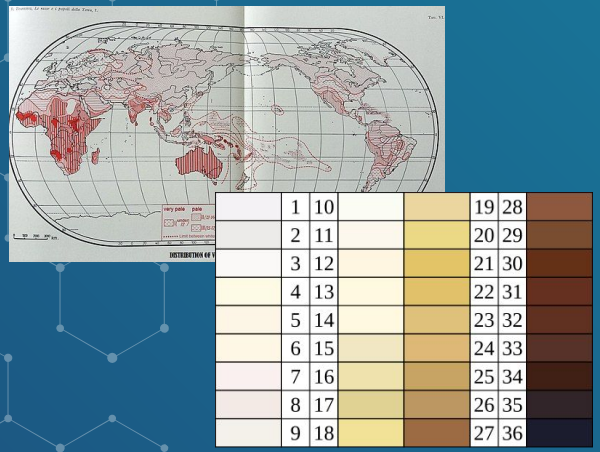
Uncovering bias: Analyzing if skin texture intensity illuminates pulse oximetry discrepancies

ENCoDE dataset

1 Introduction

Discrepancy between pulse oximeter and blood gas analysis measurement in patients with **darker skin tones** has been observed in previous studies. Previous analysis of bias in this data set has been limited to tabular data based on self-reported race, pre-existing skin tone scales, and reflectance colorimetry/spectroscopy.

PRE-EXISTING SKIN TONE SCALES

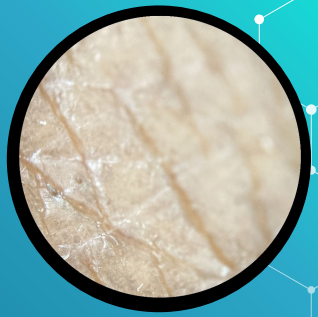


Von Luschan:
used in the 1900s to categorize race based on skin color

Fitzpatrick Skin Type Descriptions*	
Skin Type	**Description**
I	Always burns, never tans
II	Burns easily, tans minimally
III	Burns moderately, tans to light brown
IV	Burns minimally, tans to moderate brown
V	Rarely burns, tans to dark
VI	Never burns, least sensitive to changes

*Adapted from *The Surgeon General's Call to Action to Prevent Skin Cancer*

Fitzpatrick:
based on skin's reaction to sun exposure



Monk:
introduced by Google to reduce bias in computer models

Baseline model: Association between skin tone features and pulse oximeter bias (SpO_2 - SaO_2)

	coef	std err	z	P>|z|	[0.025	
Intercept	223.5947	56.062	3.988	0.000	113	
ADMINISTERED_VISUAL_SCALES_CARD_FITZPATRICKSCALE	−0.5874	1.192	−0.493	0.622	−2	
ADMINISTERED_VISUAL_SCALES_CARD_MONKSKINTONESCALE	−0.9933	0.909	−1.092	0.275	−2	
ADMINISTERED_VISUAL_SCALES_CARD_VONLUSCHANCHROMATICSCALE	0.3179	0.333	0.953	0.340	−0	
DELFIN_SKINCOLORCATCH_CIE_ASTAR	−0.3205	0.610	−0.525	0.599	−1.	
DELFIN_SKINCOLORCATCH_CIE_BSTAR	0.2003	0.077	2.610	0.009	0.0	
DELFIN_SKINCOLORCATCH_CIE_LSTAR	−1.4518	0.636	−2.283	0.022	−2.698	
DELFIN_SKINCOLORCATCH_ERYTHEMAINDEX	−0.0565	0.057	−0.991	0.322	−0.168	
DELFIN_SKINCOLORCATCH_ITA	0.1229	0.109	1.127	0.260	−0.091	0.337
DELFIN_SKINCOLORCATCH_MELANININDEX	−0.0815	0.032	−2.564	0.010	−0.144	−0.019
KONICAMINOLTA_CM700D_CIE_ASTAR	−6.6234	5.526	−1.199	0.231	−17.454	
KONICAMINOLTA_CM700D_CIE_BSTAR	1.1688	6.078	0.192	0.847	−10.743	
KONICAMINOLTA_CM700D_CIE_CSTAR	−7.8344	6.288	−1.246	0.213	−20.1	
KONICAMINOLTA_CM700D_CIE_H	0.3428	0.383	0.895	0.371	−0.	
KONICAMINOLTA_CM700D_CIE_LSTAR	−6.8191	17.416	−0.392	0.695	−40	
KONICAMINOLTA_CM700D_CIE_X	−70.2849	33.466	−2.100	0.036	−135	
KONICAMINOLTA_CM700D_CIE_Y	56.8722	47.548	1.196	0.232	−36	
KONICAMINOLTA_CM700D_CIE_Z	0.7195	5.838	0.123	0.902	−10.	
KONICAMINOLTA_CM700D_HUNTER_ASTAR	20.9237	10.281	2.035	0.042	0.7	
KONICAMINOLTA_CM700D_HUNTER_BSTAR	8.2752	9.195	0.900	0.368	−9.747	
KONICAMINOLTA_CM700D_HUNTER_L	17.9776	17.169	1.047	0.295	−15.674	
KONICAMINOLTA_CM700D_MUNSELL_CSTAR	11.1044	16.124	0.689	0.491	−20.498	42.706
KONICAMINOLTA_CM700D_MUNSELL_VALUE	−74.6664	81.354	−0.918	0.359	−234.118	84.785

