

**SOCIOECONOMIC STATUS IN PEDIATRIC HEALTH RESEARCH AND ITS ASSOCIATION
WITH CRITICAL ILLNESS AND OUTCOMES**

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DEDICATION

To my parents for always saying “okay!” when I had lofty ideas, like deciding to pursue a nursing career while I was recovering from major abdominal surgeries and had never taken a college-level science or math course.

To all the nurses who took care of me in the hospital, inspiring me with their intelligence, dedication, thoughtfulness, and sincere interest in me as both a patient and a person.

To all the nurses and doctors who continue to care for me.

And finally, to all the people who tried to dissuade me from becoming a nurse, you only further motivated me to become one.

“What an abyss of uncertainty whenever the mind feels
that some part of it has strayed beyond its own borders;
when it, the seeker, is at once the dark region through which it must go seeking,
where all its equipment will avail it nothing. Seek? More than that: create.

It is face to face with something which does not so far exist,
to which it alone can give reality and substance,
which it alone can bring into the light of day.”

- Marcel Proust

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ABSTRACT

SOCIOECONOMIC STATUS IN PEDIATRIC HEALTH RESEARCH AND ITS ASSOCIATION WITH CRITICAL ILLNESS AND OUTCOMES

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Children admitted to the pediatric intensive care unit represent a vulnerable population because of the seriousness of their health conditions and the delivery of critical care measures that include sedation and invasive procedures. Critically ill children of low socioeconomic status may be more at risk for greater illness severity upon admission to the pediatric intensive care unit and worst outcomes after discharge. We know that socioeconomic factors can adversely affect the health of children but how these factors specifically interact with aspects of pediatric critical care is not well understood. Current measurement practices of socioeconomic status in healthcare research vary widely, making comparisons between studies challenging. Furthermore, the choice of one socioeconomic measure over another in health research can result in different findings and subsequent conclusions. A new look into current socioeconomic status measurement practices is warranted; in addition, how a particular socioeconomic status measure is associated with critical illness and outcomes has not been studied in a large, United States-based, geographically diverse cohort of children mechanically ventilated for acute respiratory failure. This dissertation will use data from the *RESTORE* clinical trial [U01HL086622 and U01 HL086649(PI: Curley & Wypij)], a 31-site cluster randomized trial of a nurse-implemented sedation management intervention on mechanically ventilated children hospitalized for acute respiratory failure] to conduct secondary analyses on measures of illness severity, socioeconomic status, and health

outcomes that include resource use and health-related quality of life. By exploring associations between socioeconomic status, illness severity, and post-discharge outcomes, this dissertation will contribute new knowledge regarding how children of various socioeconomic backgrounds present upon admission and how they fare when they return home to their families.

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CHAPTER 1

INTRODUCTION

Advances in interprofessional care in the pediatric intensive care unit (PICU) have reduced mortality rates for critically ill children to 2-6%.¹ Because of decreasing mortality, critical care research has moved away from employing survival as a primary outcome of interest; rather, emphasis is on life *after* the PICU, and the short- and long-term physical, cognitive, emotional, and social morbidities that can arise.^{2,3} Critically ill children may be at increased risk for morbidities because of the totality of a critical care hospitalization: numerous invasive procedures, prevalent use of sedation, and the potentially traumatic experience of unfamiliar sights, sounds, equipment, and people amidst an austere sterile and restrictive environment. Critically ill children are already a vulnerable population, but children belonging to families of low socioeconomic status (SES) may be even more at risk for negative post-PICU outcomes because of a complex interplay of individual, family, and neighborhood characteristics, potentially arriving at the PICU more sick than their higher SES counterparts, and perhaps enduring worse quality of life after they return home.⁴

Factors related to low SES adversely affect the health of children and adults, but children are particularly vulnerable because of their dependence on parents/caregivers who may face numerous stressors and financial challenges. Low SES is highly correlated with the following health- and development-related factors: low birth weight, inadequate nutrition, uninsured or underinsured status, physical abuse, decreased health literacy, toxic stress, mental health diagnosis, and fewer opportunities for quality education.⁵⁻¹⁰ Without the necessary resources to buffer against these adversities and

prevent or attenuate them from affecting health, poor outcomes could result in devastating effects for the child, significant burden on families, and enormous costs to the healthcare system.¹¹ Many of the correlating factors present in “clusters”: for example, low birth weight, uninsured or underinsured household members, and inadequate nutrition. In addition to factors that could contribute to illness, lower SES populations may be more likely to delay treatment until illness becomes severe.¹² Children inherently adopt the socioeconomic status of their parent(s)/guardian(s) and have little opportunity to influence SES until age allows for more autonomy. For this reason, it is critical that: SES is robustly measured, socioeconomic mechanisms affecting health outcomes are identified, and interventions targeting modifiable socioeconomic mechanisms and/or policies are designed.

“Socioeconomic status” is a term and concept widely used across disciplines—nursing, medicine, public health, social work, education, political science, economics, sociology, and psychology—but there is a lack of concordance when it comes to defining and measuring it, not to mention a concerning absence of measurement theory supporting SES measure construction and use.¹³ Many studies have shown that SES impacts health outcomes along a positively associated gradient: as SES increases, health status incrementally improves.¹⁴⁻²⁰ Compared to other industrialized countries, SES-health gradients appear worse in the U.S., but they also garner less attention from a policy standpoint.²¹

Definition and measurement issues aside, the impact of SES factors on pediatric critical illness are rarely explored. On the contrary, SES is typically not included in PICU studies but when it is, SES is *controlled for* in statistical analyses.²²⁻²⁵ When SES is treated as a confounder, we cannot be certain if and how SES plays a role in illness severity, as well as post discharge morbidities and overall quality of life. When SES is

included as a variable—predictor or control—its measurement varies considerably: independent SES proxies include maternal/paternal education level, household income, occupation, the possession of a house and/or car, or some combination of these. In addition, SES data is typically obtained via self-report, but the sensitive, private nature of financial status measures often results in a significant amount of missing data. Nonetheless, when data *are* available, the heterogeneity of SES measurement approaches in pediatric health research makes it challenging to compare study populations, as a group categorized as “low SES” in one study may not be labeled such in another study.

Evidence from several pediatric critical care studies show that lower SES children are admitted to the PICU with higher illness severity.^{4,12} However, each of these studies took place in a single U.S. city (Washington D.C. and Los Angeles, respectively), which begs the question, do lower SES children arrive in the PICU with higher illness severity across the geographically diverse U.S.? If lower SES children *are* arriving at the PICU sicker, how do they fare after returning home, presumably to the same families and environments they came from prior to hospitalization? The current state of the science cannot answer either of these questions. As pediatric critical care researchers Aspesberro et al. write, “critical illness begins and ends outside of the ICU.”²⁶

The purpose of this 5-chapter, 3-paper dissertation is to describe measurement practices for conceptualizing SES in pediatric health research (Chapter 2), explore how SES is associated with illness severity on presentation to the PICU (Chapter 3), and examine the association between SES and post-discharge outcomes like health-related quality of life (HRQL) and resource use among PICU survivors (Chapter 4). Chapter 3 and Chapter 4 of this dissertation will utilize data from the *RESTORE* study (U011HL086622 and U01HL086649), a cluster randomized trial comparing the

outcomes associated with a nurse-led sedation management protocol versus usual sedation protocol.²⁷ The study enrolled 2449 children that were mechanically ventilated for acute respiratory failure across 31 U.S. sites (PICUs) and consented 2002 survivors for follow up six months after discharge. Chapter 3 and Chapter 4 will also utilize data from the U.S. census in order to assign a tract-based median income value to each *RESTORE* subject, based on place of residence.

The specific aims of this dissertation are:

Aim 1: To conduct a scoping review of the literature to describe current use and measurement of socioeconomic status (SES) in pediatric health research. (Chapter 2)

Aim 2: To examine the association between SES and illness severity at PICU admission in children with acute respiratory failure. (Chapter 3)

Aim 3: To examine the association of SES with health-related quality of life and resource use six months after PICU discharge in children who survived acute respiratory failure. (Chapter 4)

Background and Significance

Socioeconomic Status (SES)

Socioeconomic status (SES) has been described as: “one’s access to collectively desired resources, be they material goods, money, power, friendship networks, healthcare, leisure time, or educational opportunities,”²⁸ “differential access (realized and potential) to desired resources,”¹³ a “dimension of stratification which translates the objective distribution of societal resources into meaningful perceptions of relative desirability,”²⁹ and “all the human qualities that contribute to a certain level of income, education, and occupational status.”³⁰ SES “connotes one’s position in the social hierarchy,” with social hierarchy or “stratification” recognized as present in almost every society type.³¹

Despite the many definitions, there is little consensus regarding the operationalizing of “socioeconomic status” and how best to measure it.^{13,18,32,33} A prominent team of researchers, Robert and House³⁴ conclude that SES measurement and methodological issues will “remain unanswered” and are “perhaps unanswerable in a generic sense.” Krieger et al.,³⁵ focused on conceptual and measurement approaches to SES, suggest perceiving a measure not as “right” or “wrong,” but rather, looking at the advantages and disadvantages to each approach in the context of the specific study to be undertaken.

