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Association of Socioeconomic Position and Medical Insurance With Fetal Diagnosis of Critical Congenital Heart Disease

Vasum Peiris, MD, MPH; Tajinder P. Singh, MD, MSc; Wayne Tworetzky, MD; Erin C. Chong, BA; Kimberlee Gauvreau, ScD; David W. Brown, MD

Background—Access to beneficial novel healthcare technology has been inequitable in the United States. Fetal echocardiography, used with increasing frequency for prenatal diagnosis (PD) of congenital heart disease, allows for optimal neonatal management and possible improved outcomes. We sought to evaluate whether PD of critical congenital heart disease is related to socioeconomic (SE) position, medical insurance, and race.

Methods and Results—In a retrospective review of infants with critical congenital heart disease who underwent surgical or catheter intervention at age <30 days in our institution during 2003 to 2006, we extracted 6 SE variables for the block groups of patient residence from 2000 US Census and calculated a previously validated composite SE score for each patient. PD occurred in 222 (50%) infants. Race was not significantly associated with PD. Private insurance patients were much more likely to have PD (odds ratio, 3.7 versus public insurance; 95% CI, 2.4 to 5.7; $P<0.001$), as were patients of higher SE position (PD, 62% in highest quartile versus 35% in lowest quartile; $P=0.001$). Odds of PD increased with increasing SE score (odds ratio, 1.7, 2.3, and 2.9 for each quartile of higher SE score versus those in lowest SE quartile; $P<0.001$). Patients from economically poor neighborhoods were less likely to have PD (odds ratio, 1.2 for each 10% increase in prevalence of poverty; $P=0.04$). Private medical insurance (odds ratio, 3.4; 95% CI, 2.1 to 5.5; $P<0.001$) was the strongest predictor of PD in the logistic regression model.

Conclusion—Patients with public insurance and lower SE position are less likely to have a PD of critical congenital heart disease. (*Circ Cardiovasc Qual Outcomes*. 2009;2:354-360.)

Key Words: echocardiography ■ heart defects, congenital ■ imaging ■ access to health care

Congenital heart disease (CHD) is the most common birth defect. CHD remains a significant cause of neonatal and infant mortality in the United States. Despite a substantial reduction in CHD related mortality associated with improvements in perisurgical management during recent decades, CHD accounts for 29% of all deaths associated with congenital malformations and 5.7% of all infant deaths.¹ Neonates account for the majority (57%) of all deaths related to CHD during the first year of life.²

Advances in ultrasound technology during the last 25 years have made the prenatal diagnosis (PD) of most forms of CHD possible, sometimes as early as 10 to 15 weeks' gestation.³ The PD of critical CHD, defined as infants who require surgical or transcatheter intervention during the first month of life, allows for parental decision-making regarding continuation of the pregnancy, appropriate obstetric monitoring during gestation and delivery, and optimization of the infant's circulation during the neonatal period before required in-

vasive intervention. Although data relating PD to postoperative outcomes have been mixed,^{4–6} a clear benefit to morbidity and mortality has been demonstrated in some populations.^{7,8} Furthermore, the potential for in utero interventions, such as balloon dilation of fetal aortic stenosis, to alter the natural history of fetal heart disease makes PD an important element of high quality obstetric care.^{9,10}

Although referral for fetal echocardiography (FE) has become more common in the current era, a large number of infants with critical CHD continue to be born in the United States without the potential benefit of PD.¹¹ Current indications for FE include maternal indications such as a family history of congenital heart defect or diabetes mellitus, and fetal indications such as known or suspected chromosomal anomaly, or presence of a midline congenital defect.¹² However, the majority of critical CHDs are detected by a FE performed because of abnormal or suspicious findings on a screening midtrimester obstetric ultrasound in otherwise low

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risk pregnancies. Although minor CHDs can be challenging to diagnose by FE, the majority of critical CHD (those lesions severe enough to require intervention during the first month of life) is readily diagnosed by FE.¹³ In addition to determining the specific type of CHD, the fetal and anticipated neonatal physiology can be elucidated, allowing the most informed management plan to be developed in conjunction with the obstetric team and wishes of the parents.

