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RESEARCH

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The impact of health disparities on peripheral vascular access outcomes in hospitalized patients: an observational study

Nicholas Mielke[1,2], Charlotte O'Sullivan[1], Yuying Xing[3] and Amit Bahl[4*]

Abstract

Background Placement of peripheral intravenous catheters (PIVC) is a routine procedure in hospital settings. The primary objective is to explore the relationship between healthcare inequities and PIVC outcomes.

Methods This study was a multicenter, observational analysis of adults with PIVC access established in the emergency department requiring inpatient admission between January 1st, 2021, and January 31st, 2023, in metro Detroit, Michigan, United States. Epidemiological, demographic, therapeutic, clinical, and outcomes data were collected. Health disparities were defined by the National Institute on Minority Health and Health Disparities. The primary outcome was the proportion of PIVC dwell time to hospitalization length of stay, expressed as the proportion of dwell time (hours) to hospital stay (hours) x 100%. Multivariable linear regression and a machine learning model were used for variable selection. Subsequently, a multivariate linear regression analysis was utilized to adjust for confounders and best estimate the true effect of each variable.

Results Between January 1st, 2021, and January 31st, 2023, our study analyzed 144,524 ED encounters, with an average patient age of 65.7 years and 53.4% female. Racial demographics showed 67.2% White, and 27.0% Black, with the remaining identifying as Asian, American Indian Alaska Native, or other races. The median proportion of PIVC dwell time to hospital length of stay was 0.88, with individuals identifying as Asian having the highest ratio (0.94) and Black individuals the lowest (0.82). Black females had a median dwell time to stay ratio of 0.76, significantly lower than White males at 0.93 ($p < 0.001$). After controlling for confounder variables, a multivariable linear regression demonstrated that Black males and White males had a 10.0% and 19.6% greater proportion of dwell to stay, respectively, compared to Black females ($p < 0.001$).

Conclusions Black females face the highest risk of compromised PIVC functionality, resulting in approximately one full day of less reliable PIVC access than White males. To comprehensively address and rectify these disparities, further research is imperative to improve understanding of the clinical impact of healthcare inequities on PIVC access. Moreover, it is essential to formulate effective strategies to mitigate these disparities and ensure equitable healthcare outcomes for all individuals.

*Correspondence:
Amit Bahl
ambahl79@gmail.com
Full list of author information is available at the end of the article

Keywords Peripheral intravenous catheters, Healthcare inequities, Hospitalized patients, Racial disparities, IV functionality

Introduction

Peripheral intravenous catheter (PIVC) placement is the most common invasive procedure performed in healthcare, with an estimated 90% of hospitalized patients requiring PIVC access during their stay. Globally, this equates to around two billion PIVCs used annually [1–3]. Despite its routine nature, PIVCs have a surprisingly high failure rate, with studies reporting that 36–63% of catheters fail due to various complications, including infiltration, occlusion, phlebitis, dislodgment, and infection [2–6]. These failures cause immediate patient discomfort and increased clinical workload and have broader implications, such as prolonged hospital stays and delays in critical treatments [2].

The factors contributing to PIVC failure are multifaceted, involving clinical presentation, patient anatomy, provider skill level, and procedural circumstances. However, one significant determinant that has not been comprehensively addressed within the literature is healthcare inequities. These inequities—which include disparities based on race, ethnicity, gender, and socioeconomic status—permeate the US healthcare system, adversely influencing outcomes across a spectrum of conditions and interventions [7, 8]. It is well-documented that such disparities contribute to differential rates of chronic diseases and mortality, yet their impact on PIVC placement and outcomes has not been similarly scrutinized.

The broad scope of PIVC usage, compounded by its substantial failure rates and complications, warrants a focused examination of how healthcare inequities influence its outcomes. If particular populations are disproportionately affected by PIVC complications due to systemic inequities, then targeted interventions are critically needed. It is important to delve into the intricacies of PIVC-related inequality, the most common of all medical procedures, and to develop tailored strategies to mitigate these disparities.

Our research aims to explore the relationship between healthcare inequities and PIVC outcomes. Specifically, we seek to identify the demographic and socioeconomic factors correlating with impaired PIVC functionality and complications. By determining which patient groups are most affected by these inequities, we can move toward a healthcare practice that is more equitable and more effective in its most routine procedures.

Methods

Study design, setting, and participants

This multicenter observational investigation utilized electronic health record (EHR) data. The study included all patients over age 18 who presented to one of four Corewell Health System emergency departments (William Beaumont University Hospital, Troy, Farmington Hills, or Grosse Pointe) between January 1st, 2021, and January 31st, 2023, that underwent PIVC placement during their emergency room encounter. Epidemiological, demographic, therapeutic, clinical, and outcomes data were collected for each encounter. Participants were excluded if PIVC placement documentation was missing (Fig. 1). The study was approved by the local Institutional Review Board. Given the retrospective nature of the study, the need for written informed consent was waived.

Study definitions

Health disparities were defined by the National Institute on Minority Health and Health Disparities (NIMHD) as a health difference based on one or more health outcomes that adversely affect disadvantaged populations [9]. This includes racial and ethnic minority groups, people with lower socioeconomic status, underserved rural communities, and sexual and gender minority groups. Ethnicity was self-reported and categorized as Hispanic/Latino, non-Hispanic/Latino, or non-applicable (N/A). Individual socioeconomic status data were not collected at the study site. As a proxy, patient's home zip codes were queried within the Agency for Healthcare Research and Quality (AHRQ) 2020 Social Determinants of Health Database, which provides zip code-level data on per capita income and the percentage of people with an income-to-poverty ratio below 1.00 [10]. Next, a patient's home zip code was used to determine if they reside in an underserved rural community per the 2010 U.S. Department of Agriculture Economic Research Service Rural-Urban Commuting Area Codes definition [11].

