MHCC - Analysis of Patient-level Data from the American College of Cardiology's National Cardiovascular Data Registry

January 18, 2022

Objectives

- Evaluate the impact of NSTEMI PCI volume and STEMI PCI volume on inpatient mortality and complication rates.
- Assess various methods to calculate standard errors and confidence intervals for each of the effects generated by the volume-dependency model:
  - Clopper-Pearson (i.e., ‘exact’).
  - Agresti-Coull.
  - Jeffreys.

Specific Aims

- Analysis #1: The Impact of NSTEMI PCI Volume on Mortality and Acute Kidney Injury Rates.
- Analysis #2: The Impact of STEMI PCI Volume on Mortality and Acute Kidney Injury Rates.
- Analysis #3: The Impact of Selected Standard Errors and Confidence Intervals on Outlier Status Relative to Mortality and Acute Kidney Injury.

Methods - Data

- American College of Cardiology's National Cardiovascular Data Registry (ACC-NCDR) for CathPCI:
  - Hospitals submit detailed data to the registry.
  - Participating hospitals receive feedback on their quarterly performance for processes of care and outcomes metrics relative to previous performance.
  - Benchmarked against the national performance of all participants in the ACC-NCDR CathPCI.
- Maryland Hospitals.
- Years: 2015 to 2019.

Methods – Dependent Variables

- Mortality:
  - Inpatient mortality identified by discharge disposition.
- Acute Kidney Injury (AKI):
  - Identified through criteria modified from the Acute Kidney Injury Network (AKIN) criteria.
    - New need for dialysis post procedure.
    - Absolute increase of ≥0.3 mg/dL in serum creatinine pre- and post-PCI.
    - Relative increase of 50% in serum creatinine pre- and post-PCI.

Methods - Explanatory Variables

- PCI indication variable in the CathPCI databases used to identify NSTEMI PCI and STEMI PCI cases.
- PCI indication:
  - PCI for high-risk Non-STEMI or unstable angina.
  - Immediate PCI for STEMI.
  - PCI for STEMI (Unstable, >12 hours from symptom onset).
  - PCI for STEMI (Stable, >12 hours from symptom onset).
  - PCI for STEMI (Stable after successful full-dose Thrombolysis).
  - Rescue PCI for STEMI (after failed full-dose lytics).

Methods – Risk Adjustment

- Mortality Risk-Adjustment Variables:
  - Age, race, sex, body mass index, previous congestive heart failure, previous cerebrovascular disease, peripheral vascular disease, chronic lung disease, previous PCI, diabetes, admission symptom presentation, cardiogenic shock, pre-operative intra-aortic balloon pump, ejection fraction, and PCI status (elective, urgent, emergent, salvage).
- AKI Risk-Adjustment Variables:
  - Age, sex, body mass index, previous congestive heart failure, diabetes, hypertension, previous myocardial infarction (MI), previous PCI, previous coronary artery bypass grafting (CABG), previous cerebrovascular disease (CVD), previous peripheral arterial disease (PAD), chronic lung disease, and multiple PCI procedures.

Methods – Analytic Approach

- Hierarchical Logistic Regression Models:
  - Inpatient mortality & AKI are discrete events.
  - Modeled at the patient-encounter level.
  - Encounters occur within hospitals.
  - Estimate hospital-specific effects.

Methods – Volume-Outcome Relationship

- Separate Analysis by NSTEMI PCI and STEMI PCI volume.
- Two-Category Assessment:
  - Low- and high-volume hospitals based on the median counts of PCI procedures by hospital for indication from 2015 to 2019.
- Three-Category Assessment:
  - Hospitals categorized into three groups by terciles, using the 33rd and 66th percentile PCI counts by hospital.

RESULTS: UNADJUSTED NSTEMI PCI VOLUME BY HOSPITAL, 2015-2019

Hospital	High/Low	High/Medium/Low	2015	2016	2017	2018	2019	TOTAL
Adventist White Oak	High	High	438	435	474	303	250	1,900
Adventist Shady Grove	Low	Low	112	122	110	86	85	515
Anne Arundel Medical Center	Low	Low	160	167	196	198	125	846
Ascension Saint Agnes	High	Medium	287	297	319	202	136	1,241
Carroll Hospital Center	Low	Low	114	137	103	78	92	524
Frederick Hospital	Low	Medium	209	209	220	145	144	927
Johns Hopkins Bayview	Low	Low	123	88	123	86	97	517
Johns Hopkins Hospital	High	High	279	349	420	376	293	1,717
MedStar Southern Maryland	Low	Medium	132	151	187	241	190	901
MedStar Union	High	High	848	874	877	512	534	3,645
Meritus Medical Center	Low	Low	123	122	118	103	124	590
Peninsula Regional Medical Center	High	High	323	327	305	360	323	1,638
Sinai Hospital	High	High	348	367	420	211	123	1,469
Suburban Hospital	High	Medium	274	321	240	205	136	1,176
UM Prince George's	Low	Low	129	159	150	152	96	686
UM Baltimore Washington	Low	Medium	195	199	180	121	171	866
UM Medical Center	High	Medium	273	254	254	193	272	1,246
UM Shore Regional	Low	Low	0	0	97	90	78	265
UM St. Joseph	High	High	699	595	626	533	347	2,800
UM Upper Chesapeake	High	High	223	254	315	288	240	1,320
UPMC Western Maryland	Low	Medium	223	196	232	168	125	944
Median			**223**	**209**	**232**	**198**	**136**	**944**
First Tercile			**141**	**162**	**182**	**147**	**124**	**853**
Second Tercile			**277**	**313**	**312**	**231**	**223**	**1,295**