Although several factors may contribute to current suboptimal rates of PD of CHD, we hypothesized that socioeconomic (SE) factors play an important role. Recent studies have shown race, medical insurance, and SE position to be independently associated with disparities in the clinical use of common medical technologies, procedures and emerging therapies in the United States.^{14–17} SE position has been proposed as the most significant factor influencing health status and health care.^{18,19} Only limited data exist regarding the relationship of SE factors to PD of CHD.¹¹ Therefore, we sought to determine the relationship of race, medical insurance, and SE position with PD in a large cohort of neonates admitted to a regional quaternary care pediatric cardiac center.

WHAT IS KNOWN

- Fetal echocardiography is used with increasing frequency for prenatal diagnosis of congenital heart disease (CHD).
- Prenatal diagnosis of critical CHD (lesions requiring intervention in the first month of life) allows for optimal perinatal management of such infants and has been shown to positively impact morbidity and mortality for certain cardiac lesions.
- Socioeconomic and other factors that may influence the prenatal diagnosis of CHD have not previously been evaluated in detail.

WHAT THE STUDY ADDS

- This study assessed whether socioeconomic position, type of medical insurance (private versus public), or race were associated with prenatal diagnosis of critical CHD.
- We found that patients with private medical insurance and those in high socioeconomic position were more likely to have a prenatal diagnosis of critical CHD, demonstrating a significant inequity in access to fetal echocardiography in those with public insurance and in low socioeconomic position.

Methods

We identified all infants admitted to Children's Hospital Boston (Boston, Mass) with critical CHD between January 1, 2003, and December 31, 2006. Critical CHD was defined when a surgical or catheter intervention for CHD was performed at age ≤ 30 days. We excluded non-US residents (international subjects, $n=28$) and those without a residential address reported in the medical records ($n=17$). The study was approved by the institutional review board with a waiver of informed consent.

Patient Demographic and FE Data

Demographic and clinical data were extracted from hospital medical records and from electronic patient care databases. Prenatal diagnosis of CHD using FE was verified, and other details of maternal obstetric care were collected. Race was self-designated by the parent as a closed option within the following categories: white, African-American/black, Hispanic, Asian/Pacific Islander, American Indian or Alaskan Native, other, and unknown. Medical insurance was ascertained from the hospital electronic billing system and grouped into 2 categories: private and public (eg, Medicaid) insurance.

The driving distance (in miles) from each patient's home address to the nearest site offering FE was obtained using an internet-based mapping engine that relies on commercial mapping data sources. Its accuracy was confirmed with a second internet-based mapping engine that relied on different commercial mapping data sources. Similar methods were used to calculate the distance from each patient's home address to Children's Hospital Boston. The location and distance of sites offering FE were obtained by contacting pediatric cardiology and obstetric offices in proximity to each patient's address to determine the closest site offering FE.

Assessment of SE Position

Each patient was linked by home address to their census block group from the 2000 US Census. A block group contains on average 1000 persons, is the smallest geographic census unit for which census SE data are tabulated, and is designed to be relatively homogeneous with respect to economic status and living conditions of its residents. A block group is thus essentially the neighborhood of a person's residence. Based on a previously described and validated measure, a composite SE score was calculated for each patient—this score was used as the main indicator of the SE position of the patient.²⁰

