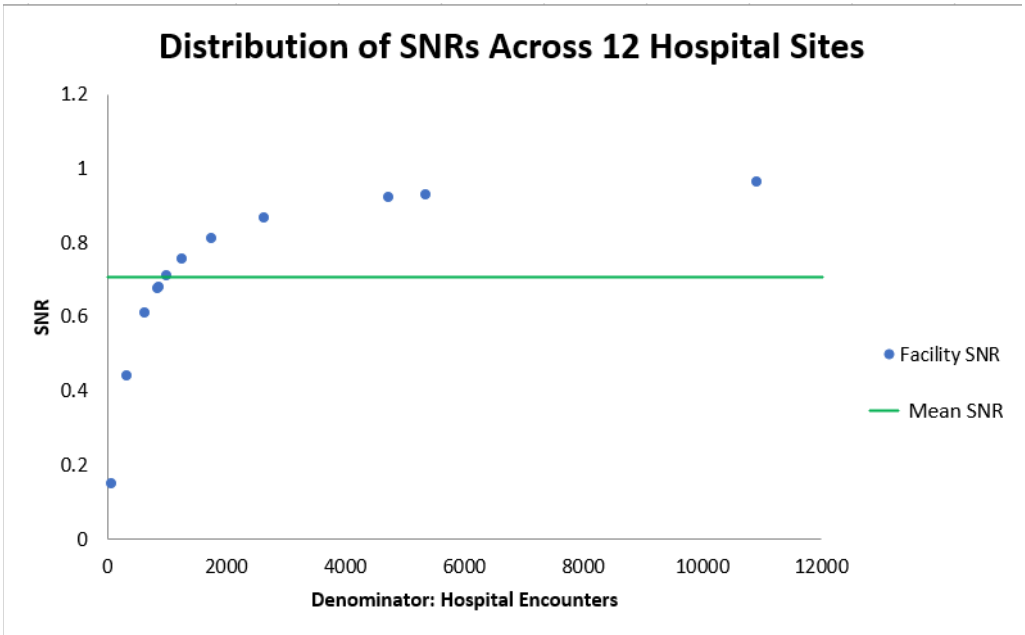
Reliability

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.

Exhibit 3: Distribution of SNRs Across Sites



Validity

Expectedly, manual abstraction is labor intensive; therefore, reducing burden while maximizing test result validity (e.g., level of power and significance) is important. To that end, we calculated the minimum required sample size (MRSS) for the abstraction using PPV as the primary endpoint and approximated MRSS using the conventional one-sample proportion formula, while accounting for the intracluster correlation: $n = \frac{z_{\frac{\alpha}{2}}^2 \cdot p \cdot (1-p)}{moe^2} \times VIF$ where a denotes the type I error rate, moe denotes the margin of error, p is PPV, and VIF is the variance inflation factor that accounts for the intracluster correlation. We simulated a series of *moes*, target ps, and the 95% confidence intervals associated with each p for different MRSS. Simulations indicated that with a $moes$ of 2.5%, a target PPV of 0.9, a reasonable precision of PPV bounded by 0.875 and 0.925, and a conventionally accepted minimum number of observations that can render the sampling distribution of p to be normal, MRSS approximated 100 to 200 records. Using the mid-point, we therefore randomly sampled at least 155 cases (50 denominators, 50 numerators, and 55 denominator exclusions) per hospital system.

Table 6: Frequency of Exclusion Occurrence Overall (All Sites)

Initial Population	Excl 1	Excl 2	Excl 3	Excl 4	Excl 5	Excl 6	Excl 7	Excl 8	Excl 9
59,579	87	30	30	94	1,331	102	93	2,405	1,708

Table 7: Exclusion Testing (All Sites)

