Social Determinants of Health as an Independent Factor Following a ST-segment elevation myocardial infarction Percutaneous Coronary Intervention

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Introduction

This report is an addendum to a recent evaluation by Advanta Government Services (AGS) that found that Maryland hospitals with relatively high ST-segment elevation myocardial infarction (STEMI) percutaneous coronary intervention (PCI) volume tend to have lower mortality rates, after controlling for demographic and clinical factors. Feedback from the Maryland Health Care Commission (MHCC) Cardiac Services Advisory Committee (CSAC) indicated that the relationship between STEMI PCI volume and mortality may appear counter intuitive, given that 8 of the 12 low volume hospital are tertiary centers that perform cardiac surgery in addition to PCI. Interventional cardiologists at the tertiary hospitals are likely the most experienced and cover interventional procedures at many of the non-tertiary institutions that have higher primary PCI volume. Additionally, each of the tertiary institutions have specialized units with experienced and trained staff. One hypothesis is that low STEMI PCI volume hospitals treat patients with higher socioeconomic deprivation as defined by such things as insurance status, income level, educational level, and immigration status. In the analysis of STEMI PCI volume, high-volume hospitals performed STEMI PCIs on relatively high proportions of White and Asian patients while low-volume hospital treated relatively more Black and Hispanic patients. CSAC members raised a concern that unmeasured social determinants of health may affect symptom to first medical contact or symptom-to-device time. In 2019, the percentage of the Maryland population without insurance, by race, was 3.8 percent of the White population, 6.2 percent of the Black population, and 21.0 percent of the Hispanic population. If STEMI patients without insurance delay going to the hospital, then patients presenting at low volume hospitals may present at a later time in the course of their STEMIs. To improve the understanding of the relationship between STEMI PCI volume and mortality, the objective of this evaluation was to assess the extent to which social determinants of health vary by STEMI PCI volume and inpatient mortality following a STEMI PCI procedure.

The first aim of this additional study was to evaluate the relationship between STEMI PCI volume and social determinants of health. The rationale is that tertiary hospitals that perform cardiac surgery in addition to PCI may tend to treat patients with worse social determinants of health. Because many of the tertiary hospitals have low STEMI PCI volume, measures of social determinants of health for STEMI patients treated at these hospitals may be worse compared to high STEMI PCI volume hospitals. The second aim was to determine the impact of local area socioeconomic deprivation, along with STEMI PCI volume, on inpatient mortality. The rationale is that the local Area Deprivation Index (ADI), as a measure of local socioeconomic deprivation, may be an independent factor that explains inpatient mortality following a STEMI PCI. A third aim was to assess other differences between high and low STEMI PCI volume hospitals that may impact inpatient mortality beyond the effect of volume alone.

Methods

The analytic approach for the first aim, an evaluation of the relationship between STEMI PCI volume and social determinants of health, was to analyze the variance between low and high volume hospitals to assess whether statistically significant differences exist with respect to STEMI PCI volume and ADI. This analysis used the data on STEMI PCI volume for 2015-2019 from the prior evaluation of Maryland hospitals. The patient ZIP Code from Maryland hospitals' submissions to the American College of

Cardiology's National Cardiovascular Data Registry (ACC-NCDR) for CathPCI was linked to local Area Deprivation Index (ADI) data at the ZIP Code level.

The ADI is a measure of social and economic disadvantage based on where people live. The tool provides a means of comparing localities based on the social determinant health domains of education, income/employment, housing, and household characteristics.[1] The measures to create the ADI were downloaded from the U.S. Census Bureau's five-year American Community Survey data, at the ZIP Code tabulation area (ZCTA) level. Any missing measure data at the ZCTA level was imputed using the state average for the measure. The ZCTAs are grouped into quintiles with the lowest quintile representing the lowest levels of socioeconomic disadvantage and the highest quintile having the greatest disadvantage. Some ZIP Codes, like post office boxes, do not have a geographic component and are grouped into the "Unknown" group.

The analytic approach for the second aim used a hierarchical logistic model with inpatient mortality as the dependent variable using the previously collected CathPCI data for Maryland hospitals. Local area socioeconomic deprivation was assessed using the ADI calculated from the ZIP Code recorded in the CathPCI data. The impact of the area deprivation was estimated using the nation ADI quintiles as an independent variable in the logistic regression, controlling for STEMI PCI volume, demographic, and clinical measures.