Measurement Strategies and Issues

Because SES is considered a latent construct, researchers take a variety of approaches to represent it: some employ singular measures as proxies (e.g. annual income), while others include more than one measure (e.g. income, education, and occupation) in multivariable models, justifying this latter approach due to low correlations between income and education (< 0.50) and therefore little risk of collinearity when predicting outcomes.³⁶ A lack of collinearity may suggest, however, that a singular measure of SES cannot be used as a proxy for another measure of SES, which further complicates the comparison of studies that do use different singular SES measures. Composite measures—constructed by combining multiple differently weighted SES measures—draw from multiple sources of measurement and reduce these into a single (scalar) entity, but this approach forfeits the potential for studying *how* singular SES-related factors influence health outcomes.^{13,35}

After an SES measure is chosen and used in a study, measurement issues continue to persist. For instance, “annual income” and “family household income” are represented as stable, reliable values, but they can fluctuate with time and are typically assessed by self-report. Income is frequently misreported in both directions due to

memory inconsistencies or purposeful misconstruing, making it a somewhat unreliable item in research.²⁸ There is also debate over whether income as an SES proxy should be viewed as a categorical or continuous variable—if the former, how many categories and with what boundaries? Furthermore, income is age-dependent, as retired individuals may not have income but could have substantial savings. Income is not equivalent to “wealth,” which has been suggested as a more robust indicator of SES because it refers to resources related to trust funds, real estate, and inheritances. Unfortunately, “wealth” is even more difficult to measure than income because it exists in so many forms, and “negative wealth” in the form of debt can complicate this concept.³⁶

Despite the variety of SES measures available, SES researchers Oakes and Rossi¹³ point out that measurement theory has been largely absent from SES measure construction: basic psychometric principles, such as validity and reliability, are not addressed. SES composite indices in particular lack psychometric testing and thus should raise caution when making inferences. The problematic issue of *how* SES is currently measured cannot be overstated. Sound measurement of SES is critical for understanding and quantifying inequalities between and within societal strata, and for postulating which SES mechanisms affect health outcomes and how they can be altered to optimize those outcomes.

SES is frequently treated as a control variable because it *confounds* statistical analyses, but it is widely recognized that SES factors *do* affect health either directly or through mediating mechanisms.¹⁸ In *Controlling for Socioeconomic status in Pain Disparities Research: All-Else-Equal Analysis When “All Else” Is Not Equal*, the authors argue that SES is a mediator between race and health, and cannot be a confounder by definition, as it is *in* the causal pathway.³⁷ Greenland and Robins³⁸ similarly argue that controlling for a variable like SES likely produces more bias than the researcher intends

to negate. Oakes²⁸ cautions against controlling for SES in regression analyses, as this kind of adjustment is actually a form of imputation and may give comfort to the researcher, but it also assumes that the proposed model is correct and that the “confounding influence” of SES *can* be controlled.

Socioeconomic Status Data Sources in the U.S.

The U.S. Census Bureau is the primary source of SES-related information on population and neighborhood levels, and it shapes policies based on information collected via surveys. Its mission is to “serve as the leading source of quality data about the nation's people and economy.”³⁹ The census counts each U.S. resident every ten years and is mandated by Article I, Section 2 of the Constitution. The census previously existed in short and long form, the latter of which asked more questions and was given to only one out of every six households. In 2005, the American Community Survey (ACS) was created to replace the long form of the census and is administered annually to 3.5 million American residents (adults only). The ACS is now the primary source for information regarding income, employment, housing characteristics, and educational attainment. The ACS collects data in order to assess social and economic needs in each U.S. community, and may be used to lobby for the provision of additional hospitals or schools. Responses to the decennial census and the ACS are required by law, and are obtained via Internet, mail, phone interviews, and in-person interviews; response rates are near 95%.

Socioeconomic Status and Confounding Issues

While this dissertation will not focus on self-identified race/ethnicity, several studies remark on the challenges of disentangling the effects of race/ethnicity and socioeconomic status, as these two demographic variables are strongly correlated.^{40,41} *RESTORE* collected race and ethnicity variables, and therefore they *will* be included in

data analysis in both Chapters 3 and 4. SES and race/ethnicity categories are closely intertwined in the U.S., more so than in countries with homogeneous populations. Numerous pediatric studies have analyzed relationships between race/ethnicity, and morbidity and mortality outcomes, some of which found significant associations.⁴²⁻⁴⁶

Low Socioeconomic Status in the U.S.

While there is not a precise definition of “low socioeconomic status,” it is generally accepted that individuals of low SES tend to be less educated, have less desirable occupations, and have lower incomes. They are more likely to be unemployed, uninsured or underinsured, and in fair or poor states of health. Neither income nor education deficits are the direct cause of poor health outcomes, but there are strong and pervasive connections between income and education, and the resources they procure, that have been demonstrated to affect health throughout the life course.³⁶ Mediating pathways and mechanisms by which income and education deficits operate are complex and understudied, but they are probable contributors to health outcomes and include nutrition, access to healthcare, stable housing, a cognitively stimulating home environment, discrimination, parenting style, stress, and coping patterns.^{32,35,36}

In the U.S., the National Center for Children in Poverty (NCCP) estimates that currently 15 million children (21% of children) belong to families living below the *federal poverty threshold*, a measure updated by the U.S. Census Bureau each year and primarily used for statistical purposes; the threshold does not vary by geographic location, though cost of living across the United States *does*.⁴⁷ Research has shown that the federal poverty threshold *underestimates* the actual needs of families by half; if this hypothesized measurement were considered the threshold, 43% of all children would be categorized as below the poverty threshold. In 2011—the midpoint of the *RESTORE* study—the overall U.S. poverty rate was 15.0% (46.2 million people) and the child

poverty rate was 21.9%.⁴⁸ In this same year, children comprised roughly 16% of the uninsured population, with an overall uninsured rate of 9.7%. (As of note, shortly after the close of the *RESTORE* study in 2015, due to the Affordable Care Act (ACA), this overall uninsured rate for children precipitously dropped to 4.8%⁴⁹).

While “poverty threshold” is a more familiar term, the *poverty guidelines* are what determine eligibility for federal programs such as Medicaid, Head Start, and the Supplemental Nutrition Assistance Program (SNAP), taking family size—but still not geographic location—into consideration. These too are updated every year but by the U.S. Department of Health and Human Services (HHS).⁵⁰ The variation within the federal government’s categorization of poverty, a measure that revolves around income, exemplifies the complexity and difficulty with operationalizing the even more nebulous term, socioeconomic status (SES). Nonetheless, federal guidelines affect how we conceptualize SES levels because they firmly and quantitatively demarcate what *is* and *isn’t* poverty. “Low socioeconomic status” is not federally defined but those living *in* poverty are usually considered to be of low socioeconomic status.

Low Socioeconomic Status and Child Development

Across fields such as epidemiology, psychology, education, and public health, it is widely demonstrated that SES is a strong predictor of health outcomes in both children and adults: low SES is associated with more diagnoses of preventable chronic diseases,⁵¹ more injuries,⁵² increased mortality,⁵³ and decreased cognitive performance.^{5,6,10} Low SES children experience “health disparities” that can result from lack of insurance or access to health care, insufficient income to provide adequate nutrition, and the tendency to live in more polluted areas. Health disparities exist when “a health outcome is seen to a greater or lesser extent between populations,” or more specifically, they are “a particular type of health difference that is closely linked with

social, economic, and/or environmental disadvantage."⁵⁴ Children are particularly vulnerable to SES-linked health disparities because they have little mobility or decision-making opportunities for changing their circumstances. The U.S. is unique in that it is the only "very highly developed" country on the United Nation's (UN) list of thirty-three developed countries without universal healthcare.⁵⁵

Childhood health provides the foundation for adult health, not to mention educational attainability and financial well-being. There is substantial evidence that childhood SES impacts adult health independent of adult SES, suggesting that even if SES improves from childhood to adulthood, the childhood SES effects may be enduring.^{36,56-59} Low SES has been found to shape a child's personality,⁶⁰ increase the incidence of aggression, depression, school absenteeism, child abuse, and neglect, and decrease rates of educational success and language ability.⁶¹

Socioeconomic Status and Pediatric Mortality

Socioeconomic status is inversely associated with infant, child, and adult mortality in the United States generally, and in acute hospital settings.^{19,62-65} Matching ZIP code level median income to patient data, a large retrospective study looked at the association between socioeconomic status and mortality in 42 U.S. children's hospitals.⁶⁶ Death occurred in 8950 of the 1,053,101 hospitalizations (0.85%) over the span of two years, 2009 and 2010. Compared to survivors, non-survivors tended to have government insurance (51.5% vs 47.5%, $p < .001$), use ICU services (55.1% vs 14.1%, $p < .001$), and require mechanical ventilation (87.1% vs 8.2%, $p < .001$). For all hospitalizations, there was a negative association between observed-to-expected mortality ratios and income, i.e. mortality rate decreased as income increased and vice versa. However, when hospitalizations were categorized by service (e.g. cardiac, respiratory, etc.), not all associations were significant, suggesting that

there is variability in the SES-mortality relationship depending on the body system and/or illness category.