*	Den Count (N)	Den Change (%)	Num Count (N)	Num Change (%)
Current specification	30,843	.	95	.
Relax Exclusion 1: Patients who have mechanical ventilation that starts more than one hour prior to the start of the first operating procedure (OR) procedure	30,847	0.013%	100	5.26%
Relax Exclusion 2: Patients With arterial partial pressure of oxygen (PaO2)<50 mmHg within 48 hours or less prior to the start of the first OR procedure	30,853	0.032%	96	1.05%
Relax Exclusion 3: Patients with arterial partial pressure of carbon dioxide (PaCO2)>50 mmHg combined with an arterial pH<7.30 within 48 hours or less prior to the start of the first OR procedure	30,844	0.003%	97	2.11%
Relax Exclusion 4: Patients with a principal diagnosis for acute respiratory failure	30,846	0.010%	96	1.05%
Relax Exclusion 5: Patients with a secondary diagnosis for acute respiratory failure present on admission	30,905	0.201%	120	26.32%
Relax Exclusion 6: Patients with any diagnosis present on admission for the existence of a tracheostomy	30,852	0.029%	95	0.00%
Relax Exclusion 7: Patients where a tracheostomy is performed before or on the same day as the first OR procedure	30,849	0.019%	97	2.11%
Relax Exclusion 8: Patients with any diagnosis for neuromuscular disorder or degenerative neurological disorder	31,437	1.926%	179	88.42%
Relax Exclusion 9: Patients with any procedure for selected pharyngeal, nasal, oral, facial, or tracheal surgery involving significant risk of airway compromise likely to require prophylactic retention of the endotracheal tube for at least 48 hours	32,272	4.633%	121	27.37%

Table 8: PPV, Sensitivity, NPV, and Specificity Values (All Sites)

Measure Population	Per EHR	Per the Abstraction	PPV	Sensitivity	NPV	Specificity
Initial population	621	621	99.5%	100%	100%	99.1%
Denominator exclusion	214	215	99.5%	100%	100%	99.8%
Denominator not in numerator	310	319	99.4%	96.6%	96.5%	99.3%
Numerator	97	87	90%	97.7%	99.6%	98.1%

Table 9: PPV, Sensitivity, NPV, and Specificity Values (Cerner Site, System A, Hospital 1)

Measure Population	Per EHR	Per the Abstraction	PPV	Sensitivity	NPV	Specificity
Initial population	137	137	100%	100%	100%	100%
Denominator exclusion	37	37	100%	100%	100%	100%
Denominator not in numerator	91	91	100%	100%	100%	100%
Numerator	9	9	100%	100%	100%	100%

Table 10: PPV, Sensitivity, NPV, and Specificity Values (Epic Site, System B, Hospital 2)

Measure Population	Per EHR	Per the Abstraction	PPV	Sensitivity	NPV	Specificity
Initial population	155	155	100%	100%	100%	100%
Denominator exclusion	55	55	100%	100%	100%	100%
Denominator not in numerator	96	97	100%	99%	98.3%	100%
Numerator	4	3	75%	100%	100%	99.3%

Table 11: PPV, Sensitivity, NPV, and Specificity Values (Epic Site, System C, Hospital 3)

Measure Population	Per EHR	Per the Abstraction	PPV	Sensitivity	NPV	Specificity
Initial population	157	157	100%	100%	100%	100%
Denominator exclusion	57	57	100%	100%	100%	100%
Denominator not in numerator[1]	84	84	99%	99%	99%	99%
Numerator[1]	15	15	93%	93%	99%	99.3%

Table 12: PPV, Sensitivity, NPV, and Specificity Values (Epic Site, System D, Hospitals 4-12)

Measure Population	Per EHR	Per the Abstraction	PPV	Sensitivity	NPV	Specificity
Initial population	172	172	100%	99%	99%	98%
Denominator exclusion	65	66	100%	99%	100%	98%
Denominator not in numerator	39	47	97%	81%	93%	99%
Numerator	69	60	87%	100%	100%	92%

Equity

Table 13: PSI 11 Disparity Analysis

Population-Based Disparity Factor	N (beneficiaries)	Observed Rate per 1,000	Adjusted Rate per 1,000
Race	*	*	*
Unknown	19662	4.781	5.820
White	920041	5.507	5.198
Black	78549	8.453	6.046
Other	11585	5.697	4.831
Asian	9340	5.782	4.749
Hispanic	14199	7.465	5.687
North American Native	6124	7.348	5.748
Gender	*	*	*
Female	605665	5.006	5.197

[1] Instance of one false-positive and one false-negative cancelling each other out to yield unchanged numbers of numerator and non-numerator cases but discordance.