Findings

Relationship Between STEMI Volume and the Area Deprivation Index

Table 1 presents the count and percentages of STEMI PCIs allocated to the ADI quintile for the home ZIP Code of the patient. Lower percentiles reflect areas of higher socioeconomic deprivation as measured by the ADI.

Table 1. Distribution of STEMI PCIs by High and Low STEMI Volume Hospitals and ADI Quintiles

	Quintile	High STEMI PCI Volume		Low STEMI PCI Volume	
		Count	Percent	Count	Percent
Low Deprivation	Lowest 20th Percentile	4,169	59.3%	1,701	42.6%
	20-40th Percentile	1,627	23.1%	765	19.1%
	40-60th Precentile	555	7.9%	477	11.9%
	60-80th Percentile	126	1.8%	392	9.8%
High Deprivation	Highest 20th Percentile	73	1.0%	162	4.1%
	Unknown	481	6.8%	499	12.5%

The STEMI patients receiving PCIs at high volume hospitals tended to be from areas with less deprivation than low volume hospitals. For high volume hospitals, 82.4 percent of patients receiving PCIs for STEMI were from areas in the 60th percentile or below in the ADI, compared to 61.7 percent for low volume hospitals.

Table 2 shows the mean national ADI percentiles for the STEMI PCI patients treated at high and low volume hospitals. The mean values may be regarded as representative of patients at each location.

[1] https://www.cdc.gov/pcd/issues/2016/16_0221.htm. Accessed May 4, 2022.

Table 2. Mean ADI Quintiles for High and Low STEMI PCI Hospitals(2015 – 2019)

Variable	Observations	Mean	St. Dev.	95% Confidence Interval
High STEMI PCI Volume	6,550	0.197	0.159	0.193 - 0.201
Low STEMI PCI Volume	3,497	0.291	0.240	0.283 - 0.299
Combined	10,047	0.230	0.196	0.226 - 0.234
Difference	0.095			0.087 - 0.102

The representative STEMI patient at a high STEMI volume hospital was in the 20th percentile of ADI, compared to the representative STEMI patient treated at a low STEMI volume hospital who was in the 30th percentile of ADI. The higher level of deprivation for STEMI patients at low STEMI volume hospitals compared to STEMI patients at high STEMI volume hospitals is statistically significant ($p < 0.001$).

Table 3 presents the impact of the ADI quintile on inpatient mortality following a STEMI PCI, after controlling for patient demographics, clinical comorbidities, and hospital STEMI PCI volume.

Table 3. Impact of ADI Quintile on Inpatient Mortality

Low Deprivation

High Deprivation

Quintile	Odds Ratio	St. Err.	P-value	95% Confidence Interval
Lowest 20th Percentile	0.539	0.168	0.047	0.293 - 0.991
20-40th Percentile	0.638	0.203	0.157	0.342 - 1.188
40-60th Precentile	0.716	0.243	0.325	0.369 - 1.392
60-80th Percentile	0.93	0.328	0.838	0.466 - 1.857
Highest 20th Percentile (Referent)	1			

After controlling for individual characteristics, clinical patient profiles, and the hospital STEMI PCI volume, the area socioeconomic deprivation index had an impact on inpatient mortality for STEMI PCI patients following PCI. STEMI patients living in areas with the least socioeconomic deprivation, as measured by the upper quintile of the ADI, had an odds ratio of 0.539 ($p = 0.047$) relative to STEMI patients living in areas with the highest deprivation. This suggests STEMI patients with the least socioeconomic deprivation have a lower risk of dying following a PCI compared to those with the higher levels of deprivation. The odds ratio decreased as the ADI percentiles decreased, but only demonstrated statistical significance below to 20th percentile. This improvement in mortality suggests that decreasing socioeconomic deprivation may have measurable health outcomes.

Other Differences Between High and Low STEMI PCI Volume Hospitals that Impact Inpatient Mortality

Table 4 shows the source of admission for the STEMI PCI recipients treated at high and low volume hospitals for STEMI PCI procedures. The source of admission for PCI was recorded as admission through the emergency department, transferred in from another acute care hospital, or other sources. The cases in which no admission source was identified were recorded as unknown.