RESULTS: CHARACTERISTICS BY NSTEMI PCI VOLUME MEASURES

	Low vs High Volume					Low vs Medium vs High Volume								
	Low Volume (n = 7,502)		High Volume (n = 17,962)			Low Volume (n = 3,898)		Medium Volume (n = 7,235		High Volume (n = 14,331)		Pairwise Comparison of Means (p values)		
Variable	Mean	S.D.	Mean	S.D.	p value	Mean	S.D.	Mean	S.D.	Mean	S.D.	M vs L	H vs L	H vs M
Age	64.246	11.857	66.872	11.958	<0.001	64.261	11.974	65.169	11.973	67.068	11.904	<0.001	<0.001	<0.001
Age: ≤ 25	0.000	0.000	0.000	0.015	0.196	0.000	0.000	0.000	0.000	0.000	0.017	1.000	0.218	0.123
Age: 25 - 35	0.006	0.078	0.004	0.063	0.019	0.007	0.083	0.005	0.068	0.004	0.062	0.097	0.013	0.417
Age: 35 - 45	0.042	0.200	0.030	0.171	<0.001	0.042	0.201	0.042	0.200	0.027	0.162	0.900	<0.001	<0.001
Age: 45 - 55	0.180	0.384	0.129	0.335	<0.001	0.180	0.385	0.155	0.362	0.128	0.334	<0.001	<0.001	<0.001
Age: 55 - 65	0.302	0.459	0.278	0.448	<0.001	0.298	0.457	0.300	0.458	0.274	0.446	0.850	0.003	<0.001
Age: 65 - 75	0.274	0.446	0.295	0.456	0.001	0.274	0.446	0.280	0.449	0.297	0.457	0.501	0.005	0.010
Age: > 75	0.196	0.397	0.264	0.441	<0.001	0.198	0.399	0.218	0.413	0.269	0.444	0.018	<0.001	<0.001
Male	0.662	0.473	0.656	0.475	0.367	0.673	0.469	0.652	0.476	0.656	0.475	0.021	0.047	0.491
Female	0.338	0.473	0.344	0.475	0.367	0.327	0.469	0.348	0.476	0.344	0.475	0.021	0.047	0.491
Race: White	0.759	0.428	0.736	0.441	<0.001	0.731	0.444	0.732	0.443	0.752	0.432	0.875	0.008	0.002
Race: Black	0.200	0.400	0.219	0.414	0.001	0.209	0.407	0.226	0.418	0.208	0.406	0.032	0.927	0.002
Race: Asian	0.026	0.160	0.040	0.197	<0.001	0.037	0.189	0.037	0.190	0.035	0.185	0.945	0.575	0.425
Race: American Indian	0.003	0.059	0.002	0.045	0.031	0.003	0.058	0.003	0.056	0.002	0.043	0.873	0.088	0.055
Race: Native Hawaiian	0.001	0.033	0.001	0.037	0.580	0.001	0.028	0.002	0.042	0.001	0.033	0.144	0.588	0.183
Ethnicity: Hispanic	0.027	0.163	0.020	0.138	<0.001	0.041	0.199	0.021	0.143	0.017	0.130	<0.001	<0.001	0.084
Body Mass Index (BMI)	31.087	7.429	30.408	8.045	0.078	30.954	7.814	30.571	7.237	30.531	8.191	0.015	0.003	0.723
BMI: < 18.5	0.015	0.122	0.012	0.110	<0.001	0.008	0.090	0.018	0.133	0.012	0.109	<0.001	0.070	<0.001
BMI: 18.5 - 25	0.153	0.360	0.186	0.389	0.137	0.158	0.365	0.176	0.381	0.181	0.385	0.017	0.001	0.434
BMI: 25 - 30	0.334	0.472	0.344	0.475	<0.001	0.341	0.474	0.344	0.475	0.340	0.474	0.757	0.939	0.601
BMI: > 30	0.498	0.500	0.458	0.498	0.058	0.493	0.500	0.462	0.499	0.467	0.499	0.002	0.005	0.448
On Current Dialysis	0.032	0.175	0.037	0.188	<0.001	0.034	0.182	0.041	0.198	0.032	0.177	0.068	0.535	0.001
Hypertension	0.813	0.390	0.856	0.351	<0.001	0.806	0.396	0.831	0.375	0.860	0.347	<0.001	<0.001	<0.001
Prior Myocardial Infarction	0.268	0.443	0.338	0.473	<0.001	0.259	0.438	0.304	0.460	0.340	0.474	<0.001	<0.001	<0.001
Prior Heart Failure	0.119	0.323	0.169	0.375	<0.001	0.111	0.314	0.160	0.366	0.163	0.369	<0.001	<0.001	0.512
Prior PCI	0.360	0.480	0.425	0.494	<0.001	0.346	0.476	0.384	0.486	0.433	0.496	<0.001	<0.001	<0.001
Prior CABG	0.154	0.361	0.206	0.404	<0.001	0.129	0.335	0.169	0.375	0.218	0.413	<0.001	<0.001	<0.001
Prior CVD	0.113	0.317	0.152	0.359	<0.001	0.114	0.318	0.133	0.339	0.152	0.359	0.008	<0.001	<0.001
Prior PAD	0.086	0.281	0.137	0.344	<0.001	0.086	0.281	0.112	0.316	0.137	0.344	<0.001	<0.001	<0.001
Chronic Lung Disease	0.132	0.338	0.158	0.365	<0.001	0.124	0.330	0.148	0.355	0.158	0.365	0.001	<0.001	0.053
Diabetes	0.398	0.489	0.428	0.495	<0.001	0.388	0.487	0.414	0.493	0.431	0.495	0.008	<0.001	0.019