Population-Based Disparity Factor	N (beneficiaries)	Observed Rate per 1,000	Adjusted Rate per 1,000
Male	453835	6.751	5.386
Age	*	*	*
<50	39287	7.865	5.757
50-54	27247	7.487	5.417
55-59	42943	7.778	5.431
60-64	55682	7.669	5.192
65-69	307397	4.447	5.242
70-74	262105	5.135	5.305
75-79	180021	5.916	5.212
80-84	95877	6.394	5.217
85-89	39029	8.840	5.424
90 plus	9912	8.676	4.986

Note: * Cells intentionally left blank.

Clinical Practice Guidelines

Risk assessment for and strategies to reduce perioperative pulmonary complications for patients undergoing noncardiothoracic surgery: a guideline for the American College of Physicians (ACP) (2006)

Qaseem, A., Snow, V., Fitterman, N., Hornbake, E. R., Lawrence, V. A., Smetana, G. W., Weiss, K., Owens, D. K., Aronson, M., Barry, P., Casey, D. E., Jr, Cross, J. T., Jr, Fitterman, N., Sherif, K. D., Weiss, K. B., & Clinical Efficacy Assessment Subcommittee of the American College of Physicians (2006). Risk assessment for and strategies to reduce perioperative pulmonary complications for patients undergoing noncardiothoracic surgery: a guideline from the American College of Physicians. Annals of internal medicine, 144(8), 575–580.

The ACP guidelines were developed to prevent perioperative pulmonary complications in patients undergoing non- cardiothoracic surgery. The purpose of this guideline is to provide guidance to clinicians on clinical and laboratory predictors of perioperative pulmonary risk before noncardiothoracic surgery. It also evaluates strategies to reduce the perioperative pulmonary risk and focuses on atelectasis, pneumonia, and respiratory failure. The target audience for this guideline is general internists or other clinicians involved in perioperative management of surgical patients. This guideline applies to adult patients undergoing noncardiopulmonary surgery.

The development of the guideline used the U.S. Preventive Services Task Force (USPSTF) criteria for assigning hierarchy of research design, grading a study's internal validity as our basis for assessing study quality, and assigning summary strength of recommendations for each risk factor and laboratory test. These guidelines were developed based on two systematic reviews:

- Lawrence, V. A., Cornell, J. E., Smetana, G. W., & American College of Physicians (2006). Strategies to reduce postoperative pulmonary complications after noncardiothoracic surgery:

systematic review for the American College of Physicians. Annals of internal medicine, 144(8), 596–608.

- Smetana, G. W., Lawrence, V. A., Cornell, J. E., & American College of Physicians (2006). Preoperative pulmonary risk stratification for noncardiothoracic surgery: systematic review for the American College of Physicians. Annals of internal medicine, 144(8), 581–595.

The Lawrence study (linked above) conducted a systematic review of the literature on interventions to prevent postoperative pulmonary complications after noncardiothoracic surgery. The authors qualitatively synthesized, without meta-analysis, evidence from eligible studies. Good evidence (2 systematic reviews, 5 additional RCTs) indicates that lung expansion interventions (for example, incentive spirometry, deep breathing exercises, and continuous positive airway pressure) reduce pulmonary risk. Fair evidence suggests that selective, rather than routine, use of nasogastric tubes after abdominal surgery (2 meta-analyses) and short-acting rather than long-acting intraoperative neuromuscular blocking agents (1 RCT) reduce risk. The evidence is conflicting or insufficient for preoperative smoking cessation (1 RCT), epidural anesthesia (2 meta-analyses), epidural analgesia (6 RCTs, 1 meta-analysis), and laparoscopic (vs. open) operations (1 systematic review, 1 meta-analysis, 2 additional RCTs), although laparoscopic operations reduce pain and pulmonary compromise as measured by spirometry. While malnutrition is associated with increased pulmonary risk, routine total enteral or parenteral nutrition does not reduce risk (1 meta-analysis, 3 additional RCTs). Enteral formulations designed to improve immune status (immunonutrition) may prevent postoperative pneumonia (1 meta-analysis, 1 additional RCT). The overall quality of the literature was fair: Ten of 20 RCTs and 6 of 11 systematic reviews were good quality. The authors concluded that few interventions have been shown to clearly or possibly reduce postoperative pulmonary complications.