Additional health disparity data were collected per the Healthy People 2030 Leading Health Indicators, which is an initiative by the U.S. Department of Health and Human Services Office of Disease Prevention and Health Promotion [12]. These variables included history of drug overdose, exposure to unhealthy air, annual influenza vaccination, persons with medical insurance less than 65 years old, and history of suicide attempt. Exposure to unhealthy air was defined by the United States Environmental Protection Agency (EPA) 2022 Air Quality Index (AQI) [13]. The median AQI based on the patient's home zip code was categorized by level of health concern per the EPA definition [14].

Patient data from the past two years, excluding the index encounter, was reviewed for all International Classification of Diseases 10 (ICD10) codes in their medical

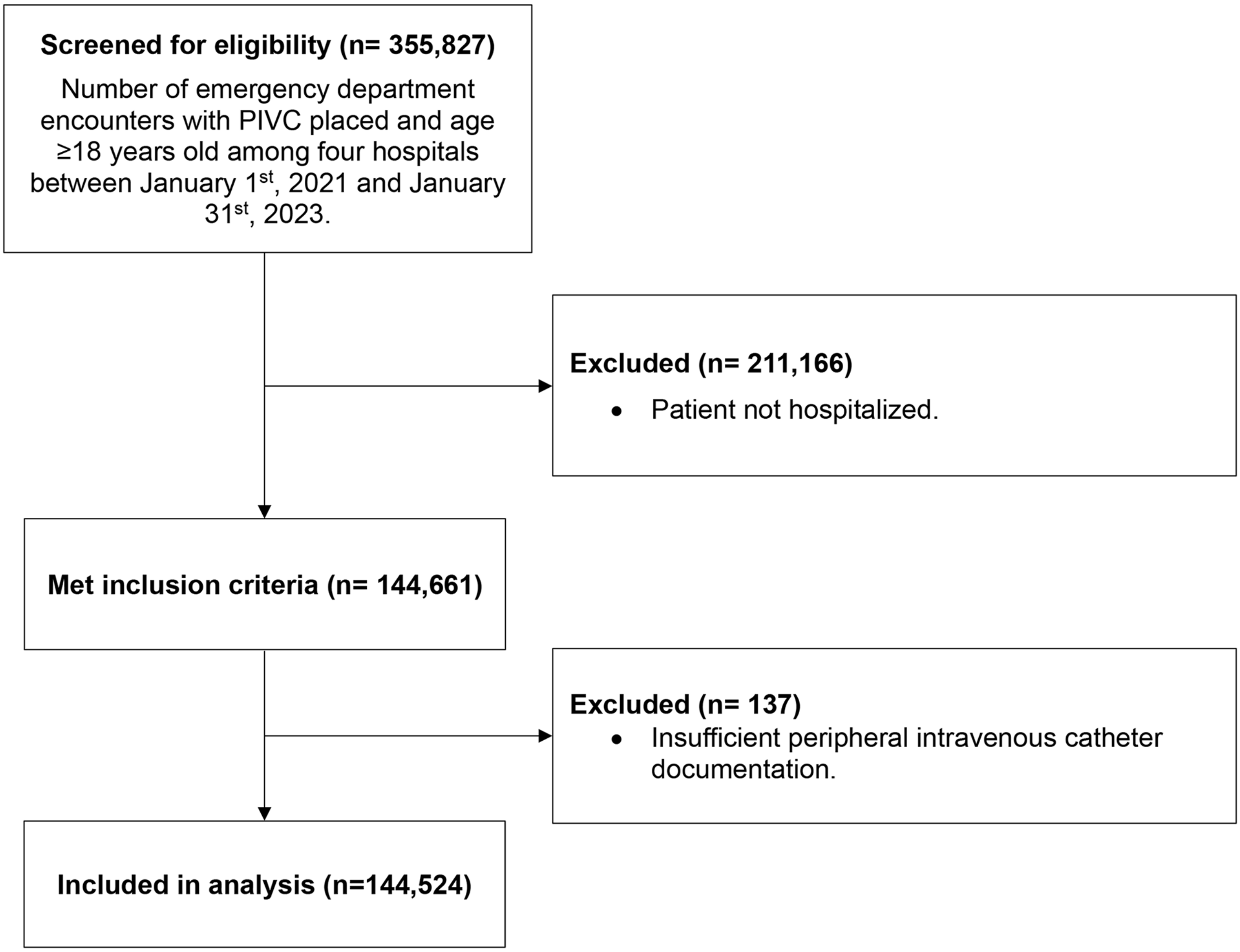

Fig. 1 Flow figure of inclusion and exclusion criteria. Flow figure demonstrating total number encounters screened for eligibility, number of excluded encounters, and final number of encounters included in the analysis

history, problem list, and discharge diagnoses. A history of drug overdose was flagged if an encounter included the "All Drug Overdose" ICD10 code, as defined by the CDC National Center for Health Statistics [15]. A history of suicide attempt was marked as "yes" if the ICD10 code T14.91 was present. Comorbidities were evaluated using the Charlson Comorbidity Index [16–18]. Body mass index (BMI) was classified as underweight, healthy weight, overweight, or obese following the Centers for Disease Control and Prevention's (CDC) criteria [19].

Self-reported tobacco use, alcohol use, and illicit substance use were standardized questions used by clinicians involved in the patient's care. Although the state of Michigan passed Proposal 1 in 2018, which effectively legalized the use of marijuana for adults 21 years and older, the United States Drug Enforcement Administration still considers cannabis a Schedule I drug and, therefore, illegal under federal law through the Controlled Substances Act [20, 21]. Emergency severity index (ESI) assists EDs with stratifying the urgency of a patient's presenting symptoms [22]. Intravenous medications were categorized as irritants or vesicants as defined by the Infusion Nurses Society Standards of Practice [23].