Table 4. Source of Admission for High and Low STEMI PCI Hospitals (2015 – 2018Q1)

	2015		2016		2017		2018Q1		2015 - 2018Q1	
Admit Source	High	Low	High	Low	High	Low	High	Low	High	Low
Emergency Department	1,371	561	1,274	578	1,229	552	348	173	4,222	1,864
Transfer in from another acute care facility	175	164	167	122	154	120	36	31	532	437
Other/Unknown	43	11	30	26	67	26	9	8	149	71

Transfers from another acute care facility make up 19.5 percent of the admissions for low STEMI volume hospitals compared to 9.2 percent ($p < 0.001$) for high STEMI volume hospitals.

Table 5 shows the STEMI PCI cases at high and low volume hospitals that indicated a delay in the PCI procedure.

Table 5. STEMI Delay Differences Between High and Low STEMI PCI Hospitals

	Mean	S.E.	95 % Confidence Interval	
High STEMI Volume	0.133	0.007	0.119 -	0.147
Low STEMI Volume	0.147	0.009	0.130 -	0.164
Difference: High vs Low	-0.0138	p = 0.225		

With respect to the proportion of STEMI cases that had a delay in the PCI procedure, there was no statistically significant difference between high and low volume hospitals.

Table 6 presents the mean recorded time from symptom onset to first device at high and low STEMI PCI volume hospitals. Cases with missing symptom onset or first device time was excluded from the calculations and the analysis included both in-hospital or out-of-hospital STEMIs.

Table 6. Time From Symptom Onset to First Device for Differences Between High and Low STEMI PCI Hospitals (2018Q2 – 2019)

	Mean	S.E.	95 % Confidence Interval	
High STEMI Volume	55.446	3.257	49.060 -	61.833
Low STEMI Volume	42.603	3.008	36.704 -	48.502
Difference: High vs Low	12.843	p = 0.004		

Low STEMI PCI volume hospitals had a shorter time (42.6 minutes) from recorded symptom onset to first device relative to high volume hospitals (55.4 minutes). The 12.8-minute difference was statistically significant ($p = 0.004$). Approximately 15.4 percent of the STEMI cases were missing a symptom onset time for STEMI cases which makes the onset to device time difficult to interpret.

Table 7 presents the mean recorded time from arrival time to first device at high and low STEMI PCI volume hospitals. Cases with missing first device time was excluded from the calculations and no distinction was made for STEMI occurring in-hospital or out-of-hospital.

Table 7. Time From Arrival to First Device for Differences Between High and Low STEMI PCI Hospitals

	Mean	S.E.	95 % Confidence Interval	
High STEMI Volume	19.245	1.481	16.342 -	22.149
Low STEMI Volume	20.440	1.898	16.718 -	24.161
Difference: High vs Low	-1.194	p = 0.620		

The difference between high and low STEMI PCI volume hospitals was not statistically significant for arrival to first device time.

Table 8 presents the impact of PCI delay, onset-to-device time, and arrival-to-device time on inpatient mortality following a STEMI PCI, after controlling for patient demographics, clinical comorbidities, and hospital STEMI PCI volume. A delay, in this context, is a delay in the time to PCI that is related to the patient rather than the facility or healthcare staff. The delay must happen within 90 minutes of arriving at the hospital and the reason must be documented in the patient record.

Table 8. Impact of STEMI Time and Delay on Inpatient Mortality (2018Q2 – 2019)

Variable	Odds Ratio	St. Err.	P-value	95% Confidence Interval
Delay	5.445	1.121	0.000	3.637 - 8.152
Time: Sympton Onset to First Device	1.000	0.001	0.813	0.998 - 1.002
Time: Arrivl to First Device	1.000	0.001	0.836	0.997 - 1.002

STEMI PCIs with a recorded delay in PCI procedures had 5.445 greater odds of inpatient death relative to cases without PCI delay. The timing of STEMI notation, onset-to-device time, and arrival-to-device time did not independently have a statistically significant impact on inpatient mortality.

Table 9 presents the PCI delay reasons recorded at high and low STEMI PCI volume hospitals.