The Smetana study (linked above) conducted a systematic review of the literature on preoperative pulmonary risk stratification before noncardiothoracic surgery. The authors determined random-effects pooled estimate odds ratios and, when appropriate, trim-and-fill estimates for patient- and procedure-related risk factors from studies that used multivariable analyses. They assigned summary strength of evidence scores for each factor. Good evidence supported patient-related risk factors for postoperative pulmonary complications, including advanced age, American Society of Anesthesiologists class 2 or higher, functional dependence, chronic obstructive pulmonary disease, and congestive heart failure. Good evidence also supported procedure-related risk factors for postoperative pulmonary complications, including aortic aneurysm repair, non-resective thoracic surgery, abdominal surgery, neurosurgery, emergency surgery, general anesthesia, head and neck surgery, vascular surgery, and prolonged surgery. Among laboratory predictors, good evidence exists only for serum albumin level less than 30 g/L. The authors found that there was insufficient evidence to support preoperative spirometry as a tool to stratify risk. The authors concluded that selected clinical and laboratory factors allow risk stratification for postoperative pulmonary complications after noncardiothoracic surgery.

For the completion of these guidelines, studies and systematic reviews were graded as good, fair, or poor on the basis of extent of literature searched, inclusion or exclusion of non–English-language publications, statements of inclusion and exclusion criteria, protocols for appraisal of study quality and data abstraction, data synthesis methods, presentation of results, and discussion of clinical inferences and future research needs. A list of additional guidelines that support the measure can be found in **Table 14**. Note: These 2006 ACP guidelines are currently inactive.

Table 14: ACP (2006) Additional Guidelines that Support the Measure

Verbatim Guideline	Strength of Recommendation	Quality of Evidence
Recommendation 1. All patients undergoing noncardiothoracic surgery should be evaluated for the presence of the following significant risk factors for postoperative pulmonary complications in order to receive pre- and postoperative interventions to reduce pulmonary risk: chronic obstructive pulmonary disease, age older than 60 years, American Society of Anesthesiologists (ASA) class of II or greater, functionally dependent, and congestive heart failure.	Ungraded recommendation	Not specified
Recommendation 2. Patients undergoing the following procedures are at higher risk for postoperative pulmonary complications and should be evaluated for other concomitant risk factors and receive pre- and postoperative interventions to reduce pulmonary complications: prolonged surgery (>3 hours), abdominal surgery, thoracic surgery, neurosurgery, head and neck surgery, vascular surgery, aortic aneurysm repair, emergency surgery, and general anesthesia.	Ungraded recommendation	Not specified
Recommendation 3. A low serum albumin level (<35 g/L) is a powerful marker of increased risk for postoperative pulmonary complications and should be measured in all patients who are clinically suspected of having hypoalbuminemia; measurement should be considered in patients with 1 or more risk factors for perioperative pulmonary complications	Ungraded recommendation	Not specified
Recommendation 4. (Included in MUC form) All patients who after preoperative evaluation are found to be at higher risk for postoperative pulmonary complications should receive the following postoperative procedures in order to reduce postoperative pulmonary complications: 1) deep breathing exercises or incentive spirometry and 2) selective use of a nasogastric tube (as needed for postoperative nausea or vomiting, inability to tolerate oral intake, or symptomatic abdominal distention)	Ungraded recommendation	Not specified
Recommendation 5. Preoperative spirometry and chest radiography should not be used routinely for predicting risk for postoperative pulmonary complications	Ungraded recommendation	Not specified
Recommendation 6. The following procedures should not be used solely for reducing postoperative pulmonary complication risk: 1) right-heart catheterization and 2) total parenteral nutrition or total enteral nutrition (for patients who are malnourished or have low serum albumin levels)	Ungraded recommendation	Not specified

The European Respiratory Society (ERS) / American Thoracic Society (ATS) Official ERS/ATS Clinical Practice Guidelines: Noninvasive Ventilation for Acute Respiratory Failure (2017)

Rochwerg, B., Brochard, L., Elliott, M. W., Hess, D., Hill, N. S., Nava, S., Navalesi, P., Members Of The Steering Committee, Antonelli, M., Brozek, J., Conti, G., Ferrer, M., Guntupalli, K., Jaber, S., Keenan, S., Mancebo, J., Mehta, S., & Raoof, S., Members Of The Task Force (2017). Official ERS/ATS clinical practice guidelines: noninvasive ventilation for acute respiratory failure. *The European respiratory journal*, *50*(2), 1602426.