Socioeconomic Status and Pediatric Critical Care Research

In a scoping review of all randomized controlled trials (RCTs) conducted in the pediatric intensive care unit (PICU) up until 2013, only 3 out of the 248 included studies reported on socioeconomic status.⁶⁷ The principal investigator of the review subsequently created an ongoing database of the RCTs that is updated quarterly and currently includes 377 PICU-based RCTs. The database and scoping review collectively show that four studies reported SES, but no study included SES in statistical models related to study outcomes.

While infrequently included in PICU-based randomized controlled trials and only as a demographic characteristic, SES *has* been explored as a potential causal mechanism in a handful of PICU studies. In a study utilizing census data and conducted in pediatric intensive care units located in Washington D.C., the authors found that lower SES children were disproportionately admitted to the PICU emergently and with higher illness severity.¹² When median household income increased by \$10,000, rates of PICU admissions fell by 9%. In this particular study, occupation and education variables—often used independently or together with income as a proxy for SES—were found to be less important indicators. A more recent study conducted in a Los Angeles PICU and focusing on the effects of racial/ethnic minority status and neighborhood-level SES on illness severity found that lower median income was associated with higher illness severity upon admission, but no variable was associated with PICU mortality, which was low in general (5.2%).⁴ This particular study was 57.8% Latino, and additionally found that living in a “Latino ethnic enclave” was associated with higher presenting severity of illness.

Illness Severity in Pediatric Critical Care

The pediatric intensive care unit admits a heterogeneous group of infants and children in need of specially trained staff and sophisticated equipment. Critical illnesses and injuries can range from neurological insults due to vehicular accidents or near drowning to common respiratory afflictions such as pneumonia or bronchiolitis that are severe enough to necessitate supportive care. Over the last three decades of pediatric critical care, length of stay and illness severity ranges have remained largely the same, while mortality has significantly decreased (11% in 1982 to 4.8% in 2005-2006); however, moderate or severe disability at follow-up has significantly increased (8.4% in 1982 to 17.9% in 2005-2006).² In a study that described all admissions in a 12-month period at 16 U.S. PICUs (n = 11,106), trauma accounted for 1.5% - 28.8% of admissions, while surgery accounted for 25.7% - 56.0%, demonstrating the difference in admission types among PICUs.⁶⁸

Critically ill children are collectively characterized by physiological dysfunction to the extent that there are disturbances in the body's homeostasis.^{69, 70} These disturbances are measured by the distance of specific physiological variables, (e.g. blood pressure, creatinine) from the accepted normal range. Depending on the variable and underlying diagnosis, higher and lower than normal values may both be indicative of dysfunction. These physiological variables are aggregated into a prognostic, composite score where a particular number of "points" are assigned to each variable proportional to its predictive weight. Prognostic scores were designed to predict risk of mortality but can also characterize baseline severity of illness.⁶⁹ The death rate operates as the measure that validates prognostic, composite scores like the Pediatric Index of Mortality (PIM) score and the Pediatric Risk of Mortality score (PRISM). PIM and PRISM are the most

widely used scores in pediatric critical care, with the PIM primarily used outside of North America and the PRISM within it.

In addition to predicting mortality risk, PRISM scores have been used to: control for severity of illness in studies; compare PICU quality of care by calculating standardized mortality ratios (SMRs); study resource utilization; assure that the process of randomization was successful in randomized clinical trials, with treatment and comparison groups balanced in terms of illness severity.^{71,72} While the PRISM score was not originally validated to predict long-term mortality risk or morbidity occurring after PICU discharge,⁶⁹ Pollack et al. tested its ability to predict morbidity in a prospective cohort study: morbidity rates, assessed with the Functional Status Scale (FSS), as well as mortality rates, were significantly associated ($p < 0.001$) with physiological dysfunction, as measured by PRISM III.⁷² Furthermore, as PRISM III scores increased (i.e. greater illness severity), so did morbidity risk, demonstrating a gradient effect that only ceased when potential morbidities progressed to death. Pollack et al.⁷² conclude that new morbidities can be concurrently modeled with mortality using PRISM III scores, suggesting that PICU-based measures of illness severity may be able to predict health status after discharge.

While PRISM III represents dysfunction throughout the body, several markers of illness severity are particular to the respiratory system: oxygenation index (OI), oxygenation saturation index (OSI), and severity of pediatric acute respiratory distress syndrome (PARDS), which is based on the worst OI or OSI from the first 24 hours of PICU admission.⁷³ The OI, assessed through an arterial line, and the OSI, assessed by a pulse oximeter, are associated with respiratory failure and indicate hypoxemia severity. There are four PARDS severity categories.

Health-Related Quality of Life (HRQL)

Health-related quality of life (HRQL) has been described as, “how well a person functions in their life and his or her perceived well-being in physical, mental, and social domains of health”⁷⁴ and “those aspects of self-perceived well-being that are related to or affected by the presence of disease or treatment.”⁷⁵ It is well-established that morbidities observed post PICU discharge could contribute to a decrease in HRQL.⁷⁶⁻⁷⁸ Additional studies have found that lower SES contributes to lower HRQL scores in children.⁷⁹⁻⁸³

HRQL instruments focus on the *burden* or *perception* of current functional status, allowing for the possibility that an “objective” assessment of function may not match the individual’s subjective assessment.⁸⁴⁻⁸⁶ The patient perspective is critical to understanding the effectiveness of critical care.⁸⁷ Post-discharge morbidity is often assessed using more objective measures like functional status or adaptive behavior scales, which relate to activities of daily living (ADLs), or what a child is capable and not capable of doing.³ When “functional status” and “HRQL” are used interchangeably, the assumption is that the perceived burden of dysfunction or illness is a result of changes in abilities. However, when functional abilities are held constant, child perceptions vary due to differences in temperament, personality, and family supports.⁷⁹ These HRQL measures therefore offer an interpretation of health status not captured by traditional physiological and functional endpoints.

Illness Severity and Health-Related Quality of Life (HRQL)

Several pediatric critical care studies have shown an inverse relationship between illness severity and HRQL.^{78,88-92} Polic et al.⁷⁸ found that higher severity of illness correlated with lower HRQL six months post PICU discharge, but not at two years; Ebrahim et al.⁸⁸ found a worsening in HRQL from baseline to one week, an improvement from one week to one month, but overall, HRQL was still poor at one

month. These studies suggest that follow-up time-points are important to consider when assessing HRQL and may be affected by factors such as diagnosis and age. In Buysse et al.,⁸⁹ illness severity was only associated with the physical functioning domains, as assessed by HRQL instruments. One of these studies states that unmeasured SES factors are likely influencing post PICU health and health related quality of life.⁹¹

Healthcare Resource Use

The usage of healthcare resources, sometimes referred to as healthcare utilization, includes medications, medical equipment, procedures, laboratory tests, appointments with providers, hospitalizations, homecare needs, and emergency room (ER) visits. Pediatric illness can affect the entire family, particularly if the child's health has not returned to baseline and new home care and healthcare resource needs arise.¹¹ An increase in pediatric resource use has been associated with diminished quality of life and overall productivity in the form of missed days of work and school.⁹³⁻⁹⁵ Post-PICU discharge resource use, therefore, reflects health needs that have financial implications for the family, regardless of SES. A single center study (n = 163) quantifying resource use after a PICU hospitalization that included respiratory failure found that a significant portion required new medications and homecare services up to two years after discharge, with functional status predicting these needs but without an investigation of any socioeconomic factors.⁹⁶

Socioeconomic Status and Follow-Up Research

It is important to the generalizability of studies to represent a diverse sample of the population in health research, but socioeconomic factors may affect participation in research. Pediatric research has shown that loss to follow-up (LTFU) can occur due to SES-related factors such as financial limitations, perceived burden in participating, and tendency to change residences. This may in turn contribute to sampling bias and

threaten external validity.⁹⁷⁻⁹⁹ Many studies have shown those lost to follow-up may be sicker than those who do follow up, thus preventing research on a vulnerable group that may have significant needs.^{91,100,101}

Innovation

To our knowledge, there are no studies focused on the association between socioeconomic status (SES) and presenting illness severity, and SES with post-discharge health-related quality of life (HRQL) and resource use in critically ill children enrolled in a large, multi-site clinical trial. Knowledge derived from a rich data source like the *RESTORE* study has the potential to inform future thinking about the care of our sickest and most vulnerable pediatric patients. *RESTORE* also included a six month follow-up component that may illuminate further insights into the long-term effects of a PICU hospitalization on the lives of both the enrolled children and their families. In addition, a proxy for SES will be considered as a contributor to presenting illness severity and post discharge life. More broadly, the scoping review may expose the problematic variability of measuring SES in pediatric studies and offer recommendations for best practices in future research.