Data sources/measurement

Data and variables were abstracted from the Qlik PIVC dashboard, which integrates directly with the institution's electronic health record system, Epic Systems (Verona, Wisconsin, United States).

Outcomes and measurements

The primary outcome was the proportion of PIVC dwell time to hospitalization length of stay, expressed as the proportion of dwell time (hours) to hospital stay (hours) x 100%. Secondary outcomes included PIVC dwell time, time from ED arrival to PIVC placement, and reason for removal of the PIVC.

Statistical analysis

Descriptive analysis was used to summarize patient characteristics. Continuous variables were summarized using means, standard deviations, medians, and interquartile ranges. Categorical variables were presented as frequencies and percentages. The ANOVA test was used to compare continuous variables among groups, while the Chi-square test was employed for categorical variables.

Multivariable linear regression was employed to assess the relationships between demographic and socio-economic variables and the proportion of dwell time to hospital length of stay. This analysis controlled for confounding variables identified through clinical knowledge, including the Charlson Comorbidity Index, use of an intravenous vesicant, insertion method, ESI, PIVC location, orientation, and gauge size. Demographic and socio-economic variables, such as age, gender, BMI, percentage of the population with income to poverty, community, history of drug overdose, and history of suicide attempt, were considered. Variables with missing values exceeding 5% were not considered.

To select the most relevant variables for the outcome, we first employed multivariable linear regression to quantify the relationships between each demographic and socio-economic variable and the outcome while controlling for identified confounding variables. Variables demonstrating significance at a 15% level were selected for further analysis. Subsequently, a random forest (RF) classification with default parameters was utilized, capturing complex interactions among predictors [24]. Variables with lower importance from the RF, such as history of drug overdose and population size of home zip code, were excluded. The variable that reported the patient's home zip codes' income to poverty ratio was also excluded due to the multicollinearity with race. The remaining demographic variables, along with the confounding variables, were used in the final multivariable linear regression with sex and race interaction. Only white and black race categories were kept for the final analysis due to their higher representation in the dataset.

The proportion of dwell time to hospital length of stay was transformed into LN due to left skewness. The transformed results were then back-transformed to percentages for reporting. Results were reported with corresponding 95% confidence intervals (CI) and p-values. All statistical tests were two-sided, and significance was determined using a p-value threshold of less than 0.05. The analysis was conducted using R-4.3.1, provided by the R Foundation for Statistical Computing.

Results

Between January 1st, 2021, and January 31st, 2023, 144,524 ED encounters met inclusion criteria. The average age was 65.7 years, and 53.4% were female. 97,069 (67.2%) encounters identified as White, 38,956 (27.0%) identified as Black, 2,908 (2.0%) identified as Asian, 484 (0.3%) identified as American Indian or Alaska Native, and 5,107 (3.5%) identified as a race other than the four predominant categories. Home zip codes demonstrated 98.8% (n=142,797) of the cohort lived in a metropolitan area, 18.5% (n=26,768) resided in a zip code with ≥20% of the population living with an income-to-poverty ratio under 1.00, and 26.0% (n=36,724) were categorized as living in a zip code with moderate air quality. 98.8% of the cohort<65 years old had active health insurance (Table 1).

Most encounters occurred at a large, academic, tertiary care center (n=55,362; 38.3%). Individuals identifying as Black presented to a community (250+bed) hospital (n=20,970; 53.8%) more often than any other race ($p<0.001$). PIVCs were mostly commonly 20 gauge (n=101,637; 75.0%), placed in the antecubital fossa (n=81,882; 56.7%), and inserted using the traditional palpation technique (n=137,105; 94.9%). The median proportion of PIVC dwell time to hospital length of stay for the entire cohort was 0.88; individuals identifying as Asian had the highest value (0.94), while individuals identifying as Black had the lowest value (0.82). The median PIVC dwell time was 68.3 h (Table 2).

In an analysis of White and Black race, which comprised 94.2% of the cohort, 36.9% were White females, 34.4% were White males, 16.7% were Black females, and 12.0% were Black males. The median length of stay was 95.5 h, and 94.8% of the PIVCs were placed using the traditional palpation technique. The median proportion of PIVC dwell time to hospital length of stay among Black females was 0.76, compared to White males at 0.93 ($p<0.001$). Failure as the reason for PIVC removal was highest in Black females (39.5%), followed by White females (37.5%), Black males (33.7%), and White males (31.2%; $p<0.001$) (supplementary Table 1).

A multivariable linear regression analysis with confounding variables (supplementary Table 2) for the outcome of the proportion of PIVC dwell time to hospital length of stay was used in conjunction with a random forest model (supplementary Fig. 1) to determine appropriate variables for the multivariable linear regression analysis and the variables' contribution to the models' predictive accuracy, respectively. Multivariable linear regression with sex and race interaction variable analysis of the proportion of dwell time to hospital length of stay demonstrated that compared to Black females, Black males had a 10.0% greater proportion of dwell to stay ($p<0.001$), and White males were 19.6% greater ($p<0.001$) (Fig. 2; Table 3).