The ERS/ATS guidelines were developed to set recommendations for the use of noninvasive mechanical ventilation in acute respiratory failure. The guideline committee was composed of clinicians, methodologists, and experts in the field of noninvasive ventilation (NIV). Members were either physicians (pulmonologists or intensivists) or respiratory therapists. The guideline committee developed recommendations for 11 actionable questions in a PICO (population intervention–comparison–outcome) format.

The committee developed recommendations based on the GRADE (Grading, Recommendation, Assessment, Development and Evaluation) methodology for each actionable question. Each recommendation was designated as "strong" or "conditional." The guideline used the phrasing "we recommend" for strong recommendations and "we suggest" for conditional recommendations. Within each recommendation, the strength of recommendation is indicated in **Table 15**.

Table 15: ERS/ATS (2017) Strength of Recommendation and Rationale

Strength of Recommendation	Rationale
Strong Recommendation	• **For patients**: Most individuals in this situation would want the recommended course of action, and only a small proportion would not. • **For clinicians**: Most individuals should follow the recommended course of action. Formal decision aids are not likely to be needed to help individual patients make decisions consistent with their values and preferences. • **For policy makers**: The recommendation can be adopted as policy in most situations. Adherence to this recommendation according to the guideline could be used as a quality criterion or performance indicator.
Conditional Recommendation	• **For patients**: The majority of individuals in this situation would want the suggested course of action, but many would not. Decision aids may be useful in helping patients to make decisions consistent with their individual risks, values, and preferences. • **For clinicians**: Different choices will be appropriate for individual patients, and clinicians must help each patient arrive at a management decision consistent with the patient's values and preferences. Decision aids may be useful in helping individuals to make decisions consistent with their individual risks, values, and preferences. • **For policy makers**: Policymaking will require substantial debate and involvement of various stakeholders. Performance measures should assess whether decision-making is duly documented.

The quality of evidence of the recommendations are graded based on the GRADE approach on a scale from very low certainty in the evidence of effects to high certainty in the evidence of effects. A high

evidence grading is indicative of higher-quality evidence (e.g., RCTs and meta-analyses); a low evidence rating is indicative of lower-quality evidence (e.g., observational studies).

The Evidence to Decision framework ensures each of the following factors are considered in recommendation development: quality of the evidence, balance of desirable and undesirable consequences of compared management options, assumptions about the values and preferences associated with the decision, implications for resource use and health equity, acceptability of intervention to stakeholders, and feasibility of implementation. The overall certainty of the evidence was based on the following criteria: risk of bias, precision, consistency, directness of the evidence, risk of publication bias, presence of dose-effect relationship, magnitude of effect and an assessment of the effect of plausible residual confounding or bias. Recommendations and their strength were decided by consensus.

Within each recommendation, the quality of the supporting evidence is shown in **Table 16**. The additional guidelines to support this measure are shown in **Table 17**.

Table 16: ERS/ATS (2017) Strength of Evidence Criteria

Quality of Evidence	Rationale
High Quality	Further research is very unlikely to change our confidence in the estimate of effect
Moderate Quality	Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate
Low Quality	Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate
Very Low Quality	Any estimate of effect is very uncertain

Table 17: ERS/ATS (2017) Additional Guidelines that Support the Measure

Verbatim Guideline	Strength of Recommendation	Quality of Evidence
We suggest that NIV be used to prevent post-extubation respiratory failure in high-risk patients post-extubation	Conditional recommendation	Low certainty of evidence
We suggest that NIV should not be used to prevent post-extubation respiratory failure in non-high-risk patients	Conditional recommendation	Very low certainty of evidence

American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) / American Geriatrics Society (AGS) Guidelines (2012)

Chow, W. B., Rosenthal, R. A., Merkow, R. P., Ko, C. Y., Esnaola, N. F., American College of Surgeons National Surgical Quality Improvement Program, & American Geriatrics Society (2012). Optimal preoperative assessment of the geriatric surgical patient: a best practices guideline from the American College of Surgeons National Surgical Quality Improvement Program and the American Geriatrics Society. *Journal of the American College of Surgeons*, *215*(4), 453–466.