To determine this score, data on 6 SE variables for each subject's block group were collected from the 2000 US Census web site. The 6 SE variables selected for the composite score were originally described by Diez Roux et al²⁰ using factor analysis, a statistical technique to determine which variables of a large set (for example a large set of Census SE variables) can be meaningfully combined into a composite score. Three of these variables represent dimensions of wealth and income (log of the median household income, log of the median value of housing units, and the percentage of households receiving interest, dividend, or net rental income), 2 represent education (the percentage of adults 25 years of age or older who had completed high school, and the percentage of adults 25 years of age or older who had completed college), and the 6th variable represents occupation (the percentage of employed persons 16 years of age or older in executive, managerial, or professional specialty occupations) of the residents of the block group. For each variable, a z score for each block group was calculated by subtracting the overall mean (across all block groups in the sample) from the value of the variable for that block group and dividing by the standard deviation. The composite SE score for each subject was calculated by summing the 6 z scores (1 for each of the 6 variables) for that subject. Finally, we also collected data on a simple measure of SE position, the proportion of individuals living in the block group who were below the federally defined poverty level.

Data Analysis

Continuous data are summarized using the median and either the range or interquartile range as indicated. The percentages of patients with a prenatal diagnosis were compared across study years using a χ^2 test for trend. Patients were divided into 4 groups (quartiles) based on their composite SE scores. Patient characteristics were compared for neonates who did and did not have a prenatal diagnosis using the Wilcoxon rank sum test for continuous variables and Fisher exact test for categorical variables. Comparisons across racial groups were performed using the Fisher exact test. Logistic regression analysis was used to assess the relationships between prenatal diagnosis using FE and SE position, race, and medical insurance. Odds ratios are presented with 95% confidence intervals. Stata version 10 was used for statistical analysis.

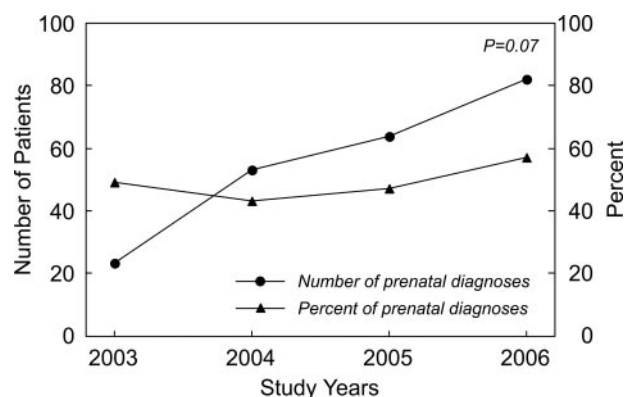


Figure 1. Temporal trends of prenatal diagnoses. During the study period, the number and percent of PD by FE increased.

Results

A total of 444 neonates were included in the final analysis. Nearly half of this group (217, 49%) resided in Massachusetts. Seventy-six percent (338) were from the New England region (states included Massachusetts, Rhode Island, Connecticut, Vermont, New Hampshire, and Maine). The remaining 24% (106 patients) were from the United States outside the greater New England area. For the entire cohort, 31% (138) were from more than 100 miles from Children's Hospital Boston.

PD of CHD in the study cohort was made in 222 (50%). Evaluation of temporal trends revealed a slight increase in frequency of PD over the 4 year period (Figure 1, probability value for trend over time=0.07).

A comparison of baseline demographic and clinical characteristics in neonates who did or did not have a PD of CHD

is summarized in Table 1. Only 1 patient was documented to have had no prenatal care (no PD); all others received standard routine obstetric care. The distribution of cardiac diagnoses was significantly different between the 2 groups. Hypoplastic left heart syndrome (HLHS) was the most common diagnosis among patients with PD; 75% of patients with HLHS were diagnosed in utero. In contrast, transposition of the great arteries with intact ventricular septum (TGA/IVS) was the CHD least commonly prenatally diagnosed; only 27% of patients with TGA/IVS were diagnosed before birth. Patients with PD of CHD were more likely to be born at a slightly earlier gestational age; however, there was no significant difference between the 2 groups with respect to birth weight. There was also no significant difference between the 2 groups with respect to distance to a center offering FE; the median driving distance was 15 miles for both groups, and 82% of the entire cohort was within 30 miles of a center offering FE.