2

Hypothesis

We hypothesize that **skin color intensity**, which incorporates visual features such as skin **texture** will provide deeper **insight** into pulse oximeter bias. **Image informatics** related to **intensity** may provide valuable information to extract from the data set.

Main Objective

To determine if skin intensity features is associated with pulse oximetry discrepancies

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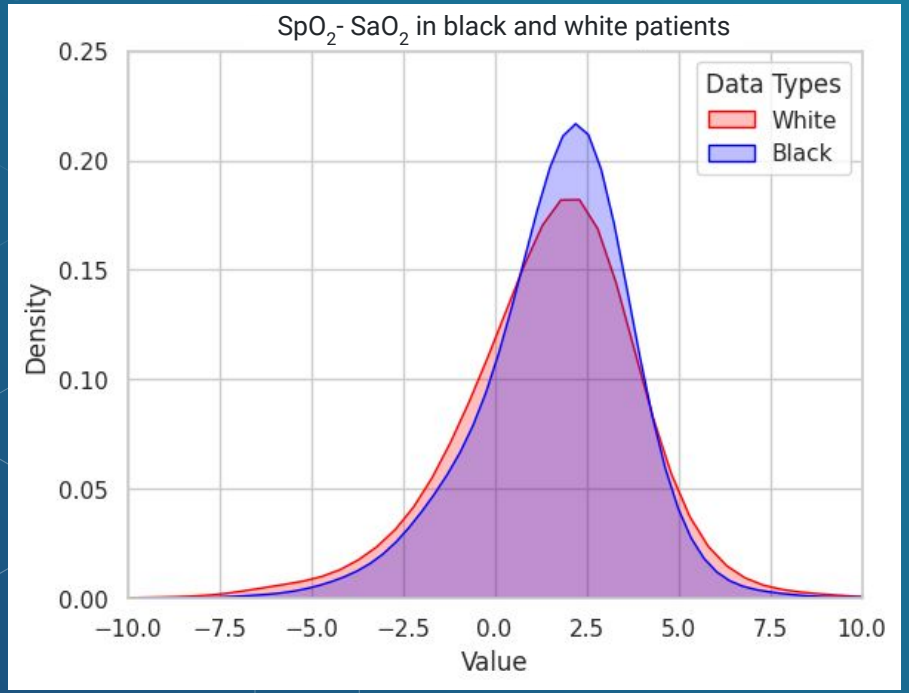
Population study

Understanding the **demographic distribution** of patients in the ENCoDE data set

Table 1: **Racial distribution** of patients, subdivided by gender and ethnicity

			Grouped by race			
		Missing	Overall	Black or African American	Other	White
n			127	57	15	55
gender, n (%)	FEMALE		51 (40.2)	23 (40.4)	3 (20.0)	25 (45.5)
	MALE		76 (59.8)	34 (59.6)	12 (80.0)	30 (54.5)
ethnicity, n (%)	Not Hispanic or Latino		120 (94.5)	57 (100.0)	12 (80.0)	51 (92.7)
	Hispanic or Latino		4 (3.1)		1 (6.7)	3 (5.5)
	Uknown		3 (2.4)		2 (13.3)	1 (1.8)
age, median [Q1,Q3]		0	58.0 [48.0,67.0]	55.0 [47.0,66.0]	57.0 [49.0,62.5]	61.0 [49.0,68.0]

Figure 1: **Oximeter bias** (difference between non-arterial vs arterial oxygen saturation measurements)



Median, [Q1, Q2]:

- Black: -2.0 [2.9,0.7]
- White: -1.8 [2.8,0.3]