The ACS NSQIP/AGS guidelines were developed to guide optimal perioperative management for geriatric (e.g., age over 65 years) patients, and include recommendations for preventing postoperative pulmonary complications in this population. Recommendations from ACS NSQIP/AGS are evidence-

based, though not graded according to strength of the evidence. These best practices are a compilation of the most current and evidence-based recommendations for improving the perioperative care of this vulnerable population. The pulmonary recommendations were adapted from:

Roberts J., Lawrence V., Esnaola N. ACS NSQIP Best Practices Guideline: Prevention of Postoperative Pulmonary Complications (2010). Chicago: American College of Surgeons.

One recommendation applies to this measure, which is shown in **Table 18**.

Table 18: ACS NSQIP/AGS (2012) Additional Guidelines that Support the Measure

Verbatim Guideline	Strength of Recommendation	Quality of Evidence
Preoperative strategies for preventing postoperative pulmonary complications include: • Preoperative optimization of pulmonary function in patients with COPD and asthma that is not well controlled • Smoking cessation • Preoperative intensive inspiratory muscle training • Selective chest radiograph and pulmonary function tests	Ungraded recommendation	Not specified

Perioperative Management of Elderly Patients (PriME): Recommendations from an Italian Intersociety Consensus (2020)

Aceto, P., Antonelli Incalzi, R., Bettelli, G., Carron, M., Chiumiento, F., Corcione, A., Crucitti, A., Maggi, S., Montorsi, M., Pace, M. C., Petrini, F., Tommasino, C., Trabucchi, M., Volpato, S., & Società Italiana di Anestesia Analgesia Rianimazione e Terapia Intensiva (SIAARTI), Società Italiana di Gerontologia e Geriatria (SIGG), Società Italiana di Chirurgia (SIC), Società Italiana di Chirurgia Geriatrica (SICG) and Associazione Italiana di Psicogeriatria (AIP) (2020). Perioperative Management of Elderly patients (PriME): recommendations from an Italian intersociety consensus. Aging clinical and experimental research, 32(9), 1647–1673.

These guidelines focus on surgical outcomes in geriatric patients, and these guidelines were developed through the Perioperative Management of Elderly patients (PriME) project. PriME is a collaborative initiative of SIAARTI (Italian Society of Anesthesia, Analgesia, Intensive Care, and Intensive Care), SIGG (Italian Society of Gerontology and Geriatrics), SIC (Italian Society of Surgery), Society of Geriatric Surgery (SICGe), and AIP (Italian Association of Psychogeriatrics). These societies appointed a 14-member Expert Task Force, which met in September 2018 to define the scope of the project, identify key issues, and agree consensus methods. It was decided that the focus should be on hospitalized patients aged > 65 years undergoing elective surgery; three main areas for investigation were identified (preoperative, intraoperative, and postoperative care), and corresponding subcommittees appointed.

A modified Delphi approach was used to achieve consensus, and the U.S. Preventive Services Task Force system used to rate the strength of recommendations (**Table 19**) and level of certainty/quality of evidence (**Table 20**).

A total of 81 recommendations were proposed, and we have identified three guidelines that apply to our measure (see Table 8). The authors review notes that postoperative pulmonary complications (PPCs) increase postoperative mortality, and health care costs while older age may be an independent predictor of PPCs (Mohanty et a., 2016; Miskovic, 2017). Compared with patients under 50 years of age, the incidence of PPCs is almost fivefold higher in those aged > 80 years (Canet and Gomer, 2010). The

recommendations find that periodic evaluation of oxygen saturation, arterial blood gases, and respiratory rate is recommended in older patients.

