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Research Article

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Oxygen Saturation Levels among Covid-19 patients Higher in Blacks than Whites on Admission: Real or an artifact of Pulse Oximetry?

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Abstract

Objective: *This study aims to examine whether there exist disparities in oxygen saturation levels upon admission between black and white COVID-19 patients during the pandemic.*

Methods: *A retrospective analysis was conducted on COVID-19-infected patients admitted to the Barnes-Jewish Hospital Health Care Systems in the US, between March 2020 and December 2020. A total of 14,663 patients were identified and after inclusion and exclusion criteria, a finalized sample size of 11,717 patients, self-identified as either black or white, were included in the study. We used linear regression analysis to model the association between oxygen saturation on admission and race, and then used logistic regression for the association between mortality and oxygen saturation on admission, while controlling other factors associated with social and demographic background.*

Results: *Among the cohort of COVID-19 survivors in this study, black patients exhibited a 0.64% higher oxygen saturation level upon admission compared to white patients. Conversely, in the non-survivor group, black patients demonstrated an approximately 1.6% higher oxygen saturation level than white patients. Additionally, a unit increase in oxygen saturation levels on admission decreased mortality by 6%.*

Conclusion: *Our findings suggest that African American patients had higher oxygen saturation levels than white patients upon admission, regardless of their COVID-19 survival outcome. The difference in oxygen saturation levels was more pronounced in the non-survival groups compared to the survival groups. Interestingly, despite their higher oxygen saturation levels on admission, African American patients had a higher mortality rate, though higher oxygen saturation levels on admission serves as a protective factor against mortality. These results provide support for the hypothesis that pulse oximetry may overestimate oxygen saturation in black patients relative to white patients. Therefore, it is crucial to recognize this racial difference in oxygen saturation overestimation when utilizing pulse oximetry for clinical decision-making.*

Keywords: COVID-19, Pulse Oximetry, Public Health, Oxygen Saturation Levels, and Racial Disparity.

1. Background

During the COVID-19 pandemic, numerous aspects of human life have been significantly impacted, including health, social systems, and the economy. Globally, there have been over 600 million cases and 6 million deaths, with over 90 million cases and one million deaths in the United States [1,2]. Despite some initial decline, the devastating effects of Covid-19 continue to persist.

During the pandemic's early stages, hospital resources were overwhelmed, and Covid-19 patients were triaged for admissions based on the severity of their symptoms [3]. Patients who did not have a low oxygen saturation level (SaO2) were sent home and asked to monitor their symptoms using a pulse oximeter [3-5]. Easy access to a pulse oximeter and its usability at home made SaO2 a mainstay for monitoring Covid-19 symptoms severity and a key parameter for determining admission of Covid-19 cases [4]. Unfortunately, research has demonstrated that pulse oximeters may overestimate SaO2 in black and brown people [4, 6-12]. This means that minority groups who were perceived to have less severe Covid-19 symptoms based on their SaO2 may have had, in fact, low SaO2, increasing their odds of mortality. This is particularly alarming given that previous studies have shown that low SaO2 on admission is associated with poorer Covid-19 prognoses, such as Intensive Care Unit (ICU) admission and mortality [13-16].

The objective of this study is to investigate whether there are differences in SaO2 levels on admission between black and white Covid-19 patients during the pandemic. Additionally, the study aims to examine whether the trend in SaO2 levels from March 2020 to December 2020 differed between blacks and whites who died or survived their Covid-19 admission. Furthermore, the study will analyze the association between SaO2 levels on admission and mortality in the US population. To the best of our knowledge, this study is the first to examine the moderating effects of Covid-19 survival outcomes on the overestimation of SaO2 by pulse oximeters in blacks compared to whites. Additionally, it is the first study to investigate the association between SaO2 levels on admission and mortality in the US population. Moreover, our study represents the largest observational study to examine the effects of pulse oximeter overestimation in blacks compared to whites.

Our study's findings could be critical in tailoring treatment plans and reducing potential disparities in care for Covid-19 patients, as well as providing essential insights to inform treatment strategies for future respiratory pandemics.