Table 2: Oximeter bias was calculated using **simultaneous** measurements of SpO_2 and SaO_2

		Grouped by race			
		Missing	Overall	Black or African American	Other	White
n			1581	816	66	699
gender, n (%)	FEMALE		658 (41.6)	367 (45.0)	7 (10.6)	284 (40.6)
	MALE		923 (58.4)	449 (55.0)	59 (89.4)	415 (59.4)
ethnicity, n (%)	Not Hispanic or Latino		1541 (97.5)	816 (100.0)	60 (90.9)	665 (95.1)
	Hispanic or Latino		23 (1.5)		2 (3.0)	21 (3.0)
	Uknown		17 (1.1)		4 (6.1)	13 (1.9)
SPO2 - SAO2, median [Q1,Q3]		0	1.9 [0.5,2.8]	2.0 [0.7,2.9]	1.9 [0.9,3.0]	1.8 [0.3,2.8]

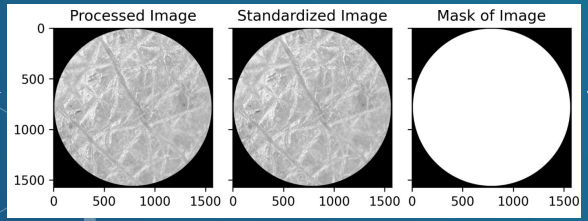
3 Experimental Design

Dataset

person_id	gender	race	ethnicity	SpO2 - SaO2	original_firstorder_10Percentile	original_firstorder_90Percentile
108	FEMALE	White	Not Hispanic or Latino	-3.9	0.674003	0.855117
111	MALE	Black or African American	Not Hispanic or Latino	2.2	0.764251	0.868282
73	MALE	Asian	Not Hispanic or Latino	2.3	0.724418	0.846694
46	MALE	Black or African American	Not Hispanic or Latino	2.0	0.786955	0.872143
78	FEMALE	White	Not Hispanic or Latino	3.0	0.834364	0.895427
23	MALE	Black or African American	Not Hispanic or Latino	3.2	0.687732	0.814108
70	FEMALE	White	Not Hispanic or Latino	1.7	0.709244	0.850005
13	MALE	White	Not Hispanic or Latino	1.3	0.714899	0.859553
2	FEMALE	White	Not Hispanic or Latino	2.3	0.757256	0.863764
106	MALE	White	Not Hispanic or Latino	0.1	0.684629	0.827562

Data Engineering

1. Converting to grayscale
2. Standardization
3. Masking of the images



original_firstorder_10Percentile
0.674003
0.764251
0.724418
0.786955

person_id	gender	race	SpO2 - SaO2	original_firstorder_10Percentile	original_firstorder_90Percentile
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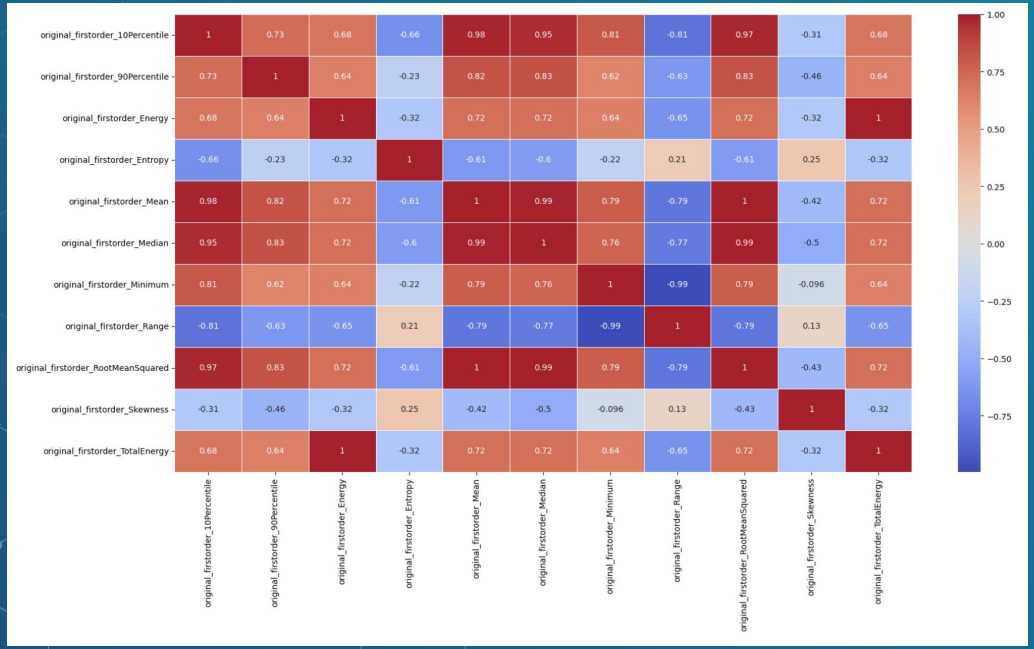
Process