Table 2 demonstrates the SE characteristics of the block groups of patient residence by quartiles. As expected, the differences between these 4 groups was statistically significant for all SE variables ($P<0.001$ for all comparisons). With each incremental quartile, the median income of block groups was higher, the median value of housing units increased, the proportion of adults who had completed high school or college education, and those in a managerial, professional, or executive profession increased, and more households had rental, interest, or dividends as a source of their income. The higher SE groups had a significantly lower proportion of individuals living below the federally defined poverty level. Those living in higher SE quartiles were significantly more likely to have private insurance ($P<0.001$; Figure 2).

Table 1. Comparison of Patient Characteristics in Groups With and Without PD of Critical CHD

	Prenatal Diagnosis (n=222)	No Prenatal Diagnosis (n=222)	P Value
Cardiac diagnosis			<0.001
HLHS	72 (32)	30 (13)	
TGA/IVS	19 (9)	52 (23)	
TGA/VSD	12 (5)	29 (13)	
DORV	11 (5)	17 (8)	
TOF/PS	15 (7)	10 (5)	
PA/IVS	14 (6)	10 (5)	
Other	79 (36)	74 (33)	
Gestational age	39 (29 to 40) [37 to 40]	40 (28 to 41) [39 to 40]	<0.001
≤36 weeks	48 (22)	27 (12)	
≥37 weeks	174 (78)	195 (88)	
Birth weight	3.1 (1 to 4.5) [2.6 to 3.4]	3.2 (1 to 4.7) [2.8 to 3.5]	0.08
<2.5 kg	40 (18)	27 (12)	
≥2.5 kg	182 (82)	195 (88)	
Distance to FE center (35th, 75th percentile), miles	15.8 7.2, 25.2	15.9 7.3, 27.3	0.69

Data are presented as n (%) or median (range) [interquartile range]. HLHS indicates hypoplastic left heart syndrome; TGA, transposition of great arteries; IVS, intact ventricular septum; VSD, ventricular septal defect; DORV, double outlet right ventricle; TOF, tetralogy of fallot; PS, pulmonary stenosis; PA, pulmonary atresia.

Table 2. SE Characteristics By Quartile*

2000 US Census Variables	SE Quartiles, Mean (SD)				P Value
	1	2	3	4	
Residents >25 years old who completed high school, %	64 (14)	80 (7)	88 (5)	94 (4)	<0.001
Residents >25 years old who completed college, %	10 (6)	21 (8)	30 (9)	51 (14)	<0.001
Employed residents in executive, managerial, or professional occupations, %	20 (6)	31 (9)	39 (8)	54 (12)	<0.001
Households with interest, dividend, or rental income, %	20 (8)	33 (9)	43 (8)	56 (11)	<0.001
Household income, \$†	28 457 (7801)	41 830 (9111)	53 792 (11 050)	74 029 (24 268)	<0.001
Value of housing units, \$†	88 798 (35 890)	119 738 (34 330)	156 773 (39 036)	252 292 (105 076)	<0.001
Below federal poverty level, %	24 (20)	11 (8)	6 (5)	4 (4)	<0.001

*Group 1 corresponds to patients living in most disadvantaged block groups and group 4 to those living in most advantaged areas. The method of calculating the SE score is described in the Methods section.

†Values have been rounded to the nearest \$100.

Table 3 summarizes the comparison between patients with and without PD for SE, medical insurance, and race variables. In univariate analysis, patients with private insurance were much more likely to have PD (odds ratio [OR], 3.7 versus public insurance; 95% CI, 2.4 to 5.7; $P<0.001$). Similarly, patients in a higher SE position were also more likely to have PD (62% in highest quartile versus 35% in lowest quartile; $P=0.001$; Figure 3). The odds of having PD increased with increasing SE score (OR, 1.7, 2.3, and 2.9 for each quartile of higher SE score compared with those in the lowest SE quartile; $P<0.001$). Patients residing in block groups with a higher prevalence of poverty were less likely to have PD (OR, 1.2 for each 10% increase in prevalence of poverty; $P=0.04$).