Table 1 Demographics, Health Disparities, Health indicators, and medical history of hospitalized encounters stratified by race

Variables‡	All	American Indian or Alaska Native	Asian	Black or African American	White or Caucasian	Other	p value
n	144,524	484 (0.3%)	2,908 (2.0%)	38,956 (27.0%)	97,069 (67.2%)	5,107 (3.5%)	
Demographics							
Age, category							< 0.001
18–64	61,003 (42.2%)	242 (50.0%)	1304 (44.8%)	21,427 (55.0%)	35,683 (36.8%)	2347 (46.0%)	
65–80	50,188 (34.7%)	142 (29.3%)	985 (33.9%)	12,090 (31.0%)	35,303 (36.4%)	1668 (32.7%)	
> 80	33,333 (23.1%)	100 (20.7%)	619 (21.3%)	5439 (14.0%)	26,083 (26.9%)	1092 (21.4%)	
Age, years							< 0.001
Mean	65.7 (18.3)	62.8 (17.9)	63.9 (19.0)	60.3 (18.4)	68.0 (17.8)	63.7 (19.1)	
Median	68.0 (54.0, 80.0)	64.5 (50.0, 77.0)	68.0(51.0,78.0)	62.0 (47.0, 74.0)	71.0 (58.0, 81.0)	66.0 (51.0, 79.0)	
Sex							< 0.001
Female	77,137 (53.4%)	273 (56.4%)	1461 (50.2%)	22,694 (58.3%)	50,238 (51.8%)	2471 (48.4%)	
Male	67,387 (46.6%)	211 (43.6%)	1447 (49.8%)	16,262 (41.7%)	46,831 (48.2%)	2636 (51.6%)	
Body mass index, kg/m^2							< 0.001
Mean	29.2 (8.3)	30.2 (8.9)	25.4 (5.9)	30.5 (9.5)	28.76 (7.8)	28.98 (7.15)	
Median	27.7 (23.5, 33.2)	28.9 (23.8, 34.8)	24.6(21.6,28.2)	28.8 (23.8, 35.3)	27.4 (23.5, 32.5)	27.9 (24.1, 32.5)	
Not documented	253	0	9	62	162	20	
Body mass index, category							< 0.001
Underweight	6681 (4.6%)	22 (4.5%)	220 (7.6%)	1957 (5.0%)	4333 (4.5%)	149 (2.9%)	
Healthy weight	42,016 (29.1%)	122 (25.2%)	1349 (46.5%)	10,093 (26.0%)	29,050 (30.0%)	1402 (27.6%)	
Overweight	41,003 (28.4%)	137 (28.3%)	864 (29.8%)	9556 (24.6%)	28,812 (29.7%)	1634 (32.1%)	
Obesity	54,571 (37.8%)	203 (41.9%)	466 (16.1%)	17,288 (44.4%)	34,712 (35.8%)	1902 (37.4%)	
Not documented	253	0	9	62	162	20	
NIMHD Health Disparities							
Ethnicity							< 0.001
Hispanic/Latino	1534 (1.1%)	11 (2.3%)	23 (0.8%)	104 (0.3%)	931 (1.0%)	465 (9.1%)	
Non Hispanic/Latino	131,394 (90.9%)	406 (83.9%)	2342 (80.5%)	37,751 (96.9%)	88,947 (91.6%)	1948 (38.1%)	
Not documented	11,596 (8.0%)	67 (13.8%)	543 (18.7%)	1101 (2.8%)	7191 (7.4%)	2694 (52.8%)	
Percentage of population with an income to poverty ratio under 1.00							< 0.001
0–19%	117,657 (81.5%)	407 (84.1%)	2626 (90.4%)	18,516 (47.6%)	91,656 (94.5%)	4452 (87.3%)	
20–39%	25,206 (17.5%)	67 (13.8%)	178 (6.1%)	19,472 (50.0%)	4980 (5.1%)	509 (10.0%)	
40–59%	1561 (1.1%)	10 (2.1%)	101 (3.5%)	932 (2.4%)	381 (0.4%)	137 (2.7%)	
60–79%	1 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.0%)	0 (0.0%)	
Not documented	99	0	3	36	51	9	
Population Size of Home Zip Code							< 0.001
Metropolitan	142,797 (98.8%)	473 (97.7%)	2899 (99.8%)	38,917 (99.9%)	95,472 (98.4%)	5036 (98.8%)	
Micropolitan	515 (0.4%)	6 (1.2%)	5 (0.2%)	20 (0.1%)	469 (0.5%)	15 (0.3%)	
Rural	1151 (0.8%)	5 (1.0%)	1 (0.0%)	16 (0.0%)	1082 (1.1%)	47 (0.9%)	
Not documented	61	0	3	3	46	9	
Self-reported Gender Identity							< 0.001
Non-Cisgender Identity	114 (0.4%)	1 (0.6%)	3 (0.4%)	18 (0.3%)	89 (0.4%)	3 (0.4%)	
Cis Female	17,862 (55.7%)	110 (61.5%)	336 (47.3%)	4012 (66.2%)	13,015 (53.3%)	389 (53.1%)	
Cis Male	14,101 (44.0%)	68 (38.0%)	371 (52.3%)	2026 (33.5%)	11,296 (46.3%)	340 (46.4%)	
Not documented	112,447	305	2198	32,900	72,669	4375	
Healthy People 2030 Health Indicators							
History of Drug Overdose							< 0.001
Yes	3533 (2.4%)	8 (1.7%)	53 (1.8%)	802 (2.1%)	2634 (2.7%)	36 (0.7%)	
History of Suicide Attempt							< 0.001
Yes	457 (0.3%)	3 (0.6%)	4 (0.1%)	99 (0.3%)	348 (0.4%)	3 (0.1%)	

Table 1 (continued)