Table 9. Reasons for PCI Delay for High and Low STEMI PCI Hospitals (2018Q2 – 2019)

	High PCI Volume		Low PCI Volume	
PCI Delay Reason	Count	Percent	Count	Percent
Cardiac Arrest and/or need for intubation before PCI	125	40.5%	92	37.9%
Difficult Vascular Access	50	16.2%	26	10.7%
Difficulty crossing the culprit lesion	54	17.5%	50	20.6%
Emergent placement of LV support device prior to PCI	6	1.9%	6	2.5%
Other/Unknown	58	18.8%	49	20.2%
Patient delays in providing consent for PCI	16	5.2%	20	8.2%

Cardiac Arrest and/or need for intubation before PCI was the most frequently occurring reason for PCI delay at high and low volume hospitals, followed by difficulty crossing the culprit lesion and difficult vascular access, for the known reasons.

The PCI status is an important indicator of inpatient mortality, specifically for rescue STEMI PCI. These cases are defined by a reperfusion for a failed fibrinolysis to prevent blood clots.[2] For the 2015 to 2019

[2] Eeckhout, E. (2007). Rescue percutaneous coronary intervention: does the concept make sense? *Heart*, *93*(5), 632-638.

study period, 187 salvage STEMI PCIs were identified in the Maryland data. The mortality rate for the rescue STEMI PCIs was 60.4 percent. Low volume hospitals had more salvage cases than high volume, both in terms of total cases (134 vs 78) and as a percentage of cases (3.4% vs 1.3%). When the analysis is run without the salvage cases included, the odds ratio for high vs. low STEMI PCI volume on mortality increased from 0.65 ($p < 0.001$) to 0.78 ($p = 0.008$). This shows that while the difference in the odds ratio for mortality of STEMI PCI patients at high vs. low STEMI PCI programs decreased, there was still a statistically significant difference even after removing patients who might otherwise be regarded as skewing the results unfavorably for programs with a low volume of STEMI PCI cases. Table 10 shows the transfer and salvage cases for the data for 2015 to 2018Q1 for high and low STEMI PCI volume hospitals.

Table 10. Transfer and Salvage Cases for High and Low STEMI PCI Hospitals (2015 – 2018Q1)

	2015		2016		2017		2018Q1		2015 - 2018Q1	
Case Type	High	Low	High	Low	High	Low	High	Low	High	Low
Transfer	174	163	162	117	152	114	36	29	524	423
Salvage	24	17	21	27	9	24	1	9	55	77
Transfer & Salvage	1	1	5	5	2	6	0	2	8	14

When both salvage and transfer cases are removed, the sample is reduced by 1,101 cases (15.2%). The odds ratio for mortality of STEMI patients at high vs low volume hospitals increases to 1.002 ($p = 0.991$). This suggests that when both the salvage and transfer cases are removed from the analysis, the impact of volume on mortality for STEMI patients dissipates.

Conclusions

Low STEMI PCI volume hospitals do treat patients with higher socioeconomic deprivation factors that include income and educational level. The high STEMI PCI volume hospitals provided emergency PCI procedures to a greater proportion of individuals in the highest ADI quintile 59.3 percent of emergency PCI procedures, compared to 42.6 percent for low STEMI PCI volume hospitals. Patients from the lowest national ADI quintile (greatest level of deprivation) were four times more likely to be treated in a low STEMI PCI volume hospital. The low STEMI PCI volume hospitals were more likely to be tertiary centers that perform cardiac surgery in addition to PCI.

Local area socioeconomic deprivation, along with STEMI PCI volume, has a significant impact on inpatient mortality, at least for STEMI patients from areas with the least and most socioeconomic deprivation. STEMI patients from areas in the lowest ADI quintile (highest deprivation) had nearly twice the odds of dying in the hospital following PCI for STEMI relative to STEMI patients from areas in the highest ADI quintile (least deprivation).

While most STEMI PCI admissions arrive to the hospital through the emergency department for both high and low volume hospitals, low STEMI PCI volume hospitals tend to receive a higher proportion of transfer patients from other acute care hospitals, specifically in 19.5 percent of the admissions compared to 9.2 percent for high volume hospitals ($p < 0.001$). The low volume hospitals have a higher proportion of salvage STEMI PCIs compared to high volume hospitals, which significantly impacts the inpatient mortality rate.

This analysis indicates that there are important differences in the patients receiving PCIs for STEMI at low and high volume hospitals. The low volume hospitals have a higher tendency to care of patients

from areas of higher socioeconomic deprivation, are more likely to perform salvage STEMI PCIs, and more likely to treat patients who are transferred from another acute care hospital. Socioeconomic deprivation has a statistically significant protective effect for the people with the least deprivation (highest affluence).