Approach

This three-paper dissertation will explore what is known about the conceptualization and measurement of socioeconomic status (SES) in pediatric health research, and how SES may affect illness severity upon PICU admission as well as post PICU outcomes such as HRQL and resource use. In other words, how does SES impact both life leading up to and after PICU hospitalization? The first paper (Chapter 2) is a scoping review that addresses the measurement and use of SES in pediatric health research. It has been published in the October 2019 issue of *The Journal of Pediatrics*. The second paper (Chapter 3) will analyze associations between SES and measures of

illness severity in children with acute respiratory failure in the PICU. This manuscript has been submitted for review for publication. The third paper (Chapter 4) will examine the association of SES with health-related quality of life (HRQL) and resource use in children with acute respiratory failure six months after PICU discharge. Chapter 5 will summarize and integrate the major findings from Chapters 2-4, and present limitations, future directions, and conclusions.

Strengths and Limitations

For two of the three papers, this dissertation utilizes data from a large multicenter randomized controlled clinical trial that was rigorous in its evaluation of PICU sites, auditing of the sites throughout the duration of the trial, monitoring of data collection and analysis, and adherence to strict procedures related to the treatment of human subjects.²⁷ It was sufficiently powered and enrolled 2,449 subjects from 31 PICUs across the United States.

Secondary analysis can be a feasible strategy for addressing questions not posed in the parent study, but this is also a limitation of the specific aims of Chapter 3 and Chapter 4: socioeconomic status (SES) was not a predetermined variable of interest, but it can be reliably derived from provided residential information and the census-based methods described here. This secondary analysis of data includes post-discharge health-related quality of life—a secondary outcome of interest in the parent study—as an outcome of interest in Chapter 4. Secondary data analysis relies on the design, sampling, and procedures of the parent study; any weaknesses will factor into the findings of this proposed study. Lastly, SES as a causal mechanism cannot be assessed, but the substantial amount of data from the *RESTORE* trial may provide important insight into the field of pediatric critical care and how socioeconomic factors impact illness and outcome.

Operational Definitions

Operational definitions for the key terms discussed above and throughout the three studies will be provided below. While the conceptualization of “socioeconomic status” (SES) in pediatric health research will be the focus of the scoping review (Chapter 2), a preliminary definition is also included here.

A **scoping review** is a type of literature review that asks a broad research question, “maps” the key concepts in existing literature, identifies gaps, operationalizes definitions of important concepts, and summarizes key findings.¹⁰² Scoping reviews are preferred over systematic reviews when it is unclear what narrowly focused questions can be addressed, but the results of a scoping review may inform a future systematic review.

Socioeconomic status (SES) is a term that indicates one’s position in a stratified (hierarchical) society and is typically based on income, education, and/or occupation. It has also been defined as access to resources, whether these are concrete, such as material goods, or more abstract, such as power or social capital. SES is measured in a variety of ways including singular measures (e.g. income), multivariable measures (e.g. income and occupation), and composite measures that give a particular weight to each singular value before combining them into one scalar value.

For the purpose of the scoping review undertaken here (Chapter 2), **pediatric health research** refers to studies related to healthcare services and/or health outcomes for individuals under the age of 18 years old. The research could be conducted in a clinical setting but it could also take place in a child’s home or school, so long as it investigates a health-related variable.

The Randomized Evaluation of Sedation Titration for Respiratory Failure, abbreviated as **RESTORE**, was a cluster randomized controlled trial conducted in 31

U.S. pediatric intensive care units (PICUs) in order to compare outcomes associated with a nurse-led sedation management protocol (n = 1225) versus usual sedation protocol (n = 1224).²⁷ Inclusion criteria were as follows: intubated and mechanically ventilated, ≥ 2 weeks of age and < 18 years of age, and acute lung disease. Exclusion criteria included specific heart conditions, ventilator dependence at baseline, and spinal cord injury above the lumbar region, among others. A stratified random sample (n = 1360) was assessed six months after discharge for outcomes related to functional status, health-related quality of life (HRQL), post-traumatic stress disorder (PTSD), and resource use.¹⁰³

Children enrolled in *RESTORE* were mechanically ventilated for **acute respiratory failure**. Up to two-thirds of children admitted to the PICU, in general, will have a diagnosis of acute respiratory failure, caused by a myriad of etiologies such as pneumonia, bronchiolitis, intracranial injury, anaphylaxis, and muscular dystrophy.^{104,105} Several physiological characteristics contribute to a child's susceptibility to respiratory dysfunction: more compliant chest walls that make adequate tidal volumes difficult to attain, less elastic recoil, and smaller airways.¹⁰⁵ Acute respiratory failure is a result of impaired gas exchange, when one or both of the following occur: an adequate amount of oxygen is not present in the bloodstream or if carbon dioxide is not properly removed from the bloodstream.

In severe forms of acute respiratory failure, mechanical ventilation is necessary for adequate gas exchange, but it is accompanied by a risk of ventilator-associated secondary lung injury.¹⁰⁶⁻¹⁰⁸ The need for mechanical ventilation is one of the most common reasons for PICU admission, with 30%-64% of patients in the PICU requiring it for at least 24 hours.¹⁰⁹⁻¹¹¹ Children mechanically ventilated for acute respiratory failure

represent a particularly vulnerable cohort in the PICU, one that constituted the *RESTORE* population (n = 2449).²⁷

Illness severity is a measure of criticality within the first day of PICU admission and is often measured with the Pediatric Risk of Mortality (PRISM) score.⁷⁰ Four versions of PRISM have been published to date; this dissertation will focus on PRISM III-12, the version utilized in the *RESTORE* study. Illness severity is affected by physiological dysfunction that disturbs the body's homeostasis. PRISM III-12 represents these disturbances by assessing the deviation of variables from the accepted normal range. Points are assigned to each variable proportional to its predictive weight and these points comprise the PRISM III-12 score. This score characterizes baseline illness severity and predicts risk of mortality, with higher scores indicating greater illness severity and increased risk of mortality.⁶⁹ To specifically represent the severity of respiratory dysfunction, severity of pediatric acute respiratory distress syndrome (PARDS), based on the worst OI or OSI from the first 24 hours of PICU admission, are used.⁷³ The four categories of PARDS are: at risk (OI < 4 or OSI < 5), mild ($4 \leq \text{OI} < 8$ or $5 \leq \text{OSI} < 7.5$), moderate ($8 \leq \text{OI} < 16$ or $7.5 \leq \text{OSI} < 12.3$), and severe ($\text{OI} \geq 16$ or $\text{OSI} \geq 12.3$).

Quality of life (QOL) is defined as, "an individual's perception of their position in life, in the context of the culture and value systems in which they live, and in relation to their goals, expectations, standards and concerns."¹¹² **Health-related quality of life (HRQL)** is defined as QOL with the added dimension of "personal judgment over one's health and disease"¹¹³ and for children, HRQL can encompass "perceived health, health behavior, and well-being."⁷⁹ HRQL assessments can also be used to evaluate the impact of medical interventions and identify patients who may be at risk for disturbances in the physical, mental, social, and cognitive domains.⁸⁰ HRQL is typically measured by self-

report, but in the case of children who may be developmentally too young, parent proxy is used instead. The HRQL scores in a study can be measured against a normed reference group, or comparisons can be made between predetermined groups within the study, or a combination of these. Two measures of HRQL were used in the *RESTORE* study's follow-up: the Infant Toddler Quality of Life Questionnaire-97 (ITQOL-97) and the Pediatric Quality of Life Inventory, Version 4.0 (PedsQL). The ITQOL-97 is completed by parents for children between 2 months and 6 years, and includes items related to eating, feeding, and sleeping routines, and adjustments to new situations.¹¹⁴ The PedsQL is utilized for children over the age of 2 years and categorizes statements into four sections, all rated on a Likert scale: Health/Activities, Feelings, Getting Along With Others, and School.¹¹⁵ In *RESTORE* the ITQOL was primarily used for children 2 years and younger but it was used in children as old as 6 years old when the PedsQL was problematic due to developmental impairment.

Resource use is the usage of healthcare resources including medications, medical equipment, procedures, laboratory tests, provider appointments, hospitalizations, homecare needs, and emergency room (ER) visits. In this dissertation (Chapter 4), resource use will specifically include the following, collected six months after discharge from the PICU: in-home healthcare, healthcare providers, homecare medical equipment, prescribed medications, visiting the ER, and hospital readmissions.

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CHAPTER 2

SOCIOECONOMIC STATUS IN PEDIATRIC HEALTH RESEARCH: A SCOPING REVIEW

Abstract

Objective: To conduct a scoping review of the literature to describe current conceptualization and measurement of socioeconomic status in pediatric health research.

Study Design: Four databases were used to identify relevant studies, followed by selection and data extraction. Inclusion criteria for studies were the following: enrolled subjects <18 years old, included a health-related outcome, published from 1999 - 2018, and explicitly measured SES.

Results: The literature search identified 1768 publications and 1627 unique records. After screening for duplication and relevance, 228 studies satisfied the inclusion criteria, with 75% (n = 170) published since 2009. There were 52 unique singular measures and an additional 20 composite measures. Income-related measures were used in 65% (n = 147) of studies and measures of education in 42% (n = 95). The majority of studies using census-derived variables or insurance status were conducted within the previous ten years.

Conclusions: Pediatric studies employ a variety of SES measures, which limits comparisons between studies. Few studies provide an evidenced-based rationale that connects the SES indicator to the health outcome, but the majority of studies do find a significant impact of SES on outcomes. SES should be comprehensively studied so that meaningful measures can be used to identify specific SES mechanisms that impact child health.