Note: L, M, and H denotes Low, Medium, and High Volume respectively

CLINICAL MEASURES BY NSTEMI PCI VOLUME

	Low vs High Volume					Low vs Medium vs High Volume								
	Low Volume (n = 7,502)		High Volume (n = 17,962)			Low Volume (n = 3,898)		Medium Volume (n = 7,235		High Volume (n = 14,331)		Pairwise Comparison of Means (p values)		
Variable	Mean	S.D.	Mean	S.D.	p value	Mean	S.D.	Mean	S.D.	Mean	S.D.	M vs L	H vs L	H vs M
On Current Dialysis	0.032	0.175	0.037	0.188	<0.001	0.034	0.182	0.041	0.198	0.032	0.177	0.068	0.535	0.001
Hypertension	0.813	0.390	0.856	0.351	<0.001	0.806	0.396	0.831	0.375	0.860	0.347	<0.001	<0.001	<0.001
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Prior CVD	0.113	0.317	0.152	0.359	<0.001	0.114	0.318	0.133	0.339	0.152	0.359	0.008	<0.001	<0.001
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Chronic Lung Disease	0.132	0.338	0.158	0.365	<0.001	0.124	0.330	0.148	0.355	0.158	0.365	0.001	<0.001	0.053
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Note: L, M, and H denotes Low, Medium, and High Volume respectively

INCREMENTAL EFFECT OF INCREASING NSTEMI PCI VOLUME

INCREMENTAL EFFECT OF INCREASING NSTEMI PCI VOLUME ON MORTALITY

			95% Confidence Interval	
Year	Odds Ratio	S.E.	Lower Limit	Upper Limit
2015	1.049	0.263	0.642	1.714
2016	0.837	0.183	0.545	1.285
2017	0.697	0.163	0.441	1.102
2018	0.755	0.147	0.515	1.106
2019	0.866	0.221	0.525	1.430
2015-2019	0.846	0.109	0.658	1.088

INCREMENTAL EFFECT OF INCREASING NSTEMI PCI VOLUME ON ACUTE KIDNEY INJURY

			95% Confidence Interval	
Year	Odds Ratio	S.E.	Lower Limit	Upper Limit
2015	1.069	0.173	0.779	1.467
2016	1.000	0.137	0.764	1.307
2017	0.931	0.115	0.732	1.186
2018	0.877	0.106	0.692	1.111
2019	0.985	0.108	0.794	1.222
2015-2019	1.009	0.099	0.832	1.224

Implication: NSTEMI PCI volume is not an independent factor in explaining the mortality or AKI rates

EFFECT OF MEDIUM AND HIGH NSTEMI PCI VOLUME TO LOW VOLUME

EFFECT OF MEDIUM AND HIGH NSTEMI PCI VOLUME ON MORTALITY COMPARED TO LOW VOLUME

	Medium Relative to Low Volume				High Relative to Low Volume			
			95% Confidence Interval				95% Confidence Interval	
Year	Odds Ratio	S.E.	Lower Limit	Upper Limit	Odds Ratio	S.E.	Lower Limit	Upper Limit
2015	0.597	0.332	0.201	1.774	0.921	0.457	0.348	2.434
2016	0.555	0.264	0.219	1.408	0.632	0.274	0.270	1.479
2017	0.678	0.336	0.257	1.790	0.484	0.228	0.192	1.217
2018	1.038	0.426	0.465	2.318	0.610	0.242	0.281	1.327
2019	0.719	0.404	0.239	2.165	0.726	0.376	0.263	2.005
2015-2019	**0.677**	**0.184**	**0.397**	**1.155**	**0.692**	**0.178**	**0.418**	**1.146**

IMPACT OF HIGH VS LOW NSTEMI PCI VOLUME ON ACUTE KIDNEY INJURY COMPARED TO LOW VOLUME

	Medium Relative to Low Volume				High Relative to Low Volume			
			95% Confidence Interval				95% Confidence Interval	
Year	Odds Ratio	S.E.	Lower Limit	Upper Limit	Odds Ratio	S.E.	Lower Limit	Upper Limit
2015	0.913	0.306	0.474	1.759	1.112	0.362	0.588	2.103
2016	1.136	0.326	0.648	1.993	1.026	0.286	0.594	1.772
2017	1.337	0.323	0.832	2.147	0.918	0.216	0.579	1.457
2018	1.067	0.263	0.658	1.730	0.791	0.188	0.496	1.261
2019	1.458	0.317	0.953	2.232	1.066	0.224	0.707	1.609
2015-2019	**1.204**	**0.234**	**0.822**	**1.763**	**1.030**	**0.198**	**0.706**	**1.502**

Implication: NSTEMI PCI volume is not an independent factor in explaining the mortality or AKI rates