In addition to optimization of pulmonary status during the preoperative and intraoperative periods, several postoperative strategies can be used to prevent PPCs in older patients, including screening for signs and symptoms of dysphagia, incentive spirometry, chest physical therapy, and deep breathing exercises (Smetana et al., 2006; Las Vegas Investigators, 2017; Katsura et al. 2015). Monitoring of vital signs in the post-anesthetic setting is essential to identify patients at potential risk of postoperative respiratory failure (Schumann et al, 2019). Incentive spirometry is widely used to prevent PPCs, although clinical effectiveness data are limited, and standardized protocols are lacking (Eltorai et al, 2018a and Eltorai et al, 2018b).
These recommendations should facilitate the multidisciplinary management of older surgical patients, integrating the expertise of the surgeon, the anesthetist, the geriatrician, and other specialists and health care professionals (where available) as needed.

Table 19: US Preventive Services Task Force grading of strength of recommendations

Grade	Definition	Suggestion for practice
A	The USPSTF recommends the service. There is high certainty that the net benefit is substantial	Offer or provide this service
B	The USPSTF recommends the service. There is high certainty that the net benefit is moderate or there is moderate certainty that the net benefit is moderate to substantial	Offer or provide this service
C	The USPSTF recommends selectively offering or providing this service to individual patients based on professional judgment and patient preferences. These is at least moderate certainty that the net benefit is small	Offer or provide this service for selected patients depending on individual circumstances
D	The USPSTF recommends against the service. There is moderate or high certainty that the service has no net benefit or that the harms outweigh the benefits	Discourage the use of this service
I	The USPSTF concludes that the current evidence is insufficient to assess the balance of benefits and harms of the service. Evidence is lacking, of poor quality, or conflicting, and the balance of benefits and harms cannot be determined	Read the clinical considerations section of USPSTF Recommendation Statement. If the service is offered, patients should understand the uncertainty about the balance of benefits and harms

Table 20: Grading of quality of evidence from Perioperative Management of Elderly patients (PriME): recommendations from an Italian intersociety consensus (2020)

Quality of evidence	Description
High (A)	The available evidence usually includes consistent results from a multitude of well-designed, well-conducted, studies in representative care populations. These studies assess the effects of the service on the desired health outcomes. Because of the precision of findings, this conclusion is, therefore, unlikely to be strongly affected by the results of future studies. These recommendations are often based on direct evidence from clinical trials of screening, treatment or behavioral interventions. High-quality trials designed as "pragmatic" or "effectiveness" trials are often of greater value in understanding external validity
Moderate (B)	The available evidence is sufficient to determine the effects of the service on targeted health outcomes, but confidence in the estimate is constrained by factors such as: The number, size, or quality of individual studies in the evidence pool Some heterogeneity of outcome findings or intervention models across the body of studies Mild-to-moderate limitations in the generalizability of findings to routine care practice. As more information becomes available, the magnitude or direction of the observed effect could change, and this change may be large enough to alter the conclusion
Low (C)	The available evidence is insufficient to assess effects on health outcomes. Evidence is insufficient because of: The very limited number or size of studies Inconsistency of direction or magnitude of findings across the body of evidence Critical gaps in the chain of evidence Findings are not generalizable to routine care practice A lack of information on prespecified health outcomes Lack of coherence across the linkages in the chain of evidence. More information may allow an estimation of effects on health outcomes

Table 21: Additional Guidelines to from Grading of quality of evidence from Perioperative Management of Elderly patients (PriME): recommendations from an Italian intersociety consensus (2020)

Statement	Quality of Evidence	Strength of Recommendation
Postoperative pulmonary complications		
We recommend periodic evaluation of oxygen saturation and respiratory rate in the postoperative period	Moderate	A
We recommend that arterial blood gas analysis be used when conditions interfere with percutaneous oximetry (e.g., shivering, tremor, cold skin, hyperthermia, hypotension, advanced heart failure, high fever, atrial fibrillation, or other arrhythmias)	Moderate	A
We suggest that older patients should be treated with lung expansion techniques, such as deep breathing exercises, incentive spirometry or, when indicated, with non-invasive ventilation	Moderate	B

References:

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