Introduction

Socioeconomic status (SES), consistently associated with child health outcomes, encompasses a broad array of factors and has been described as: “one’s access to collectively desired resources, be they material goods, money, power, friendship networks, healthcare, leisure time, or educational opportunities,”¹ a “dimension of stratification which translates the objective distribution of societal resources into meaningful perceptions of relative desirability,”² and “all the human qualities that contribute to a certain level of income, education, and occupational status.”³ However, there is little consensus on how SES should be defined, measured, and used in research and practice.⁴⁻⁷ The practice of *controlling* for SES is widely debated, as SES-related factors likely mediate its association with health outcomes.^{1,5,8}

There is a well-established gradient effect between child health outcomes and SES: as one’s SES improves, health status incrementally improves.⁹⁻¹⁴ The SES-health gradient, however, has demonstrated steeper linear trends for some pediatric health outcomes, such as asthma severity and learning disability incidence¹⁴ and curvilinear trends for infant mortality.⁹ This gradient variation suggests multiple mechanisms through which SES impacts health outcomes. Low SES is correlated with low birth weight, inadequate nutrition, physical abuse, and fewer opportunities for quality education.¹⁵⁻²⁰ Given this correlation, it is imperative that SES be robustly measured, SES mechanisms affecting child health outcomes be identified, and interventions and/or policies targeting *modifiable* SES mechanisms be designed.

Here, we report a scoping review in order to gain a better understanding of current practices of SES measurement in pediatric research, which may shape our consideration of child health issues and the conclusions we draw about health outcomes. We focus exclusively on healthcare studies conducted in the United States

(U.S.), a developed country with relatively high rates of poverty and healthcare spending, but without universal healthcare or a government-designed SES index. An improved conceptualization of what SES measures (and what it does not) may lead to more reliable ways of identifying SES differences in child health outcomes, as well as associated, modifiable SES-related factors.

Methods

Scoping reviews employ literature searches that address broad research questions, “map” the existing literature, identify gaps, operationalize definitions of important concepts, and summarize key findings.²¹ This scoping review follows the methodological framework developed by Arksey & O’Malley²², with recommendations put forth by Levac, Colquhoun & O’Brien²³: Relevant literature is included regardless of study design or quality of the evidence.²² Using the structure recommended for scoping reviews—Population, Concept, and Context (PCC)²⁴—we address the following research question: *How is socioeconomic status (concept) measured and used when children (population) are studied in U.S.-based pediatric healthcare research (context)?* “Pediatric healthcare research” refers to studies pertaining to healthcare services and/or health outcomes for individuals under the age of 18 years old. Pediatric research could be conducted in a clinical setting or in a child’s home or school, so long as it investigates a health-related variable.

Search Strategy

A search of the following databases was performed: PubMed, CINAHL, EMBASE, and the Cochrane Library, from 1999 to 2018. A biomedical librarian was consulted in the initial stages of designing the search strategy, which included the following MeSH terms tailored to PubMed: “pediatric hospital,” “hospitalized children,” “health care disparity,” “socioeconomic factor,” “socioeconomic status,” and “social

class.” Terms were combined in various searches using Boolean operators (AND and OR); the search was then adapted for the other three databases. The twenty-year span was chosen so that SES was conceptualized contemporarily, taking into consideration current occupational categories, educational opportunities, assistance programs, and healthcare access options. Inclusion criteria were as follows: available in free, full-text version, in English, peer-reviewed, U.S.-based, and enrolled participants less than eighteen years old. No limitations were placed on study design. Reviews were excluded in order to avoid double-reports about studies.

Research often includes SES as a demographic variable, typically displayed in a “Table 1,” and/or as a predictor variable in statistical analyses. We included research that acknowledges that SES *could* affect some aspect of health in children and subsequently included it in data analysis, as these studies presumably give more consideration to the use and measurement of SES than studies that exclusively use it as a demographic characteristic.

Screening and Selection

Titles and abstracts of retrieved articles were screened for eligibility, but full texts were read if relevance could not be assessed from the initial screening. Reference lists of included papers were consulted if references cited within the papers appeared to fit the inclusion criteria. The abstracts of these citations were reviewed using the same inclusion criteria, with examination of the full texts if necessary. Studies were excluded if they did not explicitly refer to SES and attempt to measure it: i.e., a study that looked at the effect of “educational level” but not SES was excluded.

Data Extraction

Study characteristics were extracted and tabulated. Extracted data included: title, publication year, sample size, study setting, study design, and SES measure. In

addition, relevant information regarding why a particular SES measure was used, data source, and conclusions about the effect of SES on an outcome were collected. Adhering to traditional standards of conducting scoping reviews, no assessment of study quality was performed.²² SES measures were analyzed and coded based on discriminating features such as “self-reported income” (=SelfIncome) versus census block-derived median income (=Census1). Measures were then categorized by overall type, i.e. “Education,” and subsequent frequency counts were calculated for each measure and category.

Results

The database searches initially produced 1606 articles, with additional records (n = 162) identified from reference lists. After duplicates articles were removed, 1627 unique articles remained. Records were excluded due to the following: not U.S.-based, children not enrolled as subjects, could not access, and SES was not explicitly referenced. After screening the abstracts of the remaining records, 782 articles were read in full in order to assess for inclusion. This resulted in a total of 228 publications included in the scoping review (see Appendix A). See Figure 2-1 for details on the search and selection process.

Study Characteristics

The characteristics of included studies can be found in Table 2-1. From the total number of studies meeting selection criteria (n = 228), 74.6% (n = 170) took place in the last ten years (2009 - 2018). The most frequently used study design was a cross-sectional observational study (n = 67) followed by secondary data analysis of existing datasets (n = 40). Only 4.8% (n = 11) of studies employed a randomized clinical trial design. The majority of studies (76.3%) took place in a healthcare setting, which could include hospitals, specialty clinics, community health centers, or primary care offices.

Several studies (n = 12) included multiple settings, such as data from the hospital *and* home, and 21.8% of studies took place in a school setting (n = 50). Sample sizes ranged from 30 subjects to 4.2 million subjects, with larger sample sizes occurring in more recent studies (See Figure 2-2). Secondary analyses were typically conducted with healthcare setting-derived datasets, including those from health departments, federally-funded representative studies like the National Survey of Children's Health, chart reviews, and disease-specific registries (e.g. cancer or cystic fibrosis). Research focused on a variety of illness types (e.g. autism and diabetes), body systems (e.g. cardiovascular and respiratory), and health-related topics (e.g. sleep and vaccination). Nearly 20% of the included studies (n = 45) focused on diet, nutrition, obesity or weight.

Socioeconomic Status Measures

A total of 460 SES measures were used in the included studies (n = 228), and of those, 52 were unique singular SES measures and an additional 20 were unique composite or index measures. The majority of studies (n = 167) employed either an index or multiple measures to represent SES, as opposed to a singular measure (n = 61). The majority of studies (n = 165) did not include a rationale for the measure that represented SES, while twenty-eight studies provided an evidence-based explanation for why the SES measure was chosen, in relation to the health outcome investigated in the study. The remaining studies either stated a rationale without justifying details or citations (n = 13), or merely cited a prior study that utilized the SES measure but without a clear connection to the review study's health outcome of interest (n = 22).

Measures were organized into nine groups by type (see Table 2-2).

Assistance/Aid (1) included forms of health-related assistance such as food stamps or health insurance. Demographic (2) measures included common variables like race and age. Education (3), Employment/Occupation (4), and Income/Poverty (5) consisted of

measures related to level of education, employment status or occupation type, and level of income or poverty, respectively. Index/Composite variables (6) were constructed from multiple SES measures—such as income, marital status, and education level—but represented by a singular value, often as a result of “weighting” the importance of variables based on factor analysis. The Ownership/Possession category (7) represented SES by the ownership of a home, car, or both. School-related measures (8) were derived from the percentage of a student body financially eligible for federally funded programs like free or reduced-price lunches and Head Start. Uncategorized variables (9) included having a smoker in the household, census-derived variables such as nearest distance to a major road, and self-perceived social status. In addition, two studies used a questionnaire to assess SES but did not describe the content or questions. This review included studies that used categorical and continuous approaches to represent a range of SES measurements. All nine groups included SES as a categorical variable but only three groups included continuous measurements (Education, Income, and Index/Composite Variable).

Common SES Measures

The most common SES measures in this review were related to income (n = 147), education (n = 95), index/composite variables (n = 58), and insurance status (n = 55). Self-reported annual income was the most frequently used income measure in this review (n = 49), followed by census-derived income at the ZIP code level (n = 28). Education was most often measured as a self-reported variable using the highest level achieved (e.g. less than high school, high school graduate, some college, etc.) by one or both parents. Index/composite variables combine SES measures, typically employing factor analysis, and included income (n = 18), education (n = 44), employment status (n = 32), and neighborhood characteristics (n = 12). Each index produced a single score

that places an individual or family along an SES spectrum. The Hollingshead Four-Factor Index of Socioeconomic Status (n = 24) utilizes four individual-level pieces of data (marital status, retired/employed status, educational attainment, and occupational prestige), while Diez Roux's nSES index (n = 4) uses neighborhood-level data from the U.S. census. Insurance status was often classified into three categories: private (or commercial), public, and uninsured.