Variables‡	All	American Indian or Alaska Native	Asian	Black or African American	White or Caucasian	Other	*p* value
Air Quality Index							< 0.001
Good	104,635 (74.0%)	393 (84.2%)	2604 (90.4%)	14,926 (38.5%)	82,399 (87.4%)	4313 (86.1%)	
Moderate	36,724 (26.0%)	74 (15.8%)	278 (9.6%)	23,826 (61.5%)	11,852 (12.6%)	694 (13.9%)	
Not documented	3165	17	26	204	2818	100	
Active health insurance (< 65 years old)							0.431
Yes	60,297 (98.8%)	239 (98.8%)	1293 (99.2%)	21,173 (98.8%)	35,280 (98.9%)	2312 (98.5%)	
Medical History							
Charlson Comorbidity Index							< 0.001
0	63,183 (43.7%)	214 (44.2%)	1302 (44.8%)	15,660 (40.2%)	43,363 (44.7%)	2644 (51.8%)	
1–2	36,981 (25.6%)	113 (23.3%)	601 (20.7%)	10,655 (27.4%)	24,617 (25.4%)	995 (19.5%)	
3–4	19,170 (13.3%)	65 (13.4%)	356 (12.2%)	6144 (15.8%)	12,158 (12.5%)	447 (8.8%)	
≥ 5	10,187 (7.0%)	38 (7.9%)	189 (6.5%)	2976 (7.6%)	6778 (7.0%)	206 (4.0%)	
Not documented	15,003 (10.4%)	54 (11.2%)	460 (15.8%)	3521 (9.0%)	10,153 (10.5%)	815 (16.0%)	
Self-reported tobacco use							< 0.001
Current Smoker	20,120 (14.5%)	82 (17.4%)	142 (5.1%)	6723 (18.2%)	12,601 (13.4%)	572 (11.8%)	
Former Smoker	55,397 (39.8%)	176 (37.4%)	681 (24.5%)	12,550 (34.0%)	40,394 (42.9%)	1596 (33.1%)	
Never Smoker	63,719 (45.8%)	213 (45.2%)	1951 (70.3%)	17,627 (47.8%)	41,268 (43.8%)	2660 (55.1%)	
Not documented	5288	13	134	2056	2806	279	
Self-reported alcohol use							< 0.001
Active user	18,808 (37.9%)	50 (29.2%)	196 (19.6%)	4265 (34.3%)	13,726 (40.2%)	571 (31.1%)	
Former user	8617 (17.4%)	27 (15.8%)	166 (16.6%)	2269 (18.3%)	5881 (17.2%)	274 (14.9%)	
Never user	22,171 (44.7%)	94 (55.0%)	637 (63.8%)	5894 (47.4%)	14,556 (42.6%)	990 (54.0%)	
Not documented	94,928	313	1909	26,528	62,906	3272	
Self-reported illicit substance use							< 0.001
Active user	5912 (12.2%)	21 (12.6%)	18 (1.9%)	2264 (18.5%)	3475 (10.5%)	134 (7.6%)	
Former user	3576 (7.4%)	9 (5.4%)	47 (4.9%)	1264 (10.3%)	2154 (6.5%)	102 (5.8%)	
Never user	38,894 (80.4%)	137 (82.0%)	900 (93.3%)	8703 (71.2%)	27,618 (83.1%)	1536 (86.7%)	
Not documented	96,142	317	1943	26,725	63,822	3335	

Abbreviations: NIMHD = National Institute on Minority Health and Health Disparities

‡For continuous variables, medians (interquartile ranges, IQRs) and means (standard deviation, SD) were presented. For categorical variables, frequencies (percentage) were presented

Discussion

This study, which is one of the first large-scale investigations of over 100,000 hospitalized patients evaluating the influence of healthcare inequities on PIVC outcomes, demonstrated significant disparities among sex and race. Specifically, female gender and Black race were key predictors of adverse outcomes. Some of the differences in PIVC functionality were substantial and disproportionately impacted these vulnerable groups. In the context of PIVC dwell time compared to the patient's hospitalization length of stay, our multivariable linear regression model (Fig. 2; Table 3) demonstrated that Black females had 19.6% lesser ratio of PIVC dwell time to hospital length of stay compared to White males. In other words, Black females had reliable PIVC access for over one full day less than White males.

Regrettably, numerous studies and review articles on PIVC failure often omit or neglect to report race in their findings, a trend consistent with broader patterns in medical research [25]. However, this oversight is being addressed by recent updates in guidelines for reporting race/ethnicity, indicating a shift towards greater inclusivity in medical research [26, 27]. Some articles investigating risk factors for difficult intravenous access in patients (DIVA) have identified darker skin as a potential risk factor, given the diminished visibility of veins [28–30]. Previous literature establishes a link between darker skin pigmentation and reduced vein visibility, increasing the difficulty of PIVC placement [31]. Given the crucial role of vein visualization in standard venous assessment and its correlation with PIVC placement ease, it is unsurprising that Black patients with darker skin face a heightened risk of encountering challenging venous access. The same logic can also be applied to women as they tend to have different venous anatomy compared to men [32, 33]. Naturally, smaller target vessels create an anatomical disadvantage leading to difficult access. The well-established

Table 2 Hospital Course, PIVC characteristics, and outcomes of hospitalized patients stratified by race