RESULTS: UNADJUSTED STEMI PCI VOLUME BY HOSPITAL, 2015-2019

Hospital	High/Low	High/Medium/Low	2015	2016	2017	2018	2019	TOTAL
Adventist White Oak	Low	Low	54	45	49	38	35	221
Adventist Shady Grove	High	High	144	159	129	130	128	690
Anne Arundel Medical Center	High	High	146	115	149	132	138	680
Ascension Saint Agnes	High	Medium	126	98	85	89	91	489
Carroll Hospital Center	Low	Low	89	83	72	65	61	370
Frederick Hospital	High	High	132	103	97	111	124	567
Holy Cross Hospital	Low	Low	76	71	55	66	71	339
Howard County Hospital	High	Medium	97	99	90	117	97	500
Johns Hopkins Bayview	Low	Low	58	73	60	57	66	314
Johns Hopkins Hospital	Low	Low	63	41	64	36	40	244
MedStar Franklin Square	High	Medium	111	96	107	101	99	514
MedStar Southern Maryland	High	High	143	106	131	132	149	661
MedStar Union	Low	Medium	118	85	88	82	64	437
Meritus Medical Center	High	Medium	109	104	99	87	103	502
Peninsula Regional Medical Center	High	High	161	170	163	151	152	797
Sinai Hospital	Low	Medium	116	86	85	90	98	475
Suburban Hospital	Low	Low	41	77	79	75	70	342
UM Prince George's	Low	Medium	69	97	62	80	66	374
UM Baltimore Washington	High	High	101	98	104	97	118	518
UM Medical Center	Low	Medium	74	85	69	91	81	400
UM Shore Regional	Low	Low	0	0	15	80	71	166
UM St. Joseph	High	High	131	114	93	102	86	526
UM Upper Chesapeake	High	High	130	135	137	106	120	628
UPMC Western Maryland	Low	Low	54	71	68	75	67	335
Median			**105**	**97**	**87**	**90**	**89**	**482**
First Tercile			**75**	**84**	**70**	**80**	**70**	**371**
Second Tercile			**123**	**102**	**98**	**102**	**102**	**517**

RESULTS: CHARACTERISTICS BY STEMI PCI VOLUME MEASURES

	Low vs High Volume					Low vs Medium vs High Volume								
	Low Volume (n = 3,996)		High Volume (n = 7,037)			Low Volume (n = 2,312)		Medium Volume (n = 3,679)		High Volume (n = 5,042)		Pairwise Comparison of Means (p values)		
Variable	Mean	S.D.	Mean	S.D.	p value	Mean	S.D.	Mean	S.D.	Mean	S.D.	M vs L	H vs L	H vs M
Age	62.874	12.685	63.183	12.625	0.218	63.298	12.865	62.500	12.559	63.383	12.599	0.017	0.788	0.001
Age: ≤ 25	0.001	0.027	0.000	0.021	0.482	0.000	0.000	0.001	0.033	0.000	0.020	0.079	0.498	0.172
Age: 25 - 35	0.011	0.104	0.008	0.090	0.144	0.010	0.101	0.010	0.098	0.008	0.091	0.815	0.394	0.483
Age: 35 - 45	0.062	0.242	0.058	0.233	0.324	0.059	0.235	0.063	0.243	0.057	0.232	0.499	0.749	0.231
Age: 45 - 55	0.192	0.394	0.201	0.401	0.274	0.194	0.396	0.205	0.404	0.195	0.396	0.322	0.955	0.251
Age: 55 - 65	0.315	0.465	0.309	0.462	0.477	0.309	0.462	0.312	0.463	0.311	0.463	0.821	0.855	0.948
Age: 65 - 75	0.242	0.428	0.248	0.432	0.483	0.237	0.425	0.247	0.431	0.249	0.433	0.359	0.247	0.828
Age: > 75	0.176	0.381	0.176	0.381	0.959	0.191	0.393	0.162	0.369	0.179	0.383	0.005	0.223	0.042
Male	0.682	0.466	0.708	0.455	0.005	0.692	0.462	0.679	0.467	0.715	0.451	0.278	0.051	<0.001
Female	0.318	0.466	0.292	0.455	0.005	0.308	0.462	0.321	0.467	0.285	0.451	0.278	0.051	<0.001
Race: White	0.632	0.482	0.777	0.416	<0.001	0.783	0.412	0.605	0.489	0.785	0.411	<0.001	0.863	<0.001
Race: Black	0.321	0.467	0.152	0.359	<0.001	0.160	0.367	0.336	0.472	0.148	0.355	<0.001	0.206	<0.001
Race: Asian	0.040	0.196	0.055	0.227	0.001	0.048	0.214	0.052	0.223	0.048	0.213	0.439	0.969	0.321
Race: American Indian	0.005	0.067	0.004	0.060	0.441	0.006	0.078	0.003	0.055	0.004	0.060	0.064	0.112	0.668
Race: Native Hawaiian	0.001	0.022	0.000	0.021	0.860	0.000	0.021	0.000	0.016	0.001	0.024	0.776	0.761	0.484
Ethnicity: Hispanic	0.045	0.206	0.027	0.161	<0.001	0.058	0.234	0.024	0.152	0.029	0.167	<0.001	<0.001	0.196
Body Mass Index (BMI)	29.810	10.507	29.661	9.725	0.452	29.678	10.483	29.817	9.169	29.657	10.381	0.601	0.932	0.459
BMI: < 18.5	0.014	0.117	0.012	0.111	0.531	0.012	0.107	0.017	0.128	0.011	0.103	0.101	0.732	0.016
BMI: 18.5 - 25	0.210	0.407	0.206	0.405	0.675	0.216	0.411	0.203	0.403	0.207	0.405	0.245	0.379	0.687
BMI: 25 - 30	0.257	0.437	0.269	0.444	0.143	0.258	0.438	0.257	0.437	0.273	0.446	0.956	0.161	0.091
BMI: > 30	0.399	0.490	0.398	0.489	0.877	0.385	0.487	0.415	0.493	0.393	0.488	0.023	0.518	0.042
On Current Dialysis	0.016	0.127	0.010	0.099	0.003	0.011	0.103	0.017	0.128	0.010	0.097	0.047	0.639	0.003
Hypertension	0.716	0.451	0.656	0.475	<0.001	0.669	0.471	0.712	0.453	0.656	0.475	0.001	0.244	<0.001
Prior Myocardial Infarction	0.204	0.403	0.173	0.378	<0.001	0.189	0.392	0.195	0.396	0.174	0.379	0.593	0.113	0.013
Prior Heart Failure	0.076	0.265	0.054	0.227	<0.001	0.064	0.244	0.063	0.243	0.061	0.240	0.903	0.706	0.775
Prior PCI	0.211	0.408	0.196	0.397	0.052	0.216	0.411	0.197	0.398	0.198	0.398	0.074	0.071	0.929
Prior CABG	0.046	0.209	0.049	0.216	0.445	0.045	0.208	0.049	0.217	0.048	0.213	0.473	0.654	0.719
Prior CVD	0.090	0.287	0.075	0.264	0.005	0.078	0.268	0.095	0.293	0.071	0.257	0.017	0.333	<0.001
Prior PAD	0.065	0.246	0.044	0.205	<0.001	0.054	0.227	0.065	0.246	0.040	0.197	0.081	0.010	<0.001
Chronic Lung Disease	0.087	0.282	0.080	0.271	0.171	0.072	0.259	0.101	0.302	0.073	0.261	<0.001	0.900	<0.001
Diabetes	0.311	0.463	0.279	0.449	<0.001	0.279	0.449	0.325	0.468	0.271	0.445	<0.001	0.479	<0.001