The relationship of the various racial groups with SE position and medical insurance is shown in Table 4. Forty-five percent of blacks, 55% of Hispanics, but only 15% of whites in the study lived in the lowest quartile SE neighborhood. Similarly, 58% of blacks, 52% of Hispanics, but only 22% of whites in the study had public insurance. However, we did not find a significant association of race with PD in either univariate or multivariate analysis (Tables 3 and 5).

In a multivariable model that controlled for SE characteristics of the neighborhood of residence (SE quartile and poverty level of the block groups, Table 5), private insurance

was strongly associated with PD of CHD (OR, 3.4; 95% CI, 2.1 to 5.5; $P<0.001$). After adjusting for the type of medical insurance, the highest quartile SE group was almost twice as likely to have PD as the lowest quartile SE group (OR, 1.9; 95% CI, 1.0 to 3.6; $P=0.06$).

Comment/Discussion

In this large cohort of infants admitted with critical CHD to a quaternary care pediatric cardiac center in New England, we found that only 50% of infants had a prenatal diagnosis of CHD. There was a strong association between higher SE position and prenatal diagnosis of CHD. However, in a multivariate model that included both SE position and type of

Table 3. Summary of Patient/Family Characteristics

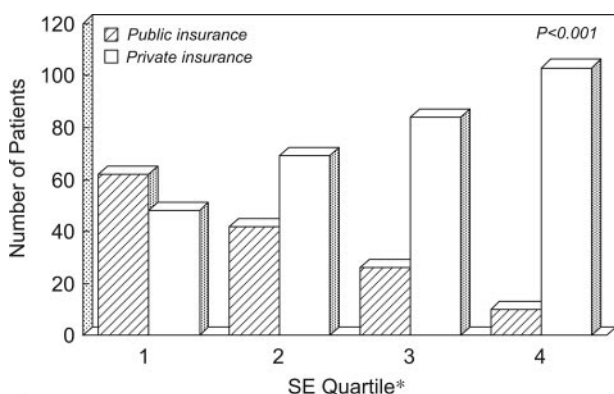
	Prenatal Diagnosis (n=222)	No Prenatal Diagnosis (n=222)	P Value
SE quartile*			0.001
1	39 (18)	71 (32)	
2	53 (24)	58 (26)	
3	61 (27)	49 (22)	
4	69 (31)	44 (20)	
Insurance status			<0.001
Public†	40 (18)	100 (45)	
Private	182 (82)	122 (55)	
Percent below poverty level‡	6 [3, 12]	8 [4, 15]	0.008
Race			0.54
Black	16 (7)	15 (7)	
White	135 (61)	120 (54)	
Hispanic	12 (5)	17 (8)	
Asian	4 (2)	5 (2)	
Other	11 (5)	8 (4)	
No answer	44 (20)	57 (25)	

Data are presented as n (%) or median (range) [interquartile range].

*Group 1 corresponds to patients living in most disadvantaged block groups and group 4 to those living in most advantaged areas. The method of calculating the SE score is described in the Methods section.

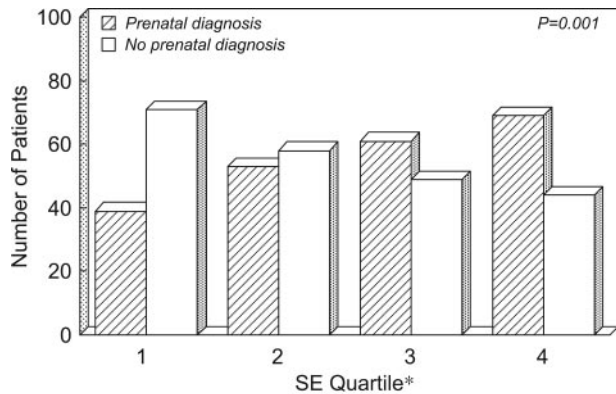
†Public or no insurance coverage, as noted in Methods section.