2. Methods

We conducted a retrospective study using the electronic health record (EHR) data stored on the ADAMS MDClone platform for patients admitted to the Barnes-Jewish Hospital Health Care Systems in the US. We selected 14,663 patients admitted to the hospital from March 2020 to December 2020 with a Covid-19 condition. Race was limited to only those identified as Blacks/African Americans and Whites, and all other races were excluded from the study. The SaO2 on admission was recorded as the first SaO2 for each patient, and the month the SaO2 was measured as the month of first SaO2. We included patients whose first SaO2 was recorded before or within the first 24 hours of their admission. Patients who had oxygen supplement therapy within 24 hours of their first oxygen saturation measurement were excluded. Also, we limited our analysis to pulse oximetry measurements as the source of oxygen saturation data. The final data used in our analysis comprised 11,717 patients (Figure 1). Other demographic characteristics included in the analysis were gender coded as male or female, age, and main language spoken as English or non-English. The comorbidities included in the study were chronic kidney disease, hypertension, chronic heart failure, chronic obstructive pulmonary disease (COPD), and diabetes. These comorbidities were defined as having ever had a diagnosis of these conditions in the patient's medical history, and the presence of these comorbidities was coded as 1 and otherwise 0. Mortality was defined as patients who died during their hospital admission coded as 1 and otherwise 0.

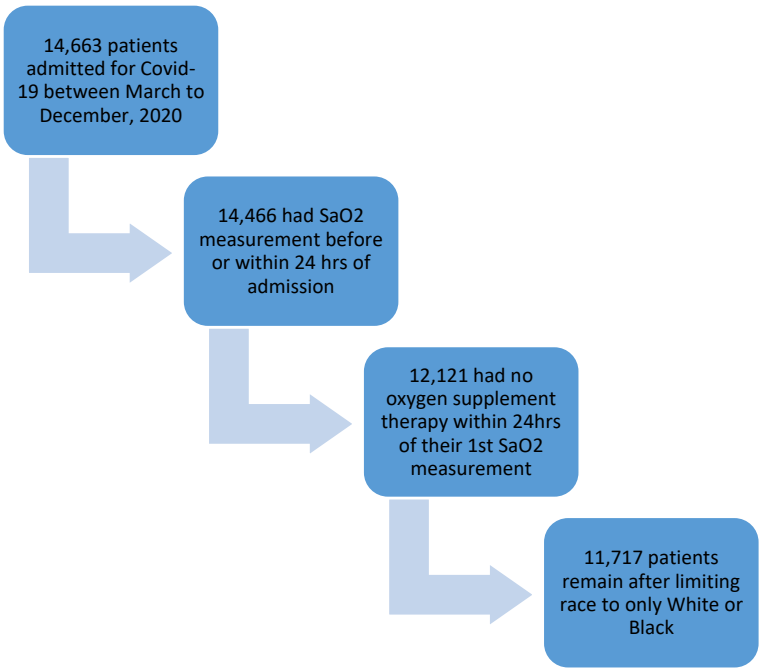

Figure 1: Study Attrition Diagram Showing Our Inclusion and Exclusion Criteria

3. Statistical Analysis

We utilized EHR data stored in the MDClone platform for data management in this study and conducted further statistical analysis, including descriptive and inferential analyses, utilizing R statistical software. Categorical/binary variables were described using chi-square statistics, while continuous variables were described using t-tests. We used linear regression analysis to model the association between SaO2 on admission and race, controlling for other sociodemographic characteristics. We also employed logistic regression to model the association between mortality and SaO2 on admission while controlling for sociodemographic characteristics.

4. Results

The overall mean age of admitted Covid-19 patients was 51 years old, whereas the mean age of those patients who died during admission was 71 years, while those who survived were 51 years old. On admission, the overall mean SaO2 level was

97%, whereas, for those who died, the mean SaO2 was 93.90%, while for those who survived SaO2 was 97.09%. Of the Blacks/African American and White populations included in this study, the whites comprised 60.6%, and those who spoke mainly non-English were 1.3%. The prevalence of chronic kidney disease was 13.2%, hypertension was 49.1%, chronic heart failure was 12.0%, COPD was 11.4%, and diabetes was 24.8% (Table 1).

The mean SaO2 for admitted white patients who died was 93.54% whereas for blacks SaO2 was 94.53%. Among those who died during the Covid-19 admission, the prevalence of chronic kidney disease was 22.1%, hypertension was 55.9%, chronic heart failure was 20.6%, COPD was 18.4%, and diabetes was 29.4% (Table 2).