Note: L, M, and H denotes Low, Medium, and High Volume respectively

CLINICAL MEASURES BY STEMI PCI VOLUME

Variable	Low vs High Volume					Low vs Medium vs High Volume								
	Low Volume (n = 3,996)		High Volume (n = 7,037)			Low Volume (n = 2,312)		Medium Volume (n = 3,679)		High Volume (n = 5,042)		Pairwise Comparison of Means (p values)		
	Mean	S.D.	Mean	S.D.	p value	Mean	S.D.	Mean	S.D.	Mean	S.D.	M vs L	H vs L	H vs M
On Current Dialysis	0.016	0.127	0.010	0.099	0.003	0.011	0.103	0.017	0.128	0.010	0.097	0.047	0.639	0.003
Hypertension	0.716	0.451	0.656	0.475	<0.001	0.669	0.471	0.712	0.453	0.656	0.475	0.001	0.244	<0.001
Prior Myocardial Infarction	0.204	0.403	0.173	0.378	<0.001	0.189	0.392	0.195	0.396	0.174	0.379	0.593	0.113	0.013
Prior Heart Failure	0.076	0.265	0.054	0.227	<0.001	0.064	0.244	0.063	0.243	0.061	0.240	0.903	0.706	0.775
Prior PCI	0.211	0.408	0.196	0.397	0.052	0.216	0.411	0.197	0.398	0.198	0.398	0.074	0.071	0.929
Prior CABG	0.046	0.209	0.049	0.216	0.445	0.045	0.208	0.049	0.217	0.048	0.213	0.473	0.654	0.719
Prior CVD	0.090	0.287	0.075	0.264	0.005	0.078	0.268	0.095	0.293	0.071	0.257	0.017	0.333	<0.001
Prior PAD	0.065	0.246	0.044	0.205	<0.001	0.054	0.227	0.065	0.246	0.040	0.197	0.081	0.010	<0.001
Chronic Lung Disease	0.087	0.282	0.080	0.271	0.171	0.072	0.259	0.101	0.302	0.073	0.261	<0.001	0.900	<0.001
Diabetes	0.311	0.463	0.279	0.449	<0.001	0.279	0.449	0.325	0.468	0.271	0.445	<0.001	0.479	<0.001

Note: L, M, and H denotes Low, Medium, and High Volume respectively

INCREMENTAL EFFECT OF INCREASING STEMI PCI VOLUME

INCREMENTAL EFFECT OF INCREASING STEMI PCI VOLUME ON MORTALITY

			95% Confidence Interval	
Year	Odds Ratio	S.E.	Lower Limit	Upper Limit
2015	0.877	0.110	0.686	1.122
2016	0.908	0.105	0.724	1.141
2017	0.636	0.099	0.469	0.863
2018	0.796	0.117	0.596	1.062
2019	0.717	0.083	0.571	0.899
2015-2019	0.794	0.059	0.686	0.919

INCREMENTAL EFFECT OF INCREASING STEMI PCI VOLUME ON ACUTE KIDNEY INJURY

			95% Confidence Interval	
Year	Odds Ratio	S.E.	Lower Limit	Upper Limit
2015	0.654	0.094	0.493	0.866
2016	0.705	0.105	0.527	0.944
2017	0.886	0.121	0.679	1.158
2018	0.803	0.133	0.581	1.110
2019	0.708	0.088	0.556	0.903
2015-2019	0.783	0.091	0.623	0.983

Implication: STEMI PCI volume, after controlling demographic and clinical characteristics, tend to be associated with lower mortality and AKI rates

