

## ONLINE DATA SUPPLEMENT

### Predicting 30-Day Pneumonia Readmissions Using Electronic Health Record Data

Anil N. Makam, MD, MAS and Oanh Kieu Nguyen, MD, MAS; Christopher Clark, MPA; Song Zhang, PhD; Bin Xie, PhD; Mark Weinreich, MD; Eric M. Mortensen, MD, MSc; Ethan A. Halm, MD, MPH

\* Anil N. Makam and Oanh Kieu Nguyen are co-first authors

<b>Supplemental Table 1. Variables for Risk Prediction Models Referenced in the Manuscript</b>	
<b>Risk prediction models</b>	<b>Variables</b>
First-day multi-condition EHR	Male sex, age, Medicare as primary payer, Medicaid as primary payer, non-elective admission status, Charlson comorbidity index, prior emergency department visits in past year, prior hospitalizations in past year, oxygen saturation, systolic blood pressure, diastolic blood pressure, pulse rate, blood urea nitrogen, sodium, b-type natriuretic peptide, anion gap, albumin, bicarbonate, creatine phosphokinase, hematocrit, lymphocyte count, mean corpuscular volume, platelet count, prothrombin time, thyroid stimulating hormone, aspartate aminotransferase
Full-stay multi-condition EHR	Age, Medicaid as primary payer, marital status, prior emergency department visits in past year, prior hospitalizations in past year, non-elective admission status, Charlson comorbidity index, albumin, aspartate aminotransferase, creatine phosphokinase, mean corpuscular volume, platelet count, prothrombin time, hospital length of stay, hospital complications (Clostridium difficile infection, pressure ulcer, venous thromboembolism), blood urea nitrogen at discharge, sodium at discharge, hematocrit at discharge, vital sign instabilities, disposition status
Pneumonia severity index	Age, sex, nursing home resident, neoplastic disease, liver disease, congestive heart failure, cerebrovascular disease, renal disease, altered mental status, respiratory rate, systolic blood pressure, temperature, pulse rate, pH level, blood urea nitrogen, sodium, glucose, hematocrit, partial pressure of oxygen, pleural effusion
CURB-65	Confusion, blood urea nitrogen, respiratory rate, systolic or diastolic blood pressure, age
CMS Pneumonia Administrative	Age, male sex, and 37 comorbidities using clinically-coherent condition categories

**Supplemental Table 2. Additional Baseline Characteristics of Patients Hospitalized with Pneumonia**

	No Readmission N=1,264	Readmission N=199	P value
<b>Clinical factors from first day of hospital stay</b>			
Individual Comorbidities, n (%)			
Myocardial infarction	68 (5.4)	18 (9.1)	0.041
Diabetes without end organ damage	127 (10.1)	28 (14.1)	0.087
Diabetes with end organ damage	46 (3.6)	10 (5.0)	0.344
Chronic lung disease	213 (16.9)	52 (26.1)	0.002
History of pneumonia	129 (10.2)	39 (19.6)	<0.001
Major psychiatric disorders	37 (2.9)	5 (2.5)	0.745
Other psychiatric disorders	45 (3.6)	12 (6.0)	0.094
Intensive care unit admission, n (%)	242 (19.2)	42 (21.1)	0.516
Mechanical ventilation in first 24 hours, n (%)	72 (5.7)	13 (6.5)	0.639
Non-invasive ventilation in first 24 hours, n (%)	67 (5.3)	14 (7.0)	0.320
Selected laboratory results, n (%)			
Albumin, g/dL			0.026
≤ 2	10 (0.8)	5 (2.5)	
2-3	287 (22.7)	54 (27.1)	
> 3	967 (76.5)	140 (70.4)	
Lymphocyte count < 1.3 x 10 <sup>9</sup> /L	850 (67.2)	145 (72.9)	0.047
<b>Clinical factors from remainder of hospital stay</b>			
Lung procedure during index admission*, n (%)	122 (9.7)	18 (9.1)	0.787
Potential hospital complications**, n (%)			
Clostridium difficile infection	10 (0.8)	6 (3.0)	0.005
Pressure ulcer	19 (1.5)	6 (3.0)	0.126
Venous thromboembolism	10 (0.8)	4 (2.0)	0.101
Respiratory failure	160 (12.7)	36 (18.1)	0.037
Physiologic or metabolic derangements	243 (19.2)	55 (27.6)	0.006
Mechanical ventilation use anytime in admission	93 (7.4)	19 (9.6)	0.280
Received ≥ 1 unit blood transfusion in admission	105 (8.3)	30 (15.1)	0.002