Variables[‡]	All	American Indian or Alaska Native	Asian	Black or African American	White or Caucasian	Other	*p* value
n	144,524	484 (0.3%)	2,908 (2.0%)	38,956 (27.0%)	97,069 (67.2%)	5,107 (3.5%)	
Hospital Course							
Hospital Setting							< 0.001
Community (250 + beds)	40,043 (27.7%)	80 (16.5%)	273 (9.4%)	20,970 (53.8%)	18,012 (18.5%)	708 (13.9%)	
Mid-size (500 + beds)	49,119 (34.0%)	192 (39.7%)	1437 (49.4%)	2768 (7.1%)	42,490 (43.8%)	2232 (43.7%)	
Academic (1000 + beds)	55,362 (38.3%)	212 (43.8%)	1198 (41.2%)	15,218 (39.1%)	36,567 (37.7%)	2167 (42.4%)	
Emergency Severity Index							< 0.001
Mean	2.6 (0.6)	2.6 (0.6)	2.5 (0.6)	2.6 (0.6)	2.6 (0.6)	2.5 (0.6)	
Median	3.0 (2.0, 3.0)	3.0 (2.0, 3.0)	3.0 (2.0, 3.0)	3.0 (2.0, 3.0)	3.0 (2.0, 3.0)	3.0 (2.0, 3.0)	
Not documented	472	2	10	85	358	17	
Length of Stay, hours							< 0.001
Mean	134.7 (147.6)	122.6 (156.6)	131.5 (144.1)	137.1 (155.2)	134.1 (143.7)	130.6 (161.6)	
Median	95.2 (53.5, 162.8)	77.4 (51.7, 126.3)	90.3 (50.7, 158.8)	95.4 (55.0, 162.9)	95.5 (53.4, 163.4)	88.2 (50.0, 153.9)	
Use of Intravenous Vesicant							< 0.001
Yes	36,696 (25.4%)	123 (25.4%)	852 (29.3%)	9527 (24.5%)	24,837 (25.6%)	1357 (26.6%)	
PIVC Characteristics							
Gauge							< 0.001
18	25,517 (18.8%)	82 (18.3%)	508 (18.6%)	6894 (18.8%)	17,137 (18.9%)	896 (18.7%)	
20	101,637 (75.0%)	339 (75.5%)	2103 (77.0%)	26,294 (71.7%)	69,196 (76.2%)	3705 (77.4%)	
22	8043 (5.9%)	28 (6.2%)	119 (4.4%)	3285 (9.0%)	4430 (4.9%)	181 (3.8%)	
24	330 (0.2%)	0 (0.0%)	2 (0.1%)	222 (0.6%)	104 (0.1%)	2 (0.0%)	
Not documented	8997	35	176	2261	6202	323	
Orientation							< 0.001
Left	70,206 (49.3%)	255 (53.5%)	1387 (48.5%)	18,351 (47.9%)	47,724 (49.9%)	2489 (49.6%)	
Right	72,099 (50.7%)	222 (46.5%)	1474 (51.5%)	19,983 (52.1%)	47,892 (50.1%)	2528 (50.4%)	
Not documented	2219	7	47	622	1453	90	
Location							< 0.001
Antecubital	81,882 (56.7%)	269 (55.6%)	1788 (61.5%)	20,803 (53.4%)	55,944 (57.6%)	3078 (60.3%)	
Forearm	38,360 (26.5%)	127 (26.2%)	708 (24.3%)	9913 (25.4%)	26,337 (27.1%)	1275 (25.0%)	
Hand/Wrist	5103 (3.5%)	20 (4.1%)	95 (3.3%)	1257 (3.2%)	3559 (3.7%)	172 (3.4%)	
Upper Arm	6440 (4.5%)	25 (5.2%)	82 (2.8%)	2797 (7.2%)	3374 (3.5%)	162 (3.2%)	
Other	12,739 (8.8%)	43 (8.9%)	235 (8.1%)	4186 (10.7%)	7855 (8.1%)	420 (8.2%)	
Insertion Method							< 0.001
Traditional	137,105 (94.9%)	455 (94.0%)	2805 (96.5%)	35,199 (90.4%)	93,690 (96.5%)	4956 (97.0%)	
Ultrasound Guided	7419 (5.1%)	29 (6.0%)	103 (3.5%)	3757 (9.6%)	3379 (3.5%)	151 (3.0%)	
Inserter Credentials							< 0.001
EDT	51,876 (47.0%)	171 (47.9%)	1083 (49.2%)	13,942 (47.0%)	34,865 (47.0%)	1815 (46.8%)	
Nurse	45,516 (41.3%)	146 (40.9%)	881 (40.0%)	13,282 (44.8%)	29,627 (39.9%)	1580 (40.8%)	
APP/Physician	778 (0.7%)	5 (1.4%)	9 (0.4%)	439 (1.5%)	300 (0.4%)	25 (0.6%)	
EMS	11,831 (10.7%)	34 (9.5%)	223 (10.1%)	1938 (6.5%)	9187 (12.4%)	449 (11.6%)	
Other	282 (0.3%)	1 (0.3%)	5 (0.2%)	73 (0.2%)	195 (0.3%)	8 (0.2%)	
Not documented	34,241	127	707	9282	22,895	1230	
Outcomes							
Proportion of Dwell to Hospital Length of Stay							< 0.001
Mean	0.68 (0.35)	0.70 (0.35)	0.74 (0.33)	0.65 (0.36)	0.69 (0.35)	0.71 (0.34)	
Median	0.88 (0.34, 0.99)	0.90 (0.37, 0.99)	0.94 (0.48, 0.99)	0.82 (0.30, 0.98)	0.90 (0.35, 0.99)	0.93 (0.41, 0.99)	

Table 2 (continued)

Variables[‡]	All	American Indian or Alaska Native	Asian	Black or African American	White or Caucasian	Other	*p* value
Dwell time, hours							< 0.001
Mean	68.3 (55.3)	62.5 (50.2)	73.8 (58.5)	65.9 (54.6)	69.1 (55.5)	68.3 (54.5)	
Median	53.0 (29.5, 91.4)	51.2 (27.6, 82.1)	58.5 (33.4, 97.5)	51.5 (28.0, 88.4)	53.7 (30.0, 92.3)	52.2 (29.4, 91.8)	
Time to PIVC Placement, hours							< 0.001
Mean	1.89 (3.70)	2.29 (5.02)	1.82 (2.46)	2.03 (2.96)	1.83 (4.05)	1.82 (2.12)	
Median	1.23 (0.63, 2.30)	1.42 (0.72, 2.60)	1.25 (0.65, 2.23)	1.27 (0.62, 2.52)	1.22 (0.63, 2.22)	1.23 (0.65, 2.23)	
Length of stay, hours							< 0.001
Mean	134.9 (147.6)	122.6 (156.6)	131.49 (144.1)	137.14 (155.2)	134.1 (143.7)	130.6 (161.6)	
Median	95.2 (53.5, 162.8)	77.4 (51.7, 126.3)	90.3 (50.7, 158.8)	95.4 (55.0, 162.9)	95.5 (53.4, 163.4)	88.2 (50.0, 153.9)	
Removal Reason							< 0.001
Completed By Discharge	42,674 (34.6%)	149 (35.6%)	1020 (40.3%)	10,426 (31.8%)	29,418 (35.4%)	1661 (37.4%)	
Failure	43,085 (34.9%)	129 (30.9%)	731 (28.9%)	12,144 (37.0%)	28,674 (34.5%)	1407 (31.7%)	
Therapy Completed	37,639 (30.5%)	140 (33.5%)	782 (30.9%)	10,214 (31.2%)	25,127 (30.2%)	1376 (31.0%)	
Not documented	21,126	66	375	6172	13,850	663	
Failure Subcategory							< 0.001
Infiltration	10,250 (42.3%)	36 (48.0%)	184 (45.4%)	3042 (43.5%)	6659 (41.6%)	329 (43.3%)	
Leaking	10,406 (43.0%)	31 (41.3%)	166 (41.0%)	2785 (39.9%)	7108 (44.4%)	316 (41.6%)	
Occlusion	3549 (14.7%)	8 (10.7%)	55 (13.6%)	1155 (16.5%)	2217 (13.9%)	114 (15.0%)	
Phlebitis	16 (0.1%)	0 (0.0%)	0 (0.0%)	6 (0.1%)	10 (0.1%)	0 (0.0%)	
Not documented	18,864	54	326	5156	12,680	648	

