

**ACC/NC+SC Grant to Reduce  
Cardiovascular Health Disparities in  
North Carolina (2022):**

***Leveraging Artificial Intelligence to  
Prevent Disparities in Percutaneous  
Coronary Interventional Outcomes in  
a Diverse, High-Risk North Carolina  
County.***



# Leveraging Artificial Intelligence to Prevent Disparities in Percutaneous Coronary Interventional Outcomes in a Diverse, High-Risk North Carolina County (Robeson Co).

A Collaboration:



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CLINICAL



# Leveraging Artificial Intelligence to Prevent Disparities in Percutaneous Coronary Interventional Outcomes in a Diverse, High-Risk North Carolina County (Robeson Co).

A Collaboration:



CLINICAL

STATISTICAL



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- Outcome disparities exist among percutaneous coronary intervention (PCI) patients based upon race, marital and socioeconomic status.<sup>1-3</sup>
- However, actions to address these disparities are limited.<sup>4,5</sup>

1. Cai A, et al. J Am Heart Assoc 2019.
2. Barbash IM, et al. Am Heart J 2013.
3. Yong CM, et al. J Am Heart Assoc 2014.
4. Nanna MG, Peterson ED. JACC Cardiovasc Interv 2020.
5. Richman L, et al. SSM Popul Health 2019.



➤ Objective:

1. Critically assess disparities in urgent PCI patient outcomes from Robeson County, NC; and then:
2. Produce an artificial intelligence (AI)-based software program that facilitates elimination of these disparities by guiding future focused follow-up care and interventions.



# ➤ Materials and Methods:

- Report Landscape (Robeson County, North Carolina; surveillance period: 12/2011-06/2017):<sup>6</sup>
  - Geographically largest county in NC.
  - Rural with racially and culturally diverse but relatively undereducated population.
  - 33.1% of population in poverty.
  - Robert Wood Johnson Foundation County Health Rankings during surveillance period: annual downward trend from 98th-to-100th place out of the 100 NC counties.
  - African and Native American residents had documented overall poorer health, expressed more physical and mental stress, and demonstrated poorer outcomes compared with Caucasians.<sup>5</sup>
  - Deteriorated from 2nd highest-to-highest age-adjusted death rate from heart disease for the 24 NC counties with established local PCI services during the surveillance period.

6. Denardo, et al. J Transl Sci 2021.





## ➤ Materials and Methods:<sup>6</sup>

- Indications for urgent PCI (N=481):
  - Acute non-ST segment elevation myocardial infarction (47.4%).
  - Unstable angina (41.0%).
  - Acute NYHA Class IV congestive heart failure (11.6%) requiring intravenous diuretic therapy (and in absence of above).
- Antithrombotic therapy (prior to initiation of PCI): Triple antiplatelet (oral aspirin, P2Y<sub>12</sub> inhibitor [dual antiplatelet therapy-DAPT] and shortened infusion of glycoprotein inhibitor; no scheduled anticoagulation).
- Selection of stent design (2<sup>nd</sup> generation drug eluting stent [DES<sub>2</sub>] vs. bare metal stent [BMS]): During earlier surveillance years, based solely on socioeconomic factor of ability of patient to afford ultra-long-term DAPT (due to residual DES<sub>1</sub>-precipitated concerns for very late thrombosis).<sup>7</sup>

7. Palmerini T, et al. J Am Coll Cardiol. 2013.



# ➤ Materials and Methods:<sup>6</sup>

## ➤ Primary outcomes:

- Major adverse cardiac events (MACE; all-cause death, myocardial infarction [MI], urgent target vessel revascularization [TVR]) at 72 hours, 30 days and 180 days following PCI.

## ➤ Secondary outcomes:

- Bleeding events (Bleeding Academic Research Consortium [BARC] criteria) at 72 hours and 30 days.

## ➤ Follow-up:

- Social Services (MSW): Date of discharge (including application of supporting services).
- Cardiology (MD): Date of discharge; 2-3 weeks; 3-6 months (unless active cardiovascular problem).