\* ICD-9 procedure codes during index admission of 32.X, 33.X, or 34.X

\*\* Defined using ICD-9-CM codes

**Supplemental Table 3. Calibration of the Pneumonia-Specific Readmissions Models**

Model	Decile of Predicted Risk	N	Mean Number of Readmissions		Mean Difference
			Predicted	Observed	
First-Day Pneumonia	1	159	4.05	1.26	2.79
	2	144	5.94	6.25	-0.31
	3	136	7.30	6.62	0.69
	4	148	9.11	9.46	-0.35
	5	145	10.91	11.72	-0.81
	6	175	12.88	15.43	-2.55
	7	120	14.62	19.17	-4.55
	8	144	17.15	11.81	5.35
	9	147	21.59	25.85	-4.26
	10	145	33.27	29.66	3.62
Full-Stay Pneumonia	1	147	3.47	2.04	1.43
	2	167	5.09	3.59	1.50
	3	134	6.49	7.46	-0.97
	4	140	7.74	7.86	-0.12
	5	153	9.52	5.88	3.64
	6	140	11.62	15.71	-4.09
	7	145	14.12	15.86	-1.74
	8	147	18.04	19.73	-1.69
	9	144	23.79	27.08	-3.30
	10	146	36.83	32.19	4.64

The Hosmer-Lemeshow test for first-day and full-stay pneumonia-specific readmission models confirm adequate model fit ( $P$  value = 0.16 and 0.31, respectively).

**Supplemental Table 4. Reclassification Table for the First-Day Pneumonia Model vs. the First-Day Multi-Condition Model for 30-Day Readmission**

		First-Day Multi-Condition		Total
		Lowest 3 Risk Quintiles	Highest 2 Risk Quintiles	
First-Day Pneumonia	Individuals with an event			
	Lowest 3 Risk Quintiles	51	27 <sup>†</sup>	78
	Highest 2 Risk Quintiles	34*	87	121
	Total	85	114	199
	Individuals without an event			
	Lowest 3 Risk Quintiles	663	166*	829
	Highest 2 Risk Quintiles	130 <sup>†</sup>	305	435
	Total	793	471	1264

\* The cells shaded in black represent improved reclassification of individuals with an event into the highest 2 risk quintiles and individuals without an event into the lowest 3 risk quintiles by the first-day pneumonia model compared to the first-day multi-condition model.

† The cells shaded in grey represent worsening reclassification by the first-day pneumonia model compared to the first-day multi-condition model.

**Supplemental Table 5. Reclassification Table for the Full-Stay Pneumonia Model vs. the Full-Stay Multi-Condition Model for 30-Day Readmission**

		Full-Stay Multi-Condition		Total
		Lowest 3 Risk Quintiles	Highest 2 Risk Quintiles	
Full-Stay Pneumonia	Individuals with an event			
	Lowest 3 Risk Quintiles	36	25 <sup>†</sup>	61
	Highest 2 Risk Quintiles	40*	98	138
	Total	76	123	199
	Individuals without an event			
	Lowest 3 Risk Quintiles	652	168*	820
	Highest 2 Risk Quintiles	150 <sup>†</sup>	294	444
	Total	802	462	1264

\* The cells shaded in black represent improved reclassification of individuals with an event into the highest 2 risk quintiles and individuals without an event into the lowest 3 risk quintiles by the full-stay pneumonia model compared to the full-stay multi-condition model.

† The cells shaded in grey represent worsening reclassification by the full-stay pneumonia model compared to the full-stay multi-condition model.