EFFECT OF MEDIUM AND HIGH STEMI PCI VOLUME COMPARED TO LOW VOLUME

EFFECT OF MEDIUM AND HIGH STEMI PCI VOLUME ON MORTALITY COMPARED TO LOW VOLUME

	Medium Relative to Low Volume				High Relative to Low Volume			
			95% Confidence Interval				95% Confidence Interval	
Year	Odds Ratio	S.E.	Lower Limit	Upper Limit	Odds Ratio	S.E.	Lower Limit	Upper Limit
2015	1.268	0.341	0.748	2.148	0.847	0.227	0.500	1.433
2016	1.234	0.294	0.774	1.968	0.867	0.206	0.544	1.383
2017	0.796	0.246	0.435	1.457	0.406	0.128	0.219	0.752
2018	1.116	0.322	0.633	1.966	0.653	0.189	0.370	1.152
2019	0.981	0.234	0.614	1.567	0.525	0.126	0.327	0.842
2015-2019	1.046	0.142	0.802	1.365	0.645	0.088	0.494	0.842

IMPACT OF HIGH VS LOW STEMI PCI VOLUME ON ACUTE KIDNEY INJURY COMPARED TO LOW VOLUME

	Medium Relative to Low Volume				High Relative to Low Volume			
			95% Confidence Interval				95% Confidence Interval	
Year	Odds Ratio	S.E.	Lower Limit	Upper Limit	Odds Ratio	S.E.	Lower Limit	Upper Limit
2015	0.643	0.185	0.366	1.131	0.427	0.123	0.243	0.750
2016	0.728	0.216	0.406	1.303	0.498	0.148	0.278	0.894
2017	0.987	0.276	0.571	1.707	0.794	0.217	0.465	1.357
2018	1.060	0.343	0.563	1.998	0.652	0.213	0.344	1.236
2019	0.833	0.207	0.512	1.356	0.507	0.126	0.312	0.823
2015-2019	0.890	0.206	0.565	1.402	0.614	0.142	0.390	0.967

Implication: STEMI PCI volume, after controlling demographic and clinical characteristics, tend to be associated with lower mortality and AKI rates

Comparison of Actual Minus Risk-Adjusted NSTEMI Mortality Proportions Using Clopper-Pearson (Exact), Agresti-Coull, and Jeffreys Methods to Calculate Standard Errors, 2015 – 2019

Hospital	Actual Rate	Risk-Adjusted Rate	Actual - Expected	Clopper-Pearson (Exact) 90% Confidence Interval		Agresti–Coull 90% Confidence Interval		Jeffreys 90% Confidence Interval	
				Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Adventist White Oak	0.010	0.010	0.000	-0.004	0.006	-0.004	0.006	-0.004	0.005
Adventist Shady Grove	0.016	0.013	0.003	-0.006	0.018	-0.005	0.018	-0.005	0.017
Anne Arundel Medical Center	0.006	0.008	-0.002	-0.006	0.006	-0.006	0.006	-0.006	0.005
Ascension Saint Agnes	0.012	0.011	0.001	-0.004	0.009	-0.004	0.009	-0.004	0.009
Carroll Hospital Center	0.010	0.011	-0.001	-0.007	0.012	-0.007	0.012	-0.007	0.010
Frederick Hospital	0.009	0.009	0.000	-0.005	0.009	-0.004	0.009	-0.004	0.008
Johns Hopkins Bayview	0.014	0.015	-0.001	-0.009	0.014	-0.009	0.014	-0.008	0.012
Johns Hopkins Hospital	0.019	0.018	0.002	-0.004	0.010	-0.004	0.010	-0.004	0.009
MedStar Southern Maryland	0.003	0.006	-0.003	-0.006	0.003	-0.006	0.004	-0.005	0.003
MedStar Union	0.008	0.009	-0.001	-0.003	0.003	-0.003	0.003	-0.003	0.002
Meritus Medical Center	0.012	0.011	0.000	-0.007	0.013	-0.006	0.013	-0.006	0.012
Peninsula Regional Medical Center	0.007	0.008	0.000	-0.004	0.005	-0.004	0.005	-0.004	0.005
Sinai Hospital	0.017	0.015	0.002	-0.004	0.010	-0.003	0.010	-0.004	0.010
Suburban Hospital	0.008	0.008	0.000	-0.005	0.006	-0.004	0.007	-0.004	0.006
UM Prince George's	0.022	0.018	0.004	-0.006	0.018	-0.005	0.019	-0.005	0.017
UM Baltimore Washington	0.005	0.006	-0.001	-0.005	0.006	-0.005	0.006	-0.005	0.005
UM Medical Center	0.032	0.028	0.004	-0.005	0.016	-0.004	0.016	-0.005	0.015
UM Shore Regional	0.008	0.011	-0.004	-0.011	0.016	-0.011	0.018	-0.010	0.013
UM St. Joseph	0.008	0.008	0.000	-0.003	0.004	-0.003	0.004	-0.003	0.004
UM Upper Chesapeake	0.008	0.009	0.000	-0.004	0.006	-0.004	0.007	-0.004	0.006
UPMC Western Maryland	0.005	0.008	-0.002	-0.006	0.005	-0.006	0.005	-0.005	0.004
Total	**0.012**	**0.011**	**0.001**	**-0.001**	**0.001**	**-0.001**	**0.001**	**-0.001**	**0.001**

Comparison of Actual Minus Risk-Adjusted NSTEMI Acute Kidney Injury Portions Using Clopper-Pearson (Exact), Agresti-Coull, and Jeffreys Methods to Calculate Standard Errors, 2015 – 2019