# ➤ Statistical Analysis:

- Preprocess data:
  - Determine whether patient at socioeconomic boundaries or not, as defined by insurance status; then:
  - Exam three social determinates (race, marital and socioeconomic status).
- Explore causal inferences from data by weighted linear model (gain weights by inverse propensity-score weighting [IPW] method) for treatment and social determinants.
- Develop a machine learning (ML) model and assess the model fairness.
- Propose refined model to improve the fairness.
- Develop R package software for the ML model and the refined model.



## ➤ Results:<sup>6</sup>

- Initial presentation included 88.4% of patients with non-ST elevation acute coronary syndrome and 68.0% with NYHA Class III or IV congestive heart failure; overall 53.2% received  $\geq 1$  DES<sub>2</sub>.
- Technical success rate for the entire PCI cohort (N=481): 99.2%.

N=481	72-hour	30-day	180-day
MACE	12 (2.5%)	21 (4.4%)	69 (14.3%)
Death	0	4 (0.8%)	16 (3.3%)
MI	12 (2.5%)	18 (3.7%)	38 (7.9%)
Q-Wave	0	0	0
Type 4a	12 (2.5%)	16 (3.3%)	38 (7.9%)
Type 4b	0	2 (0.4%)	0
TVR	0	3 (0.6%)	31 (6.5%)
Bleed			N/A
BARC 5	0	1 (0.2%)	--
BARC 3	6 (1.2%)	10 (2.1%)	--
BARC 2	4 (0.8%)	6 (1.2%)	--



## ➤ Results:

- *Pre-process data and exam the three social determinates (race, marital and socioeconomic status).*

Social Determinate	Number (percent) [N=481]
Race	NC=250 (52.0%) C=231 (48.0%)
Marital Status	S=217 (45.1%) NS=264 (54.9%)
Socioeconomic Status	DA=96 (20.0%) A=385 (80.0%)



## ➤ Results:

- *Explore causal inferences from data by IPW method for treatment and social determinants.*
- The Disadvantaged patients had at least 1 more favorable outcome compared with the Advantaged patients spanning the 3 endpoint times:

	ATE_DA_minus_A	P_value
72h MACE	0.0411657	0.3952286
72h death	0.0000000	NaN
72h MI	0.0411657	0.3952286
72h urgent TVR	0.0000000	NaN
72h BARC2	-0.0105115	0.0388524
72h BARC3	-0.0016108	0.8653356
72h BARC5	0.0000000	NaN
30d MACE	0.0322315	0.5064135
30d death	0.0017301	0.8210936
30d MI	0.0328012	0.4992476
30d TVR	-0.0086117	0.0443196
30d BARC2	-0.0138542	0.0128282
30d BARC3	-0.0134623	0.2240537
30d BARC5	0.0084044	0.2021228
180d MACE	0.0323676	0.6072640
180d death	-0.0265838	0.0129064
180d MI	0.0449009	0.4276705
180d TVR	0.0225714	0.5621889



## ➤ Results:

- *Explore causal inferences from data by IPW method for treatment and social determinants.*
- Moreover, the only other disparity was based upon race and marital status: 30d TVR, favoring Non-Caucasian and Single patients:

	ATE_NC_minus_C	P_value
72h MACE	0.0017780	0.8996309
72h death	0.0000000	NaN
72h MI	0.0017780	0.8996309
72h urgent TVR	0.0000000	NaN
72h BARC2	-0.0026508	0.6855321
72h BARC3	0.0156002	0.0876886
72h BARC5	0.0000000	NaN
30d MACE	-0.0167159	0.3573202
30d death	-0.0002756	0.9753495
30d MI	-0.0125999	0.4242964
<b>30d TVR</b>	<b>-0.0154309</b>	<b>0.0331633</b>
30d BARC2	-0.0138287	0.0788711
30d BARC3	0.0196504	0.0657297
30d BARC5	0.0038616	0.2933119
180d MACE	-0.0169797	0.6135164
180d death	-0.0096369	0.5038619
180d MI	-0.0124371	0.6646930
180d TVR	0.0054381	0.7896452