‡Poverty level as defined by the federal government.



*Increasing SE quartile implies higher socioeconomic position.

Figure 2. Insurance type by SE quartile. An inverse relationship exists between insurance type and SE quartile. Patients of a higher SE position are significantly more likely to have private insurance.



*Increasing SE quartile implies higher socioeconomic position.

Figure 3. PD by SE quartile. An inverse relationship exists between PD and SE position. Patients of a higher SE position are significantly more likely to have a PD of critical CHD by FE.

medical insurance, SE position was less strongly associated with prenatal diagnosis of CHD, and type of medical insurance was the most powerful predictor of PD. This may be explained by the finding that patients from high SE neighborhoods were also more likely to have private insurance. Geographic factors such as driving distance to the nearest center offering FE were not associated with prenatal diagnosis of CHD, as driving distances were equivalent between the 2 groups. These results demonstrate that prenatal diagnosis of CHD in the current era is significantly influenced by SE factors. The great majority of recent research evaluating inequity in access to advanced medical services and technology has focused on access to adult cardiovascular innovations. To our knowledge, this is the first study to evaluate and demonstrate inequity in access to advanced technology in fetal medicine and pediatric cardiac services. These findings are important because adequate obstetric screening and appropriate referral for FE services across SE groups may improve outcomes in neonates born with critical CHD. The effect of these disparities on patient outcomes needs to be closely examined.

The distribution of SE position was not similar across racial groups in our study. A high proportion of blacks and Hispanics lived in the low SE (first quartile) neighborhoods. However, we did not find an association between race and PD in our population. Disparities in health care and outcomes are well known in racial minorities.²¹ Although genetic/biologi-

Table 5. Multivariate Logistic Regression Model

	OR	95% CI	P Value
SE quartile			
1	1.0	...	
2	1.5	(0.8, 2.8)	0.21
3	1.8	(0.9, 3.5)	0.08
4	1.9	(1.0, 3.8)	0.06
Medical insurance			
Public	1.0	...	
Private	3.4	(2.1, 5.5)	<0.001
Poverty level (each 0.1 increase)	1.0	(0.8, 1.2)	0.73
Race			
White	1.0	...	
Nonwhite	1.4	(0.8, 2.5)	0.19
Unknown	0.9	(0.5, 1.4)	0.58

Outcome variable indicates PD by FE. All displayed variables evaluated concurrently in regression model.

cal and cultural differences between racial groups have been proposed to explain some of these differences, race is also a social construct, and is likely that SE variables play a powerful role in differences in health outcomes across different racial/ethnic groups.²² The importance of SE position is further highlighted by evidence from population studies that SE position is associated with health inequities within all racial/ethnic groups.^{23–25} Our results support previous studies that suggest that SE position, not race, is a more significant determinant of health and health-related outcomes.^{18,19,22,26} When inequities in treatments (rather than outcomes) exist, they are observed most prominently for innovative technologies and specialized medical services. Variability in access to semielective therapies related to quality of life has been associated with type of insurance coverage.¹⁶ Our study demonstrates that the use of FE, a technology available for more than 20 years, remains incomplete and unequal among SE groups. Whether these findings represent just one example of widespread disparities in pediatric advanced care or are limited to use of FE during prenatal care is unknown and requires further evaluation.