The mean SaO2 for admitted white patients who survived was 96.71% whereas for blacks SaO2 was 97.67%. However, among those who survived during the Covid-19 admission, the prevalence of chronic kidney disease was 13.1%, hypertension was 49.1%, chronic heart failure was 11.9%, COPD was 11.3%, and diabetes was 24.8% (Table 3).

All other variables held constant; a one unit increase in age increased the odds of mortality by 6%, whereas a 1% increase in SaO2 on admission decreased the odds of mortality by 6%. Also, the odds of mortality among blacks were 1.83 times that among whites admitted to the hospital for Covid-19, controlling for all other variables. In contrast, the odds of mortality among males were 2.22 times that among females. At the same time, those who were mainly non-English speakers had an increased odds of mortality of 3.42 times the odds of mortality among those who were mainly English speakers (Table 4). Among those who died during their Covid-19 admission, SaO2 on admission were 1.6% higher among blacks than whites, controlling for all other variables (Table 5). Among those who survived their Covid-19 admission, SaO2 on admission was 0.64% higher among blacks than whites, controlling for all other variables (Table 6).

There was a persistent higher trend in SaO2 on admission for patients who survived their Covid-19 admission than those who did not from March 2020 to December 2020 (Figure 2). Besides March and August of 2020, where SaO2 on admission were higher among whites than blacks, and June and November of 2020, where SaO2 on admission were roughly the same among whites and blacks, SaO2 on admission were persistently higher among blacks than whites among the patients who did not survive their Covid-19 admission (Figure 3). However, among patients who survived Covid-19 admission, SaO2 on admission among blacks were persistently higher than Whites (Figure 4).

		Mortality		
	Overall	**No**	**Yes**	**P-value**
n	11717	11581	136	
Age (Mean (SD))	50.78 (22.06)	50.54 (22.03)	71.20 (13.57)	<0.001
SaO2 (Mean (SD))	97.05 (3.65)	97.09 (3.60)	93.90 (6.09)	<0.001
Gender = Male (%)	5065 (43.2)	4979 (43.0)	86 (63.2)	<0.001
Race = White (%)	7103 (60.6)	7016 (60.6)	87 (64.0)	0.474
Main language spoken = non-English (%)	156 (1.3)	150 (1.3)	6 (4.4)	0.005
Chronic kidney disease = 1 (%)	1543 (13.2)	1513 (13.1)	30 (22.1)	0.003
Hypertension = 1 (%)	5757 (49.1)	5681 (49.1)	76 (55.9)	0.134
Chronic heart failure = 1 (%)	1408 (12.0)	1380 (11.9)	28 (20.6)	0.003
COPD = 1 (%)	1337 (11.4)	1312 (11.3)	25 (18.4)	0.015
Diabetes = 1 (%)	2907 (24.8)	2867 (24.8)	40 (29.4)	0.25

Table 1: Characteristics of Admitted Covid-19 Patients Between March and December 2020.

		Race		
	Overall	**White**	**Black/African American**	**P-value**
n	136	87	49	
Age (Mean (SD))	71.20 (13.57)	72.45 (12.79)	68.98 (14.73)	0.153
SaO2 (Mean (SD))	93.90 (6.09)	93.54 (6.36)	94.53 (5.58)	0.364
Gender = Male (%)	86 (63.2)	57 (65.5)	29 (59.2)	0.582
Main language spoken = non-English (%)	6 (4.4)	5 (5.7)	1 (2.0)	0.565
Chronic kidney disease = 1 (%)	30 (22.1)	13 (14.9)	17 (34.7)	0.014
Hypertension = 1 (%)	76 (55.9)	41 (47.1)	35 (71.4)	0.01
Chronic heart failure = 1 (%)	28 (20.6)	16 (18.4)	12 (24.5)	0.533

COPD = 1 (%)	25 (18.4)	16 (18.4)	9 (18.4)	1
Diabetes = 1 (%)	40 (29.4)	19 (21.8)	21 (42.9)	0.017

Table 2: Characteristics of admitted Covid-19 patients who died between March and December 2020 stratified by Race.