Abbreviations: PIVC = peripheral intravenous catheter; EDT = emergency department technician; APP = advanced practice provider; EMS = emergency medical services

[‡]For continuous variables, medians (interquartile ranges, IQRs) and means (standard deviation, SD) were presented. For categorical variables, frequencies (percentage) were presented

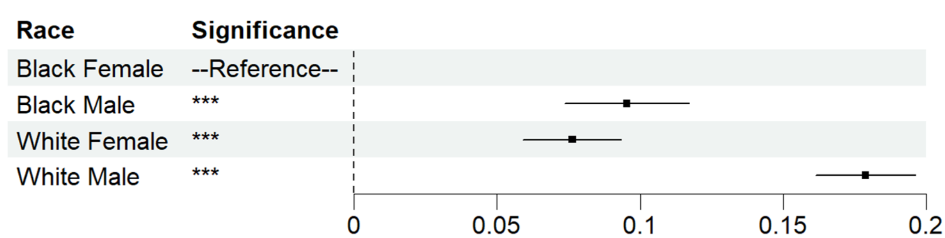

Fig. 2 Plot of the coefficients of race and sex interaction variable from multivariable linear regression analysis of the proportion of dwell time to hospital length of stay for admitted patients. The coefficients are from the multivariable linear regression with age and race interaction analysis. The dependent variable was transformed into LN form. Other covariates include age, body mass index, Charlson Comorbidity Index, use of intravenous vesicant, emergency severity index, insertion method, peripheral intravenous catheter location, orientation, and gauge size

association between DIVA patients and increased insertion attempts, as well as poor functionality outcomes, often necessitates escalation to ultrasound-guided PIVC insertion—a skill not universally available among clinical staff. In the absence of ultrasound, PIVCs are frequently placed in suboptimal locations, leading to elevated complications and early failures. Consequently, our study underscores that Black individuals and females experience a higher incidence of suboptimal site placement, resulting in shorter PIVC dwell times. Despite recognized anatomical and physiological disparities contributing to multiple puncture attempts and failures, comprehensive solutions or escalation strategies targeting PIVC outcomes for Black individuals and females remain limited.

While much of a PIVCs predictability of its survival lies within the first 24 h, regular care and maintenance of the PIVC is crucial. First, certain skin pigmentations may make identifying signs of PIVC complications, such as phlebitis, more difficult for the untrained eye [28, 31]. Next, perhaps it is related to poor health outcomes in non-white populations as a whole. Our study also demonstrated Black patients lived in areas with higher levels of poverty, and previous research has shown low socioeconomic status may result in fewer diagnostic tests and

Table 3 Multivariable linear regression with race and sex interaction variable analysis of the proportion of dwell time to hospital length of stay for admitted patients

Terms[‡]			Estimate Percentage	Estimate	*p* value
Demographics					
	Interaction of Sex and Race				
		Black Female	Reference	Reference	
		Black Male	10.0%	0.095 (0.074, 0.117)	< 0.001
		White Female	7.9%	0.076 (0.059, 0.093)	< 0.001
		White Male	19.6%	0.179 (0.161, 0.196)	< 0.001
	Age, category				
		18–64	Reference	Reference	
		65–80	-7.3%	-0.075 (-0.089, -0.062)	< 0.001
		> 80	-11.4%	-0.122 (-0.137, -0.106)	< 0.001
	Body mass index, category				
		Healthy weight	Reference	Reference	
		Underweight	-12.6%	-0.135 (-0.163, -0.106)	< 0.001
		Overweight	5.1%	0.050 (0.035, 0.065)	< 0.001
		Obesity	2.6%	0.026 (0.011, 0.040)	< 0.001
Medical History					
	Charlson Comorbidity Index				
		≥ 5	Reference	Reference	
		0	9.5%	0.091 (0.068, 0.114)	< 0.001
		1–2	1.8%	0.018 (-0.006, 0.042)	0.147
		3–4	2.0%	0.020 (-0.006, 0.046)	0.137
		Missing	5.5%	0.053 (0.025, 0.081)	< 0.001
Hospital Course					
	Emergency Severity Index		3.9%	0.038 (0.028, 0.048)	< 0.001
	Use of Intravenous Vesicant				
		No	Reference	Reference	
		Yes	-0.6%	-0.006 (-0.019, 0.007)	0.358
PIVC Characteristics					
	Gauge				
		18	Reference	Reference	
		20	1.1%	0.011 (-0.004, 0.026)	0.152
		22	-18.8%	-0.208 (-0.237, -0.179)	< 0.001
		24	-31.2%	-0.374 (-0.488, -0.260)	< 0.001
	Insertion Method				
		Traditional	Reference	Reference	
		Ultrasound Guided	-18.9%	-0.209 (-0.237, -0.182)	< 0.001
	Orientation				
		Left	Reference	Reference	
		Right	-1.4%	-0.014 (-0.026, -0.003)	0.014
	Location				
		Antecubital	Reference	Reference	
		Forearm	6.7%	0.065 (0.051, 0.078)	< 0.001
		Hand/Wrist	-15.0%	-0.163 (-0.194, -0.132)	< 0.001
		Upper Arm	-12.6%	-0.134 (-0.165, -0.104)	< 0.001
		Other	-17.7%	-0.195 (-0.218, -0.171)	< 0.001