Hospital	Actual Rate	Risk-Adjusted Rate	Actual - Expected	Clopper-Pearson (Exact) 90% Confidence Interval		Agresti–Coull 90% Confidence Interval		Jeffreys 90% Confidence Interval	
				Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Adventist White Oak	0.066	0.067	-0.001	-0.012	0.012	-0.011	0.012	-0.011	0.011
Adventist Shady Grove	0.065	0.064	0.001	-0.019	0.026	-0.017	0.026	-0.018	0.025
Anne Arundel Medical Center	0.037	0.041	-0.004	-0.015	0.012	-0.015	0.012	-0.015	0.011
Ascension Saint Agnes	0.111	0.110	0.002	-0.016	0.021	-0.015	0.021	-0.015	0.020
Carroll Hospital Center	0.021	0.031	-0.010	-0.021	0.006	-0.020	0.007	-0.020	0.005
Frederick Hospital	0.072	0.071	0.001	-0.015	0.019	-0.015	0.019	-0.015	0.019
Johns Hopkins Bayview	0.113	0.106	0.007	-0.020	0.038	-0.018	0.037	-0.019	0.037
Johns Hopkins Hospital	0.136	0.133	0.003	-0.013	0.020	-0.012	0.020	-0.013	0.020
MedStar Southern Maryland	0.098	0.098	0.001	-0.018	0.022	-0.017	0.022	-0.018	0.021
MedStar Union	0.070	0.071	-0.001	-0.009	0.008	-0.009	0.008	-0.009	0.008
Meritus Medical Center	0.063	0.061	0.002	-0.016	0.025	-0.015	0.025	-0.015	0.024
Peninsula Regional Medical Center	0.058	0.058	0.000	-0.011	0.012	-0.011	0.012	-0.011	0.012
Sinai Hospital	0.089	0.088	0.001	-0.013	0.017	-0.013	0.017	-0.013	0.016
Suburban Hospital	0.038	0.042	-0.005	-0.015	0.008	-0.014	0.008	-0.014	0.008
UM Prince George's	0.128	0.123	0.005	-0.020	0.032	-0.019	0.032	-0.019	0.031
UM Baltimore Washington	0.048	0.050	-0.003	-0.016	0.014	-0.015	0.014	-0.015	0.013
UM Medical Center	0.159	0.158	0.001	-0.019	0.023	-0.018	0.023	-0.018	0.022
UM Shore Regional	0.057	0.059	-0.002	-0.027	0.033	-0.025	0.034	-0.025	0.031
UM St. Joseph	0.064	0.064	0.000	-0.009	0.010	-0.009	0.010	-0.009	0.010
UM Upper Chesapeake	0.058	0.059	-0.001	-0.013	0.013	-0.012	0.013	-0.012	0.013
UPMC Western Maryland	0.088	0.086	0.002	-0.016	0.022	-0.015	0.022	-0.015	0.021
	0.079	0.079	0.000	-0.003	0.003	-0.003	0.003	-0.003	0.003

Comparison of Actual Minus Risk-Adjusted STEMI Mortality Proportions Using Clopper-Pearson (Exact), Agresti-Coull, and Jeffreys Methods to Calculate Standard Errors, 2015 – 2019

Hospital	Actual Rate	Risk-Adjusted Rate	Actual - Expected	Clopper-Pearson (Exact) 95% Confidence Interval		Agresti–Coull 95% Confidence Interval		Jeffreys 95% Confidence Interval	
				Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Adventist White Oak	0.045	0.057	-0.012	-0.035	0.025	-0.033	0.026	-0.034	0.022
Adventist Shady Grove	0.052	0.051	0.001	-0.015	0.020	-0.014	0.020	-0.014	0.019
Anne Arundel Medical Center	0.043	0.045	-0.002	-0.016	0.016	-0.015	0.016	-0.016	0.015
Ascension Saint Agnes	0.087	0.077	0.010	-0.013	0.039	-0.012	0.039	-0.013	0.038
Carroll Hospital Center	0.060	0.064	-0.004	-0.026	0.025	-0.025	0.025	-0.025	0.023
Frederick Hospital	0.049	0.054	-0.004	-0.020	0.017	-0.019	0.017	-0.020	0.016
Holy Cross Hospital	0.080	0.075	0.005	-0.021	0.040	-0.020	0.040	-0.020	0.038
Howard County Hospital	0.030	0.041	-0.011	-0.024	0.008	-0.024	0.008	-0.024	0.007
Johns Hopkins Bayview	0.064	0.063	0.000	-0.024	0.033	-0.022	0.034	-0.023	0.032
Johns Hopkins Hospital	0.110	0.089	0.021	-0.016	0.068	-0.013	0.068	-0.014	0.066
MedStar Franklin Square	0.064	0.060	0.004	-0.016	0.029	-0.014	0.029	-0.015	0.028
MedStar Southern Maryland	0.056	0.051	0.005	-0.012	0.025	-0.011	0.025	-0.011	0.024
MedStar Union	0.080	0.073	0.007	-0.017	0.037	-0.015	0.037	-0.016	0.036
Meritus Medical Center	0.054	0.055	-0.002	-0.020	0.022	-0.018	0.022	-0.019	0.021
Peninsula Regional Medical Center	0.039	0.043	-0.004	-0.016	0.012	-0.015	0.012	-0.016	0.011
Sinai Hospital	0.080	0.073	0.007	-0.015	0.035	-0.014	0.035	-0.015	0.034
Suburban Hospital	0.065	0.069	-0.004	-0.028	0.027	-0.027	0.027	-0.027	0.025
UM Prince George's	0.072	0.063	0.010	-0.014	0.041	-0.013	0.041	-0.013	0.039
UM Baltimore Washington	0.033	0.042	-0.009	-0.023	0.010	-0.022	0.010	-0.022	0.009
UM Medical Center	0.100	0.086	0.014	-0.013	0.048	-0.012	0.048	-0.012	0.047
UM Shore Regional	0.079	0.074	0.005	-0.031	0.058	-0.028	0.058	-0.029	0.054
UM St. Joseph	0.044	0.051	-0.007	-0.023	0.015	-0.021	0.015	-0.022	0.014
UM Upper Chesapeake	0.038	0.043	-0.004	-0.018	0.014	-0.017	0.014	-0.017	0.013
UPMC Western Maryland	0.048	0.059	-0.011	-0.031	0.018	-0.030	0.018	-0.030	0.016
Total	**0.058**	**0.058**	**0.000**	**-0.004**	**0.005**	**-0.004**	**0.005**	**-0.004**	**0.005**