		Race		
	Overall	**White**	**Black/African American**	**P-value**
n	11581	7016	4565	
Age (Mean (SD))	50.54 (22.03)	54.02 (22.41)	45.19 (20.31)	<0.001
SaO2 (Mean (SD))	97.09 (3.60)	96.71 (3.75)	97.67 (3.28)	<0.001
Gender = Male (%)	4979 (43.0)	3124 (44.5)	1855 (40.6)	<0.001
Main language spoken = non-English (%)	150 (1.3)	127 (1.8)	23 (0.5)	<0.001
Chronic kidney disease = 1 (%)	1513 (13.1)	866 (12.3)	647 (14.2)	0.005
Hypertension = 1 (%)	5681 (49.1)	3400 (48.5)	2281 (50.0)	0.117
Chronic heart failure = 1 (%)	1380 (11.9)	826 (11.8)	554 (12.1)	0.576
COPD = 1 (%)	1312 (11.3)	865 (12.3)	447 (9.8)	<0.001
Diabetes = 1 (%)	2867 (24.8)	1620 (23.1)	1247 (27.3)	<0.001

Table 3: Characteristics of admitted Covid-19 patients who survived between March and December 2020 stratified by Race.

Characteristic	**OR**	**95% CI**	**p-value**
Age	1.06	1.05, 1.08	<0.001
SaO2	0.94	0.93, 0.96	<0.001
Gender			
Female	—	—	
Male	2.22	1.55, 3.19	<0.001
Race			
White	—	—	
Black or African American	1.83	1.25, 2.67	0.002
Main language spoken			
English	—	—	
non-English	3.42	1.28, 7.65	0.006
Chronic kidney disease	0.97	0.59, 1.55	0.9
Hypertension	0.42	0.28, 0.64	<0.001
Chronic kidney disease	1.16	0.70, 1.89	0.6
COPD	1.06	0.65, 1.69	0.8
Diabetes	0.87	0.56, 1.32	0.5

OR = Odds Ratio, CI = Confidence Interval

Table 4: Association of mortality with first SaO2 measurement controlling for sociodemographic and comorbidities.

Characteristic	**Beta**	**95% CI**	**p-value**
Race			
White	—	—	
Black or African American	1.6	-0.77, 3.9	0.2
Age	0.07	-0.02, 0.15	0.14
Gender			
Female	—	—	

Male	1.5	-0.72, 3.7	0.2
Main language spoken			
English	—	—	
non-English	2	-3.1, 7.2	0.4
Chronic kidney disease	2.3	-0.73, 5.4	0.14
Hypertension	-2.6	-5.4, 0.17	0.065
Chronic heart failure	0.72	-2.6, 4.0	0.7
COPD	-0.49	-3.4, 2.4	0.7
Diabetes	-0.24	-2.8, 2.3	0.9

CI = Confidence Interval

Table 5: Association of first SaO2 on admission with race controlling for sociodemographic and comorbidities among Covid-19 patients who died.

Characteristic	Beta	95% CI	p-value
Race			
White	—	—	
Black or African American	0.64	0.51, 0.78	<0.001
Age	-0.03	-0.04, -0.03	<0.001
Gender			
Female	—	—	
Male	-0.47	-0.60, -0.34	<0.001
Main language spoken			
English	—	—	
non-English	-0.66	-1.2, -0.10	0.021
Chronic kidney disease	0.05	-0.17, 0.27	0.6
Hypertension	-0.14	-0.30, 0.03	0.1
Chronic heart failure	-0.05	-0.28, 0.17	0.6
COPD	-0.39	-0.60, -0.17	<0.001
Diabetes	-0.18	-0.35, -0.01	0.041

CI = Confidence Interval

Table 6: Association of first SaO2 measurement on admission with race controlling for sociodemographic and comorbidities among Covid-19 patients who survived.

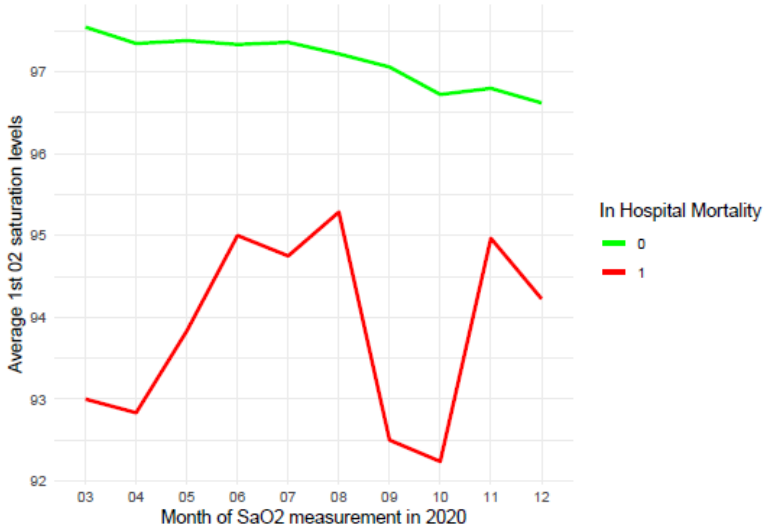

Figure 2: Trend in first Oxygen Saturation Levels Over Time

Figure 3: Trend in First Oxygen Saturation Levels Over Time Among Those Who Died Stratified by Race.