	ATE_S_minus_NS	P_value
72h MACE	0.0101861	0.4172551
72h death	0.0000000	NaN
72h MI	0.0101861	0.4172551
72h urgent TVR	0.0000000	NaN
72h BARC2	0.0188420	0.0539642
72h BARC3	-0.0015294	0.8547172
72h BARC5	0.0000000	NaN
30d MACE	-0.0046601	0.7580040
30d death	-0.0011252	0.8572320
30d MI	-0.0011621	0.9322542
<b>30d TVR</b>	<b>-0.0104957</b>	<b>0.0429565</b>
30d BARC2	0.0080168	0.4368526
30d BARC3	-0.0009165	0.9268124
30d BARC5	0.0029104	0.3088676
180d MACE	0.0065483	0.8135524
180d death	0.0066953	0.6121431
180d MI	-0.0256255	0.2355164
180d TVR	-0.0013567	0.947



## ➤ Results:

- *Develop a machine learning (ML) model and assess the model fairness.*
- Overall, the random forest model with oversampling delivered the most robust result.
- However, that model with oversampling showed unfairness among all three social determinants for certain adverse outcomes.











## ➤ Results:

- *Propose refined model to improve the fairness.*
- Further weighting methods did not provide significant relief from the unfairness.
- An increased sample size is required for a more comprehensive analysis and relief from the unfairness.



## ➤ Results:

- Purdue colleagues nonetheless *developed R Implementation package software* which contains the random forest model, the refined version (and provides a foundation for future software packages):

 extradata	9/10/2023 11:23 PM	File folder
 input_and_output	9/10/2023 11:44 PM	File folder
 main function	9/10/2023 11:04 PM	File folder
 .Rhistory	9/10/2023 11:46 PM	RHISTORY File
 prediction_example	9/10/2023 11:38 PM	R File
 readme	9/10/2023 11:42 PM	Text Document



# ➤ Results:

## ➤ The Microsoft excel input:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1	age	sex	race	Marital Stat	insurance	height (cm)	weight (kg)	BMI (kg/m <sup>2</sup> )	CHF class	Active CP	HTN	DM	lipid	cigarette	FHx	Hx MI	Hx Revasc	Hx PCI	Hx CABG	AICD	valve dz	CCPD	CPI	CerebralV c	PeriphV dz	Lab Reaso	vessel-1	type-1	vessel-2	stent design
2	72	M	C	S	P	178	68.9	21.745917	IV	N	Y	ID	Y	R	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	USA	SEC	B2	Y	D
3																														

## ➤ The R Implementation output:

	predict_result	positive_probability
72h MACE	No	0.102
72h death		
72h MI	No	0.074
72h urgent TVR		
72h BARC2	No	0.05
72h BARC3	No	0.024
72h BARC5		
30d MACE	No	0.132
30d death	No	0.076
30d MI	No	0.194
30d TVR	No	0.068
30d BARC2	No	0.086
30d BARC3	No	0.044
30d BARC5	No	0.22
180d MACE	Yes	0.524
180d death	Yes	0.51
180d MI	Yes	0.516
180d TVR	No	0.158
blank =	insuff data	



## ➤ Conclusions:

### ➤ In this pilot study:

- 72-hour and 30-day urgent PCI outcomes compare favorably with contemporary reports.<sup>6</sup>
- The favorable outcomes in the Disadvantaged, Non-Caucasian and Single patients at 30d and 180d may reflect more comprehensive discharge planning (although an incorrect assignment into socioeconomic group based upon insurance status may be a confounding variable, especially among Medicare patients).
- The remaining 180-day-specific outcomes at first blush do not appear favorable compared with contemporary reports....



## ➤ Conclusions:

- The cause of the less favorable outcomes at 180-days may be the result of:
  - High incidence of active congestive heart failure NYHA Class III-IV at initial presentation (68.0%);<sup>6,8</sup>
  - The overall relatively high use of BMS (46.8%).<sup>7</sup>
  - Decreased frequency of MD follow-up.
- Pursuit of further studies using a much larger sample size (ideally  $N \geq 4000$ ) should provide:
  - A more critical assessment in disparities; and
  - More robust modelling leading to a more robust and useful R package software.



# References:

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