Comparison of Actual Minus Risk-Adjusted STEMI Acute Kidney Injury Portions Using Clopper-Pearson (Exact), Agresti-Coull, and Jeffreys Methods to Calculate Standard Errors, 2015 – 2019

Hospital	Actual Rate	Risk-Adjusted Rate	Actual - Expected	Clopper-Pearson (Exact) 90% Confidence Interval Lower Limit	Clopper-Pearson (Exact) 90% Confidence Interval Upper Limit	Agresti–Coull 90% Confidence Interval Lower Limit	Agresti–Coull 90% Confidence Interval Upper Limit	Jeffreys 90% Confidence Interval Lower Limit	Jeffreys 90% Confidence Interval Upper Limit
Adventist White Oak	0.109	0.111	-0.002	-0.040	0.047	-0.037	0.047	-0.038	0.044
Adventist Shady Grove	0.081	0.080	0.001	-0.018	0.024	-0.017	0.024	-0.018	0.023
Anne Arundel Medical Center	0.059	0.060	-0.001	-0.018	0.019	-0.017	0.019	-0.017	0.019
Ascension Saint Agnes	0.180	0.173	0.007	-0.028	0.043	-0.026	0.043	-0.027	0.042
Carroll Hospital Center	0.041	0.054	-0.013	-0.030	0.013	-0.029	0.014	-0.029	0.012
Frederick Hospital	0.067	0.070	-0.003	-0.021	0.022	-0.020	0.022	-0.021	0.021
Holy Cross Hospital	0.119	0.119	-0.001	-0.033	0.039	-0.031	0.038	-0.032	0.037
Howard County Hospital	0.058	0.063	-0.005	-0.024	0.019	-0.023	0.019	-0.023	0.018
Johns Hopkins Bayview	0.137	0.132	0.005	-0.033	0.046	-0.031	0.046	-0.031	0.045
Johns Hopkins Hospital	0.301	0.272	0.029	-0.034	0.086	-0.032	0.085	-0.032	0.084
MedStar Franklin Square	0.099	0.097	0.002	-0.025	0.029	-0.024	0.029	-0.024	0.028
MedStar Southern Maryland	0.092	0.091	0.001	-0.020	0.026	-0.019	0.026	-0.019	0.025
MedStar Union	0.140	0.138	0.002	-0.031	0.037	-0.029	0.036	-0.030	0.035
Meritus Medical Center	0.064	0.068	-0.004	-0.025	0.020	-0.023	0.020	-0.024	0.019
Peninsula Regional Medical Center	0.069	0.071	-0.001	-0.018	0.019	-0.017	0.019	-0.017	0.018
Sinai Hospital	0.093	0.096	-0.003	-0.029	0.026	-0.027	0.026	-0.028	0.025
Suburban Hospital	0.097	0.100	-0.003	-0.032	0.034	-0.030	0.034	-0.031	0.032
UM Prince George's	0.147	0.142	0.005	-0.031	0.043	-0.029	0.043	-0.030	0.042
UM Baltimore Washington	0.064	0.068	-0.003	-0.020	0.024	-0.019	0.024	-0.019	0.023
UM Medical Center	0.208	0.198	0.009	-0.031	0.050	-0.030	0.050	-0.030	0.049
UM Shore Regional	0.061	0.080	-0.019	-0.051	0.029	-0.048	0.030	-0.048	0.025
UM St. Joseph	0.108	0.106	0.002	-0.023	0.032	-0.021	0.032	-0.022	0.031
UM Upper Chesapeake	0.077	0.078	-0.001	-0.020	0.023	-0.019	0.023	-0.019	0.023
UPMC Western Maryland	0.186	0.176	0.010	-0.032	0.054	-0.030	0.054	-0.031	0.053
Total	0.102	0.102	0.000	-0.006	0.006	-0.006	0.006	-0.006	0.006

Key Findings

- Impacts on outcomes of care related to NSTEMI PCI volume are modest, at best, and explained by variance in patient severity.
- Hospitals with relatively high STEMI PCI volume have lower mortality and kidney injury rates after controlling for demographic and clinical factors.
- The method used to calculate standard errors and confidence intervals for inpatient deaths and acute kidney injury proportions does not make a substantive difference in identifying outlier hospitals for STEMI PCI cases and NSTEMI PCI cases.

Limitations

- Although there were thousands of admission-level observations for NSTEMI and STEMI PCI procedures for each year, the analysis of the extent to which hospitals are outliers depends on the results from Maryland hospitals.
  - National assessment of hospital outliers using the full NCDR database could include approximately 2,400 hospitals.
  - The ability to detect differences in hospital outcomes is easier with a larger sample.
- The definition of outlier affects the number of hospitals identified as outliers.
  - Risk-adjustment either pre- or post-identification of outliers.


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