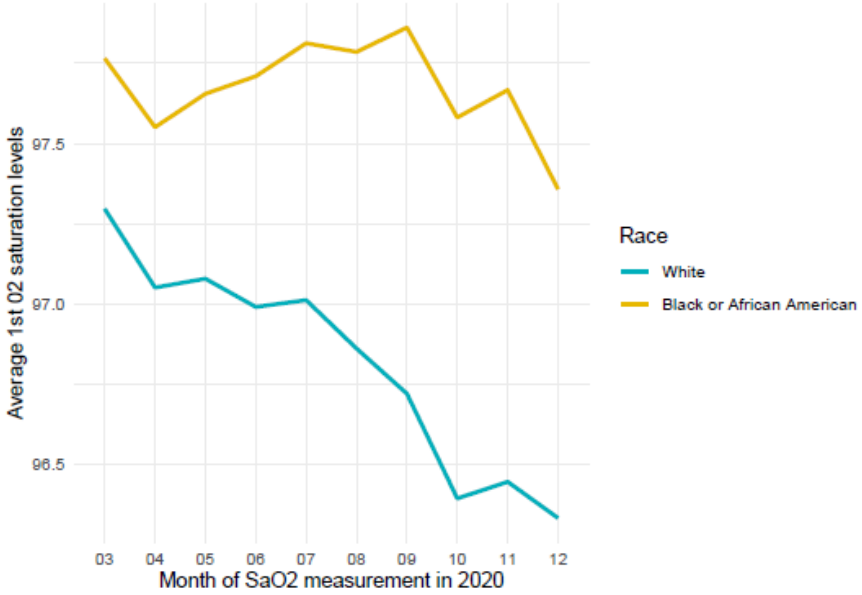

Figure 4: Trend in First Oxygen Saturation Levels Over Time Among Admitted Covid-19 Patients Who Survived Stratified By Race.

5. Discussion

SaO2 measurements upon admission have been strongly associated with COVID-19 outcomes, including mortality and ICU admission [13-16]. Consistent with previous studies, our study found a significant association between SaO2 on admission and mortality, with a one-unit increase in SaO2 decreasing mortality by 6% [13-16]. This highlights the importance of examining if different racial groups exhibit varying SaO2 levels upon admission, as it could potentially impact their survival outcomes.

In our study, we observed that, on average, black patients had higher SaO2 levels upon admission than white patients, despite facing increased odds of mortality due to COVID-19. For instance, black patients who died during their COVID-19 admission had an average SaO2 of 94.53% upon admission, while white patients had an average SaO2 of 93.54%. Controlling for other sociodemographic factors, we found a 1.6% higher SaO2 upon admission among black patients than white patients in the non-survivor population, and a 0.64% higher SaO2 among black patients in the survivor population. These findings prompted us to investigate if the differences in SaO2 levels upon admission between black and white patients were real or if they were an artifact caused by an overestimation of SaO2 in black patients

by pulse oximetry.

Our study concluded that the differences in SaO2 levels upon admission between black and white patients were indeed artifactual, resulting from an overestimation of SaO2 by pulse oximetry in black patients compared to white patients. These findings align with other studies reporting pulse oximeters to overestimate SaO2 in individuals with dark skin [4, 6-12]. Furthermore, our study provided robust evidence supporting this fact, particularly through a trend analysis of SaO2 levels during the early months of the pandemic. This analysis consistently showed higher SaO2 levels among black patients than white patients in COVID-19 patients who survived, and predominantly higher SaO2 levels among black patients in those who did not survive. The phenomenon where oxygen saturation is falsely elevated on pulse oximetry reading in black patients due to dark skin pigments is called the occult hypoxemia [17]. Clinicians should consider this phenomenon when providing care to racially diverse patient populations and to potentially adjust for this overestimation in situations where there is no opportunity to obtain an arterial blood gas measurement in patients with dark skin tones.