Effects of SES on Outcomes

The majority of studies (n = 182) found that SES had a statistically significant effect on at least one health outcome of interest when controlling for other covariates, while four studies only detected an effect in the presence of an additional variable (e.g. ethnicity). Measures used in the studies that did find an effect are represented by each of the nine categories (e.g. Assistance/Aid) in Table 2-2. Nineteen studies found no impact of SES on health outcomes; these studies employed SES measures represented by every category except "Ownership/Possession" (see Table 2-2). The remaining studies (n = 23) did not report the presence or absence of an effect. Statistical approaches to testing for and presenting effects of SES on health outcomes varied but included the reporting of significance with p-values, raw beta coefficients, and odds ratios.

Levels of Measurement

The following structural levels of SES measurement were identified: individual, family, neighborhood, and school. At the individual level, SES was collected by self-report and represented by proxies such as child insurance status, maternal education level, home ownership, and marital status. The family level included household income and family structure, taking into consideration multiple or all family members. Neighborhood level measures encompassed a particular geographical area and were

usually derived from census data, based on ZIP code, tract, or block, with ZIP codes covering the largest area and blocks covering the smallest. They included measures of income, poverty, and education. It is possible that the school level could correlate with the neighborhood level, as place of residence can mandate site of school enrollment. Nonetheless, school level measures directly related to income-based eligibility for federally funded programs.

Discussion

As income inequality grows and gaps in health outcomes widen in the U.S., the importance of accurately representing SES becomes critical, particularly when SES is shown to influence health outcomes.^{25,26} The review reveals variability in the types of SES measures used and their potential to detect an effect of SES on outcomes, with no particular category (e.g. Education) or subcategory (e.g. highest maternal education level) emerging as more or less likely to significantly impact study outcomes. While the majority of measures are income-related, remaining measures such as occupation, home ownership, and education level are arguably associated with income as well. Despite the large number of studies included in this review, few provided a rationale for choosing particular SES measures.

Issues With Common SES Measures

Besides income, additional factors with financial implications, such as wealth and debt, are two powerful indicators of SES that research has shown to more accurately reflect one's financial standing.²⁷ A recent study found that hospitalization rates were higher in areas with greater income inequality, positing that neighborhood income inequality may decrease social cohesion and result in fewer clinics and resources for low income individuals.²⁸ Education level is less prone to error and more stable over time as compared with income, and categorized similarly across studies.

But education level fails to consider differences such as public versus private education, or 2-year versus 4-year colleges. Like education level, insurance status types are simple to categorize and can be found in hospital health records, but significant variability exists within a public program like Medicaid, with income eligibility varying by state and age (133% - 375% of the federal poverty level) and “medically needy” children qualifying regardless of income.²⁹ Furthermore, private insurance options widely differ in terms of costs and coverage.

Index/composite variables offer a more comprehensive measurement of SES, but they also reduce distinctive SES factors to a single number, thus attenuating the connections made between factors and health outcomes. This review featured 20 different index/composite variables, preventing comparisons of SES level and affected outcomes between studies. The commonly used Hollingshead Four-Factor Index is a psychometrically and conceptually problematic indicator of SES: it has been shown to have low predictive power compared with family income and parental education, was never validated, and was never published.^{30,31}

Measurement Challenges

U.S.-based research typically represents SES with a univariate measure, as was the case in most studies identified in this review, but a justification for *why* is rarely given.³² Research has shown that correlation between different SES measures can be low or moderate, suggesting that each measures a distinct characteristic.²⁷ For instance, insurance status, income, and parental education level as SES proxies may perform differently in a study investigating non-urgent pediatric ED use. This lack of interchangeability highlights the importance of carefully choosing *and* justifying a measure. There is no one solution to the measurement and methodological issues surrounding SES, but rather than perceiving a measure as “right” or “wrong,” it is more

useful to consider the advantages and disadvantages to each approach in the context of the specific study.^{33,34} Studies should not *control for* SES, because the complexity and scope of SES as a concept cannot definitively be represented by a proxy measure.³²

Regardless of the measure used, *measurements* are typically extrapolated from one time point, despite the fact that SES proxies are subject to change over time. When SES measurements are obtained by self-report, the sensitive nature of financial status-based measures in particular can result in a significant amount of missing data or, just as concerning, misreported data.³⁵ When income *is* reported, it can be intentionally misreported due to its association with the receiving of government aid and resources, taxes, and social status.⁸ Individuals at the middle of the income distribution for self-report variables are the most likely to respond, and to respond truthfully, which can then skew the data and its interpretation.^{36,37}

Levels and Precision of SES Measurement

SES is measured on different structural levels—individual, family, school and neighborhood—honing in on distinct social and economic facets of everyday life. Evidence shows that measurements of SES at the neighborhood-level can affect the health of individuals, beyond what may be gleaned exclusively from individual-level SES.^{27,38-41} In a study comparing neighborhood SES measures and assessing at which geographic-level (e.g. ZIP code, tract, or block) inequalities in health could be detected, tract-level SES produced the most consistent results, and measures of economic deprivation (e.g. % of persons below poverty) most accurately reflected SES gradients in health outcomes.⁴²

Race as a Confounder

While nine studies used race as a measure of SES, many more studies included it alongside SES as a demographic characteristic and potential variable in statistical analyses. Research across disciplines has remarked on the challenge of disentangling the effects of race/ethnicity and SES on health outcomes, particularly in a heterogeneous country like the U.S.^{43,44} Numerous pediatric studies have analyzed relationships between race/ethnicity, and morbidity and mortality outcomes, some of which found significant associations.⁴⁵⁻⁴⁹ However, many studies do not consistently analyze the effects of SES and race/ethnicity together *and* separately, to identify independent associations.

Strengths and Limitations

This review has many strengths, including the consideration of a range of study designs and settings, comprehensive searching of the literature, and a search strategy that involved multiple databases known to have distinctive focuses, including one that searches nursing literature. As is custom with scoping reviews, we did not rate the level of evidence, and therefore, we may have included studies of questionable quality that met the inclusion criteria. Methodological limitations may have narrowed the scope of the review: restricting the search to studies available in English may have resulted in missing key articles, but because our geographical area of interest is the U.S., this inclusion criterion was deemed appropriate.

Future Directions and Implications

It may be important for more pediatric studies to consider SES factors as potential influencers of outcomes. Some studies may benefit from employing a bio-ecological framework that includes SES factors as mechanisms operating along distinctive pathways that affect health outcomes.⁵⁰ Such a framework could account for social determinants of health (SDOH) which closely relate to SES. Identifying and

understanding the underlying mechanisms that situate an individual within a particular SES category and impact health, positively or negatively, are key to the development of interventions to improve outcomes. In a recent pediatrician-authored article from *Pediatrics*, recommendations were made for the purpose of screening for poverty-related SDOH during the clinical encounter, thus demonstrating that collecting SES and SDOH data can be utilized in real time in order to connect pediatric patients and their families with the resources and care they need.⁵¹ Screening tool questions—and eventually interventions—may target food insecurity, childcare vouchers, literacy programs or healthcare access.

It is unlikely that a singular SES measure will be ideal in all scenarios and settings; of importance here is how SES measurements are interpreted and used in relation to child health outcomes. Measuring to what extent specific SES factors contribute to outcomes cannot be accomplished without first having a reliable measurement of SES.³² Measurement theory, however, has been largely absent from SES measure construction in healthcare research.⁴ Sound measurement of SES factors is critical for understanding and quantifying inequalities between and within societal strata, and for postulating which mechanisms mediate the association between SES and health outcomes, and how they can be altered to optimize outcomes.

The wide variability in SES measurement practices, rationales, and hypothesized associations with health outcomes should caution researchers against comparing findings across studies. As demonstrated from this review, there is significant ambiguity that surrounds the term “socioeconomic status” when it is treated as a manifest variable rather than a latent construct: SES cannot be measured directly, but indicators that contribute to the *construct* of SES, such as education level and insurance status, *can* be measured. For this reason, we recommend referring to the

indicator itself (e.g. low income in lieu of low SES) when describing measurement and effects on health outcomes within and between studies. Furthermore, we recommend assessing as many indicators of SES as is practical to collect but with the caveat that each one should be justified based on evidence in the literature that presents theoretically plausible pathways leading from SES to health outcomes.

Conclusion

Pediatric studies in the U.S. employ a variety of SES measures, but few provide a rationale for why a particular measure was chosen. Measures should be justified with the health outcome in mind and limitations regarding measurement and data collection should be acknowledged. SES should not be controlled for in studies, as it is likely associated with factors that directly impact health outcomes. The majority of SES measures either explicitly or implicitly relate to income. If feasibility of SES data collection is a concern, area-based income is a relatively reliable and easily obtainable proxy for SES in a variety of U.S.-based studies. In order to make logical inferences regarding the impact of SES factors on health outcomes, and to compare findings across studies, the indicator used should be referred to instead of “SES.” SES should continue to be comprehensively studied so that optimal measures can be used for research and screening for SES-related factors that affect health outcomes.