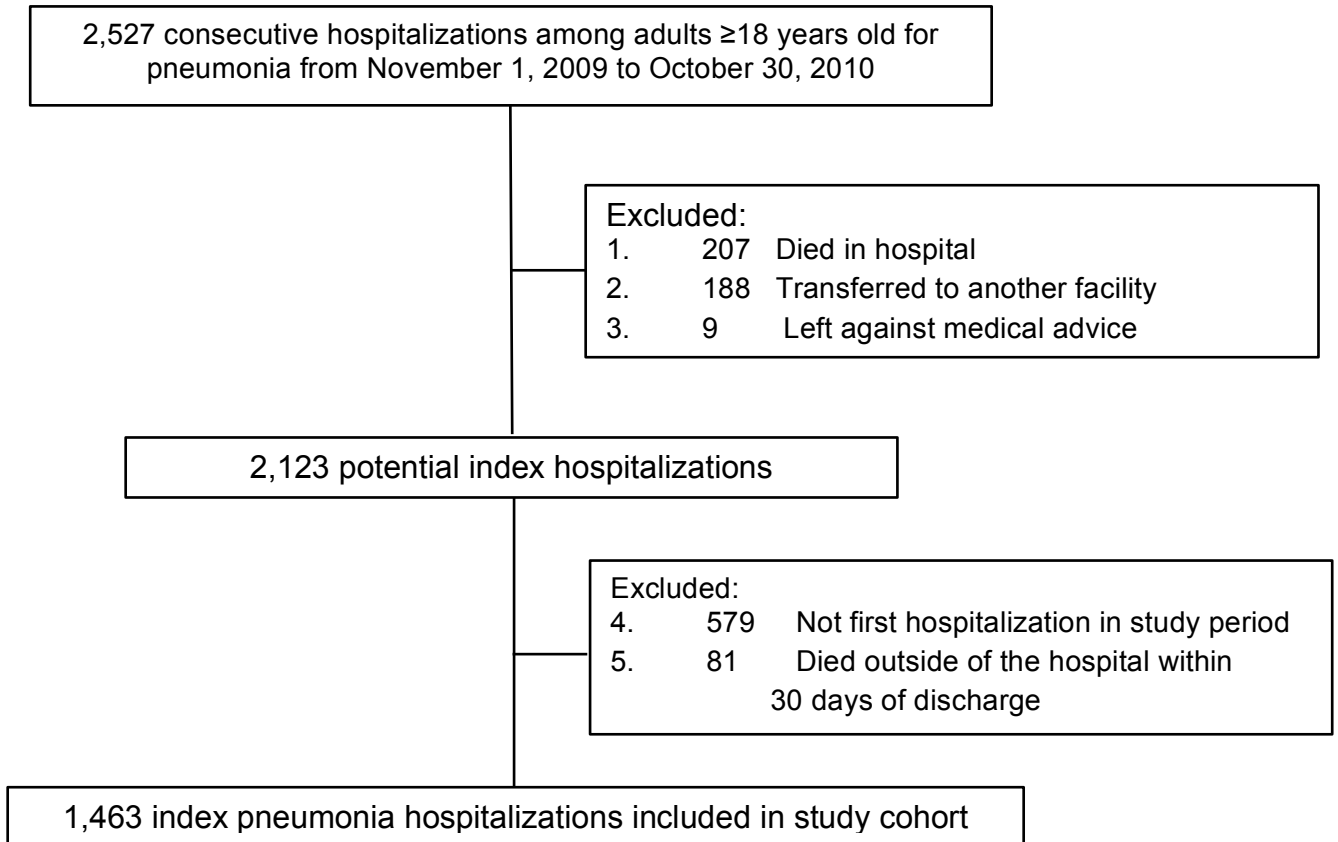
**Supplemental Table 6. Reclassification Table for the First-Day Pneumonia Model vs. the Full-Stay Pneumonia Model for 30-Day Readmission**

		First-Day Pneumonia		Total
		Lowest 3 Risk Quintiles	Highest 2 Risk Quintiles	
Full-Stay Pneumonia	Individuals with an event			
	Lowest 3 Risk Quintiles	46	15 <sup>†</sup>	61
	Highest 2 Risk Quintiles	32 <sup>*</sup>	106	138
	Total	78	121	199
	Individuals without an event			
	Lowest 3 Risk Quintiles	693	127 <sup>*</sup>	820
	Highest 2 Risk Quintiles	136 <sup>†</sup>	308	444
	Total	829	435	1264