The presence of occult hypoxia may have contributed to the health disparities and systemic inequalities experienced by black patients [18]. Developing the next generation of portable oxygen monitors that overcome the confounding effect of skin pigmentation would be a significant step towards achieving health equity. Additionally, in addition to monitoring equipment and arterial blood gas, a set of laboratory values, including leukocytosis, neutrophilia, lymphocytopenia, and CRP (>27.5 mg/L), could be used to predict the development of hypoxia in COVID-19 infection [19].

In 2021, Dr. Fawzy and colleagues conducted a retrospective chart review study on 2,907 COVID-19 patients evaluated at the Emergency Department or hospitalized in Maryland, United States, to investigate systematic racial bias in pulse oximetry readings. Their study revealed that oxygen saturation among black patients was 1.2% higher than white patients [20]. This finding is consistent with our study, where oxygen saturation was higher in black patient groups by 0.64% among survivors and 1.6% among non-survivors. Our study is unique in that we divided the study group into survivor and non-survivor groups. The difference in pulse oximetry reading was twice more noticeable in the non-survivor groups, indicating the moderating effects of covid-19 survival outcomes on pulse oximeter's overestimation of SaO2 in blacks as compared to whites. This finding suggests that the discrepancy in SaO2 overestimation by pulse oximeters may be exacerbated in critically ill patients, which, if not accounted for, can have negative implications for the survival outcomes of black individuals.

From 2020 to 2021, Dr. Sudat's research team in North California compared the accuracy of pulse oximetry between Caucasian and African American population in the setting of COVID-19 infection [6]. The study data came from 1,699 of African American patients and 7,036 of Caucasian patients with total population size of 8,725 individuals. The mean oxygen saturation among black patient group was 0.8% higher than white patient group [6]. This study outcome suggests overestimation of the oxygen pulse oximetry monitors in Black patients. Thus, it agrees with the result of Fawzy's study and our current study. Our study included 11,717 patients, nearly four times larger than Fawzy's study and 1.34 times that of Sudat's study. To the best of our knowledge, our study represents the largest observational study in terms of population size.

Our secondary outcome is on the association between SaO2 on admission and the odds of mortality from COVID-19 for hospitalized adult patients. This association was both clinically and statistically significant with a 1% increase in SaO2 on admission correlating to a 6% decrease in the odds of mortality. There is no previous research published on this relationship in the United States patient population. In 2020, Dr. Mukhtar and his colleagues in Egypt looked at this relationship using a database consisting of 72 patients under ICU level of care. Their study showed SaO2 was positively associated with hospital mortality (OR [95% CI]: 0.94 [0.91–0.97]) [21]. In the same year, Dr. Mejia's study on 369 COVID-19 patients in Peru revealed the SaO2 values of less than 80% had a positive correlation with mortality (OR [95% CI]: 7.74 [4.54-13.19]) [14]. The results of previous studies are consistent with our findings, which identified the association between hypoxia and COVID-19 mortality.

It is worth noting that our study contributes valuable insights to the existing literature as it is the first to evaluate the moderating effects of COVID-19 survival outcomes on pulse oximeters' overestimation of SaO2. Furthermore, it is the only study to evaluate the relationship between SaO2 measurements on admission and mortality within the US population, as well as the largest observational study to examine these relationships.

6. Limitation

A limitation of our study is that we only considered patients who identified as Blacks/African Americans and Whites, limiting the range of skin tones studied to those with a contrast between dark and light skin. As such, our findings cannot be generalized to other races whose skin tones may vary widely, and further research is necessary to explore the effect of pulse oximetry overestimation on different skin tones.

Additionally, our study assumes that patients who identified as Blacks/African Americans have dark skin tones. However, this is not always the case in reality, and further research is needed to accurately determine skin tones of patients and their impact on SaO2 measurements. Additionally, the lack of a clear and consistent pattern of higher SaO2 levels in blacks compared to whites among patients who did not survive may be attributed to the lower sample size among patients who did not survive.

7. Conclusion

Our findings have significant implications for clinical decision-making concerning the care, treatment, and clinical assessment of patients, not only those with Covid-19. By recognizing that pulse oximetry overestimates SaO2 in black patients,

healthcare professionals can adjust for the overestimation effect when making clinical assessments or deciding on the care and treatment of black patients based on SaO2 levels.

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