With dramatic improvements in ultrasound technology and FE techniques over the past 2 decades, FE has evolved into a powerful tool for the PD of CHD. In addition to providing the

Table 4. Race Relationships With Insurance Status and SE Quartile

	Black (n=31)	White (n=255)	Hispanic (n=29)	Asian (n=9)	Other (n=19)	No Answer (n=101)	P Value
Insurance							<0.001
Public	18 (58)	57 (22)	15 (52)	4 (44)	9 (47)	37 (37)	
Private	13 (42)	198 (78)	14 (48)	5 (56)	10 (53)	64 (63)	
SE quartile							<0.001
1	14 (45)	37 (15)	16 (55)	2 (22)	6 (32)	35 (32)	
2	10 (32)	69 (27)	7 (24)	1 (11)	4 (21)	20 (20)	
3	3 (10)	72 (28)	3 (10)	2 (22)	5 (26)	25 (25)	
4	4 (13)	77 (30)	3 (10)	4 (44)	4 (21)	21 (21)	

Data are presented as n (%).

reassurance of a normal FE in those pregnancies determined to be at high risk for CHD, PD of CHD using FE allows for informed decision-making regarding pregnancy options, appropriate modification to obstetric monitoring, and careful management of the peridelivery period to ensure proper care of the neonate with CHD. Although the impact of PD of CHD broadly on neonatal morbidity and mortality has yielded conflicting results,^{4–6} other studies in select populations, such as infants with hypoplastic left heart syndrome, as well as transposition of the great arteries, have shown clear improvements in both morbidity and mortality with PD.^{7,8} In addition, the rapidly evolving role of fetal intervention in carefully selected patients to modify the severity of disease, limit the progression of cardiac dysfunction and secondary pulmonary and cerebral pathology, and promote improved postnatal surgical outcomes^{27,28} is another potential beneficial therapy that is critically dependent on a timely fetal diagnosis.

Careful prospective study to more fully evaluate the barriers to timely PD of CHD is required, and it is likely that these findings could be extended more broadly to prenatal diagnosis of other congenital defects. Recognizing the presence of disparities or inequities in care is an important first step toward developing solutions. A critical evaluation to understand the etiology of these disparities and subsequent systematic investigations into various approaches to eliminate them are the natural steps that follow. The potential targets for such interventions are not only patients but also providers and health care organizations. Multi-level culturally sensitive interventions that target the mechanisms and causes of these disparities are most likely to be successful.^{29,30}

Limitations

Because of its retrospective nature, this study has several limitations. First, the study sample was largely drawn from a single (New England) region of the United States and may not be representative of the entire US population. However, the study population was heterogeneous (<30% patients lived within 30 miles of Boston) with a broad sample of population densities, as well as varied provider-payer relationships and practice cultures. These results, nevertheless, should be confirmed in other regions. Second, SE position of patients was defined by the SE characteristics of neighborhood of residence, and not personal or individual data obtained through direct interview of the family regarding income, education, and occupation. Some researchers advocate collection of SE data at multiple levels (individual, family, and neighborhood levels) to understand their relative contribution to health even though these variables may be highly correlated.³¹ Third, some patients may have moved between the time of their prenatal care and the time the dataset was constructed. In a prior study,²⁰ only 18% of study subjects had changed residence in a 6-year period with a high correlation between the baseline and follow-up summary SE score in these subjects. The time period of our study was shorter and thus the anticipated rate of moving was lower. In a random sample of 10% of patients from our study, only 2 patients (5%) had moved between the time of prenatal care and the time of the current study. The SE scores and quartiles for these patients remained unchanged. Fourth, the findings

regarding “race” must be interpreted with caution, as this variable was unknown for 101 of the study subjects (23%); this is likely because of this category being “optional” on demographic intake forms, and being self-reported, may not have been missing at random. Finally, we did not have access to the full details of prenatal care and thus cannot ascertain the precise obstetric factors responsible for lack of referral for FE. Although we suspect that missing, incomplete, or inadequate screening was more common in those lacking PD of CHD, this issue will require careful prospective study to answer.

Conclusion

Despite the expanding role of antenatal diagnosis in improving the management of neonates with critical CHD, our data demonstrate significant inequity in prenatal diagnosis in those with public health insurance and in low SE position. Prospective studies are warranted to elucidate more precisely the barriers to prenatal diagnosis and to evaluate the impact of this inequity on both short- and long-term patient outcomes.

Disclosures

None.

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