1. Extract radiomics	2. Perform PCA	3. Integrate EHR data with Image features	4. Adjust for environmental factors	5. Association Study
Process the patient images to extract radiomic data, specifically relate to **image intensity**	Perform principal component analysis (PCA) on the data gathered in step 1	Integrate EHR data with image-based features	Adjust the blood pressure and body temperature	Interpret the association between the skin intensity features and arterial oxygen saturation (SaO_2), using multivariate regression model

Extraction of 19 radiomic features



- 10th percentile
- 90th percentile
- Energy
- Entropy
- Interquartile range
- Kurtosis
- Maximum
- Mean absolute deviation
- Mean
- Median
- Minimum
- Range
- Robust mean absolute deviation
- Root mean squared
- Skewness
- Total energy
- Uniformity
- Variance

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Results from Principal Component Analysis

	Pulse ox bias (SpO_2-SaO_2)
Skin texture feature-1	Negative
Skin texture feature-2	Positive
Skin texture feature-3	Positive

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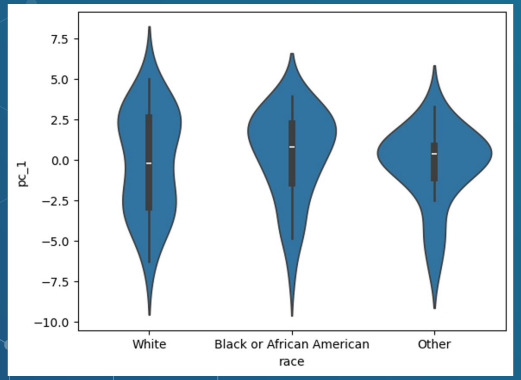
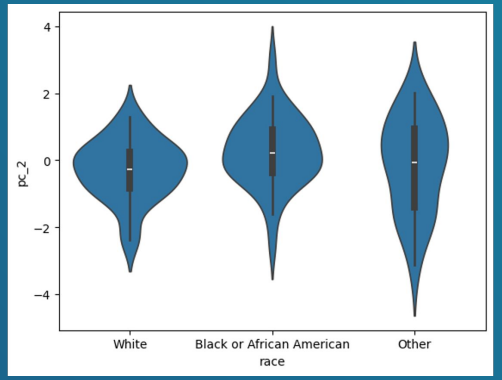
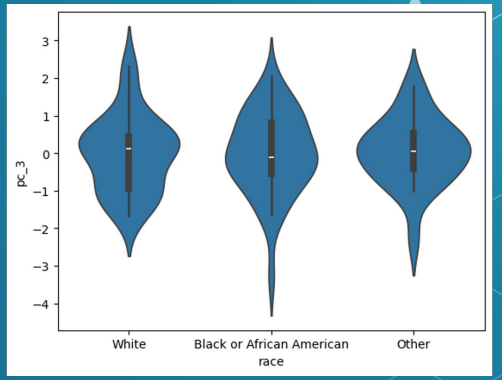
Results from Generalized Estimating Equation Regression

	Pulse Ox bias (SpO_2-SaO_2)
Skin texture feature-1	Negative
Skin texture feature-2	Positive
Skin texture feature-3	Positive

Skin Texture Features visualized based on race and ethnicity







4 Conclusion/Relevance

Novelty

Our proposed method took a in-depth view on patients' **skin texture** from **images**, and found associations between features representing **skin texture** and pulse oximetry **bias**.

Limitations

- Limitation of scope: Families of data related to different image features (ex. GLCM) would provide more insight into tissue texture

- Sample size too small due to primary dataset

THANK YOU!

Team 2:

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Image credits:

https://en.wikipedia.org/wiki/Von_Luschan%27s_chromatic_scale
Sharma AN, Patel BC. Laser Fitzpatrick Skin Type Recommendations. [Updated 2023 Mar 6]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK557626/
https://suttonderm.com/whats-your-type/
https://qz.com/2176270/googles-more-inclusive-skin-tone-scale-could-minimise-internet-racism
https://statnews.com/2022/07/05/pulse-oximeters-accuracy-skin-color/