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Figure 2-1. Selection process of articles to include in scoping review of socioeconomic status in pediatric health research.

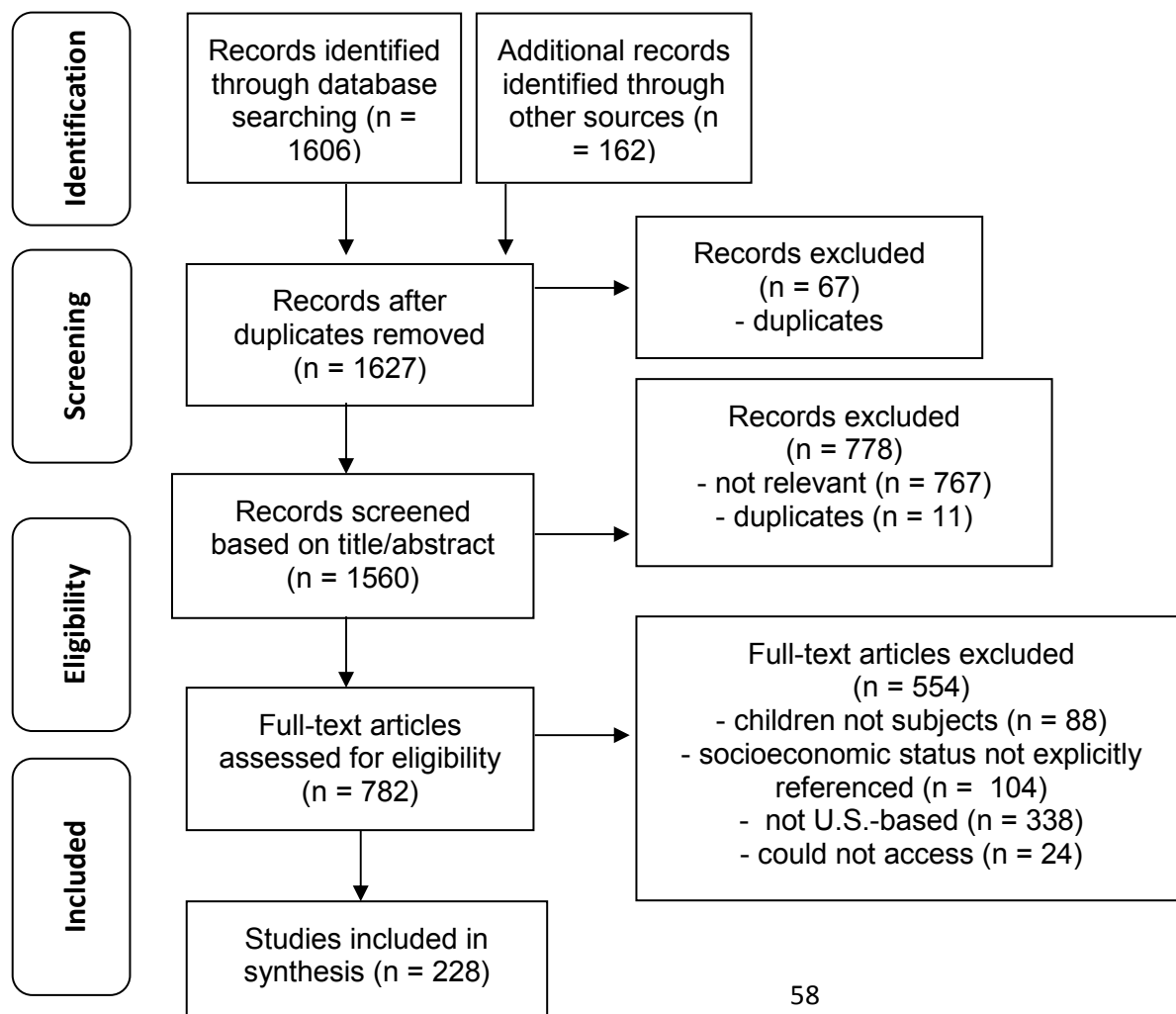


Table 2-1. Characteristics of Included Studies.

Characteristic	Number (n = 228)	Percentage (%)
<i>Publication year</i>		
2009 – 2018	170	74.6
1999 – 2008	58	25.4
<i>Study setting</i>		
Healthcare	174	76.3
School	50	21.9
Multiple Settings	12	5.3
Home	7	3.1
Unknown	3	1.3
<i>Study Design</i>		
Randomized Clinical Trial	11	4.8
Prospective Longitudinal	32	14.0
Prospective Cohort	16	7.0
Prospective Observational	4	1.8
Case-control	13	5.7
Retrospective Cohort	11	4.8
Retrospective Observational	33	14.5
Cross-sectional	67	29.4
Secondary Data Analysis	40	17.5
Qualitative	1	<1
<i>SES Measure</i>		
Income	147	64.5
Education	95	41.7
Assistance/Aid	63	27.6
Indexes/Composites	60	26.3
Demographic	32	14.0
Employment/Occupation	22	9.6
Uncategorized	16	7.0
School	13	5.7
Ownership/Possession	12	5.3

<i>Health Focus</i>		
Diet/Obesity	45	19.7
Cancer	17	7.5
Asthma	15	6.6
Behavioral	15	6.6
Psychosocial/Emotional	15	6.6
Cardiovascular	14	6.1
Cognitive/Language	14	6.1
Neurological	11	4.8
Multiple Illnesses	10	4.4
Diabetes	9	3.9
Inflammation/Infection	8	3.5
Respiratory	8	3.5
Autism	7	3.1
Cystic Fibrosis	7	3.1
GI/GU	7	3.1
Sleep	7	3.1
Musculoskeletal	5	2.2
Vaccination	5	2.2
Violence/Abuse	4	1.8
Auditory	3	1.3
Dental	3	1.3

Figure 2-2. Scatter plot of studies by sample size and publication year.

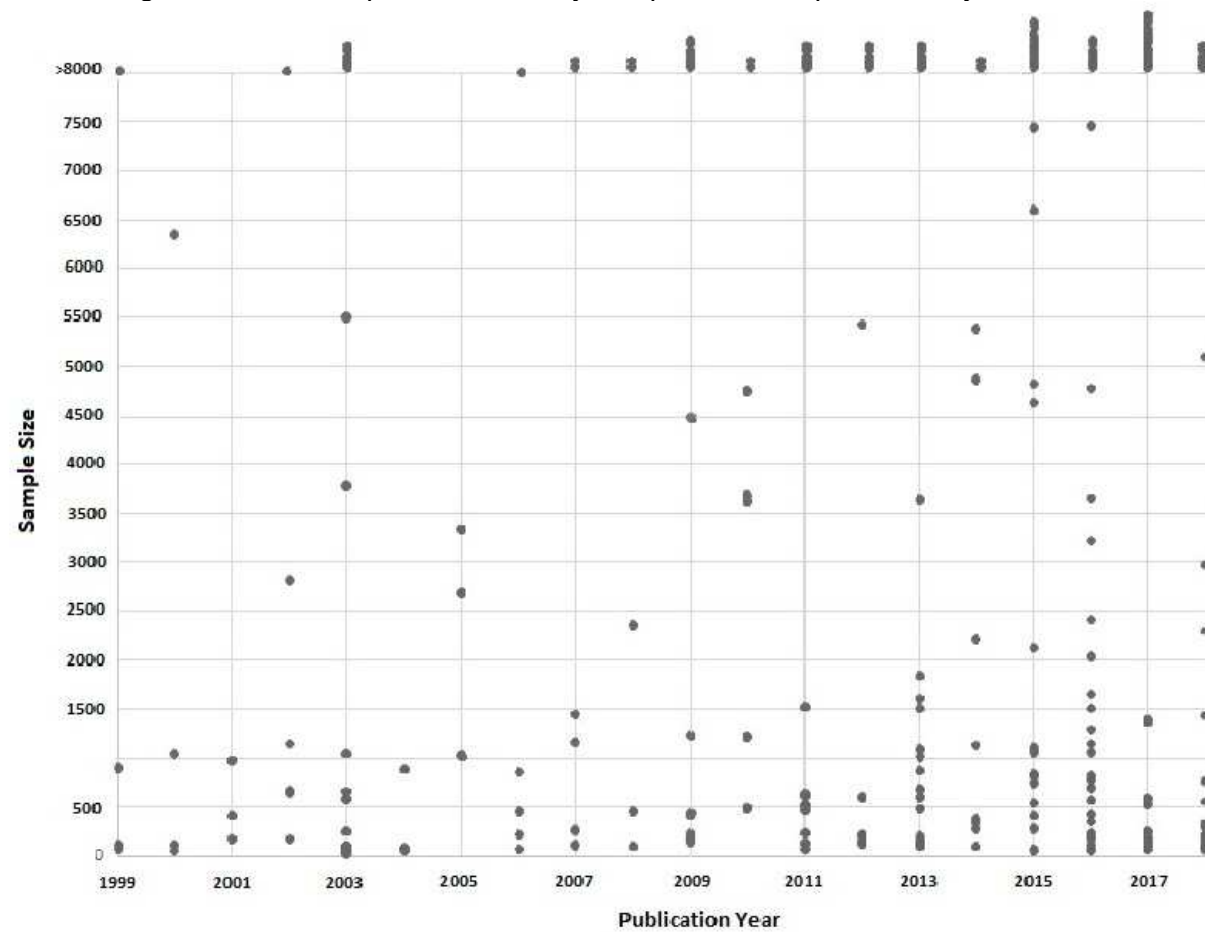


Table 2-2. Types of Socioeconomic Status (SES) Measures.