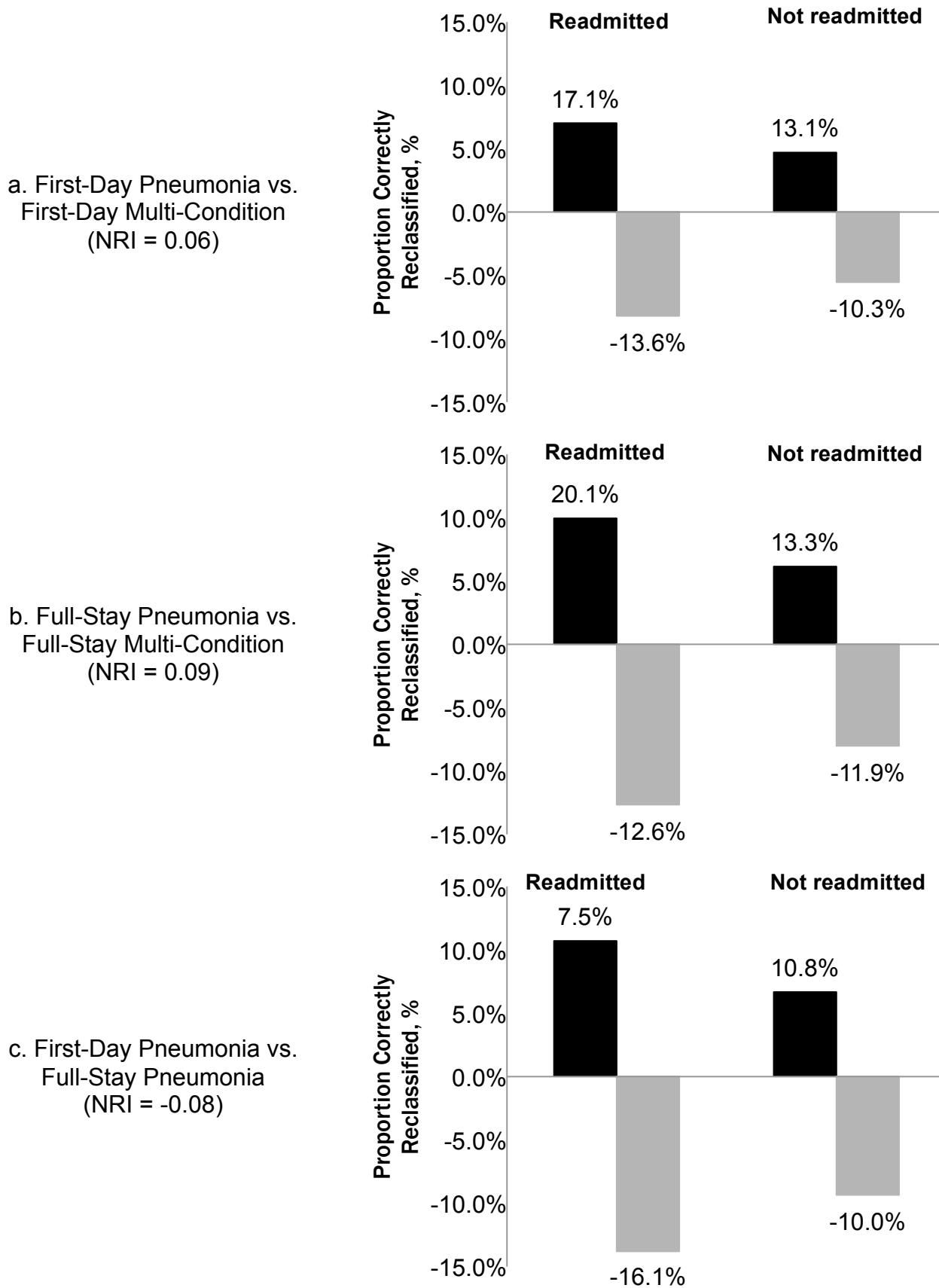
\* The cells shaded in black represent improved reclassification of individuals with an event into the highest 2 risk quintiles and individuals without an event into the lowest 3 risk quintiles by the full-stay pneumonia model compared to the first-day pneumonia model.

† The cells shaded in grey represent worsening reclassification by the full-stay pneumonia model compared to the first-day pneumonia model.

## Supplemental Figure 1. Study Flow Diagram



## Supplemental Figure 2. Net Reclassification Comparisons



NRI = Net Reclassification Index. The NRI is equivalent to the [total proportion correctly reclassified] – [total proportion incorrectly reclassified]. Negative values (grey bars) indicate proportion of individuals incorrectly reclassified for each model compared with the reference model. Thus, in box (a) above,  $NRI = [0.171+0.131]-[0.136+0.103] = 0.302-0.239 = 0.063$ .