Abbreviations: CI = confidence interval; PIVC = peripheral intravenous catheter

[‡] The dependent variable "proportion of dwell time to hospital length of stay" was transformed into LN form due to left skewness

medications for chronic illnesses [34]. Or, perhaps, it is even more complex than we can imagine, and the answer lies in a multifaceted biopsychosocial factor that still needs to be uncovered.

The disparities unveiled in our study are also indicative of broader systemic issues in healthcare delivery. This discrepancy could be attributed to factors such as differential access to quality care, potential biases in patient treatment, or differences in health literacy and patient advocacy. Historically, medical textbooks have predominantly featured illustrations of light-skinned individuals. This bias that could inadvertently impact the preparedness of healthcare professionals in performing PIVC placement on patients with darker skin tones [35, 36]. This reality highlights the critical necessity for more comprehensive and inclusive educational materials and training programs that address the needs of a diverse patient demographic.

Nevertheless, in light of these findings, our study urges a reevaluation of PIVC placement protocols to account for the disparities identified. Tailoring interventions to address the unique challenges faced by different demographic groups is imperative for improving overall PIVC success rates and reducing complications. The implications extend beyond immediate patient care, encompassing potential reductions in hospital stays and more efficient delivery of critical treatments. This research advances our understanding of the intersection between routine medical procedures and healthcare disparities, emphasizing the need for targeted strategies to enhance equity in PIVC outcomes. As we navigate the complexities of healthcare delivery, addressing disparities in the most common medical procedures is a pivotal step toward a more equitable and effective healthcare system.

Limitations

This study offers valuable insights into disparities in PIVC outcomes across various demographic groups; however, several limitations warrant consideration. First, its retrospective design limits the ability to establish causality between demographic factors and PIVC outcomes, and the data sourced from a single healthcare system may not be representative of other settings, potentially affecting the generalizability of our findings. Second, the possibility of unmeasured confounders, such as individual clinician skill or patient-specific anatomical variations, alongside the reliance on administrative data, which may not capture all relevant clinical details, could influence outcomes. Third, the categorization of race and ethnicity into broad groups may oversimplify their complex interplay with healthcare outcomes and not fully represent individuals with multiple racial or ethnic identities. Fourth, inherent biases in the data collection process, including selection and information bias, must be considered.

It's important to contextualize these findings within our healthcare setting, which features a robust PIVC training program, including early escalation to ultrasound for patient care [37–39]. This aspect of our practice suggests that the disparities observed in our study might be even more significant in environments with less developed escalation protocols for PIVC placement. While this study sheds light on important disparities in PIVC outcomes, these limitations highlight the need for cautious interpretation of the findings and underscore the importance of further research to develop more comprehensive and effective strategies to reduce healthcare disparities in PIVC outcomes and beyond.

Conclusions

Overall, this observational cohort study of over 140,000 hospitalized patients demonstrated that significant health disparities exist within PIVC survivability. Black females face the highest risk of compromised PIVC functionality, resulting in approximately one full day less reliable PIVC access than White males. Additional research is required to improve the understanding of the impact on health disparities and PIVC outcomes as well as potential solutions.

Abbreviations

PIVC	Peripheral Intravenous Catheters
ED	Emergency Department
N/A	Not Applicable
BMI	Body Mass Index
CDC	Centers for Disease Control and Prevention
AHRQ	Agency for Healthcare Research and Quality
EPA	Environmental Protection Agency
AQI	Air Quality Index
ICD10	International Classification of Diseases 10
ESI	Emergency Severity Index
RF	Random Forest
CI	Confidence Intervals
DIVA	Difficult Intravenous Access

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

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Author contributions

NM, CO, and AB designed the study, had full access to the data, and take responsibility for the integrity and accuracy of the data analysis. YX contributed to data and statistical analysis. All authors contributed to the writing and editing of the manuscript. All authors contributed to data acquisition, analysis and interpretation, and all reviewed and approved the final version of the manuscript. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The Beaumont Health Institutional Review Board approved this study (IRB #2023-097). A Research Waiver of Authorization was granted only for the stipulation of identification/data collection of the specific data variables for this study given it is not practical or feasible to obtain consent/assent for 100,000 + participants for this chart review. The use of PHI is necessary to collect study variables/data points to achieve the study objectives.

Consent for publication
Not applicable.

Competing interests
AB has research grant support from B. Braun Medical, Becton-Dickinson, Teleflex, and Medline Industries. AB is a paid consultant for Lineus Medical and Skydance Vascular. All other authors declare no relevant conflicts of interest relevant to this work.

Author details
[1]Oakland University William Beaumont School of Medicine, Rochester, MI, United States of America
[2]Department of Medicine, Creighton University School of Medicine, Omaha, NE, United States of America
[3]Corewell Health Research Institute, Royal Oak, MI, United States of America
[4]Department of Emergency Medicine, Corewell Health William Beaumont University Hospital, 13 Mile Rd, Royal Oak, MI
48073, United States of America

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