The measures below are organized into nine categories according to type. Included studies measured SES categorically and continuously. The range represents the number of groups when the SES type was measured categorically (e.g. insurance status as “Medicaid” vs “Private” vs “uninsured” = 3 groups). The mode represents the most commonly used number of groups.

Socioeconomic Measure	Number (n = 228)	Percentage (%)	Categorical Variable Range	Categorical Variable Mode
Assistance/Aid	63	27.6	2 – 5	2
Insurance Status	55	24.1		
Receiving Public Assistance	7	3.1		
Receiving SNAP Benefits	1	<1		
Demographic	32	14.0	2 – 5	2
Marital Status	10	4.4		
Race	9	3.9		
Family Structure	7	3.1		
Age	4	1.8		
Language spoken at home	1	<1		
# of children	1	<1		
Education	95	41.7	2 – 7	4
Highest education level (either parent, not specified)	37	16.2		
Highest maternal education level	29	12.7		
Area/census-based	14	6.1		
Highest education level between mother and father	11	4.8		
Highest paternal educational level	4	1.8		
Employment/Occupation	22	9.6	2 – 9	2
Employment status	12	5.3		
Occupation type	7	3.1		
% Blue collar workers	2	<1		
Military Officer Ranking	1	<1		
Income/Poverty	147	64.5		
Self-reported income	49	21.5		
Census-derived (ZIP code level)	28	12.3		
% Persons below poverty level	20	8.8		
Census-derived (tract level)	16	7.0		
Income-to-needs ratio	15	6.6		
Census-derived (block level)	13	5.7		
Unknown	4	1.8		
Census-derived (ZIP code tabulation zone level)	1	<1		
Perceived financial status	1	<1		
Index/Composite Variable	60	26.3	2 – 7	2
Other	30	13.2		
Hollingshead	24	10.5		
Diez Roux	4	1.8		
Gini	2	<1		
Ownership/Possession	12	5.3	2	2
Home	3	1.3		
Mean home value	4	1.8		
Car	2	<1		

*Other census variables include: high school graduation rate, % single female-headed household, distance to nearest major road, etc.

Appendix A (online supplement). Studies included in scoping review.

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CHAPTER 3

SOCIOECONOMIC STATUS AND PRESENTING ILLNESS SEVERITY IN CHILDREN WITH ACUTE RESPIRATORY FAILURE

Abstract

Objective

The purpose of this study is to investigate the association between socioeconomic status and illness severity upon PICU admission in children with acute respiratory failure.

Methods

Children, 2 weeks - 17 years old, mechanically ventilated for acute respiratory failure who were enrolled in the multicenter Randomized Evaluation of Sedation Titration for Respiratory Failure (*RESTORE*) clinical trial. This study is a secondary analysis of subjects who had parental consent for follow-up and residential addresses that could be matched with census tracts ($n = 2006$). Census tract median income was a proxy for socioeconomic status.

Results

Subjects were categorized into quartiles based on income, with a median income of \$54,036 for the census tracts represented in the sample. Subjects in the highest income quartile were more likely to be older, non-Hispanic white, and hospitalized for pneumonia. Subjects in the lowest income quartile were more likely to be black, younger, and hospitalized for asthma or bronchiolitis as well as to have normal functional status at baseline and histories of prematurity and asthma. Income quartiles were not independently associated with Pediatric Risk of Mortality (PRISM) scores. After controlling for age group, gender, race, and primary diagnosis, there were no associations between income quartile and either PRISM or pediatric acute respiratory distress syndrome (PARDS).

Conclusion

As measured, SES was not associated with illness severity upon PICU admission in this cohort of patients. More robust and reliable methods for measuring SES may help to better explain the mechanisms by which SES affects critical illness.

Introduction

Children belonging to families of low socioeconomic status (SES) may be at higher risk for poor outcomes because of a complex interplay of individual, family, and neighborhood characteristics. SES—measured by proxy variables such as education, income, or insurance status—and health outcomes can exhibit a gradient effect: as SES increases, health status improves.¹⁻⁷ In the United States (U.S.), low SES is correlated with many health- and development-related factors including low birth weight, inadequate nutrition, low maternal education level, decreased health literacy, and uninsured or underinsured status.⁸⁻¹³ In addition to factors that contribute to the initial cause and subsequent progression of illness, lower SES populations are more likely to delay treatment until illnesses worsen to the point of requiring hospitalization.^{14,15} As a result, low SES children may be at risk for greater illness severity upon pediatric intensive care unit (PICU) admission.

Illness severity represents to what extent physiological variables deviate from clinically normal ranges. Studies conducted in two major U.S. metropolitan areas found that lower SES children arrived at the PICU sicker than their higher SES counterparts, as measured by illness severity scores.^{16,17} In addition to higher severity scores, one of these studies found that low SES children were disproportionately admitted to the PICU, positing that primary care efforts for this group may have been lacking due to failures in the healthcare system at large.¹⁶ Specific SES-related factors such as poverty, literacy, and race/ethnicity are known to interfere with healthcare access and illness prevention, leading to worsening health conditions that can only be treated emergently.^{17,18} However, the association between SES and illness severity upon PICU admission has not been studied in a large, geographically diverse cohort of children admitted to U.S. hospitals. Using collected baseline demographic and health characteristics, we

examined the association between SES—operationalized using census tract median income—and severity of illness within the first day of PICU admission for acute respiratory failure. We hypothesized that lower median income would be associated with higher illness severity scores.

Patients and Methods

Study Design and Population

This study is a secondary analysis of the Randomized Evaluation of Sedation Titration for Respiratory Failure (*RESTORE*) study, a cluster randomized controlled trial that enrolled 2449 mechanically ventilated subjects across 31 U.S. pediatric intensive care units (PICUs) from 2009 – 2013 (ClinicalTrials.gov NCT00814099).^{19,20} Its primary aim was to investigate the impact of a nurse-led sedation management protocol (versus usual care) on duration of mechanical ventilation. While the intervention did not significantly reduce the duration of mechanical ventilation, analyses of secondary outcomes found that the intervention arm subjects were safely managed in a more awake and calm state and had less exposure to opioids but without a significant increase in inadequate pain and sedation management. Details of the study's methodology and primary results have been reported elsewhere.^{19,20}

Patients were eligible to enroll in *RESTORE* if they were mechanically ventilated for acute respiratory failure and were between 2 weeks and 17 years of age. Of the total *RESTORE* population, parents/guardians of 2138 subjects consented to post-PICU follow-up. Our sample of analysis consists of all subjects whose families consented to follow-up and provided residential addresses that could be matched with census tracts.

Data Collection

Baseline data included demographic variables, primary cause of acute respiratory failure, and functional status at baseline as measured by the Pediatric

Cerebral Performance Category (PCPC) and Pediatric Overall Performance Category (POPC).²¹ Illness severity was evaluated with two measures, including the Pediatric Risk of Mortality (PRISM III-12) score, a prognostic composite measure of criticality consisting of seventeen variables and representing physiological dysfunction.²² It was assessed within the first twelve hours of PICU admission, with higher scores indicating increased risk of mortality.²² The highest oxygenation index (OI) or the oxygenation saturation index (OSI) for each subject on day 0/1 was used to compute the severity of pediatric respiratory acute distress syndrome (PARDS) using the 2015 Pediatric Acute Lung Injury Consensus Conference (PALICC) criteria: 1) at-risk (OI, < 4.0 or OSI, < 5.0), 2) mild (OI, 4.0 to < 8.0 or OSI, 5.0 to < 7.5), 3) moderate (OI, 8.0 to < 16.0 or OSI, 7.5 to < 12.3), or 4) severe (OI, $\geq$ 16.0 or OSI, $\geq$ 12.3).²³ The OI is calculated using an arterial blood gas while the OSI uses a non-invasive pulse oximeter to acquire the peripheral capillary oxygen saturation (SpO₂). Each patient had at least one OI or OSI value, and for patients who had multiple values, the worst value was used to calculate PARDS severity.

The *RESTORE* study included SES-related questions in the follow-up phase, but 63% of subjects' consenting parents/guardians declined to provide their annual income and 29% did not provide highest level of education.²⁴ However, evidence shows that measurements of SES at the neighborhood level are both feasible to collect and can be representative of individual level SES, which is prone to underreporting as well as misreporting.²⁵⁻²⁹ As a result, we derived an approximation of a subject's SES using the U.S. census tract-derived variable, "median family income by presence of own children under 18 years" from the year 2011 (the midpoint of the *RESTORE* study) to represent SES. Income in particular has been linked to health outcomes because of the resources it procures, such as better healthcare and workplace benefits, as well as a tendency to

live in desirable, non-polluted areas and have higher social capital.²⁵ The residential address for each *RESTORE* subject was matched to a unique 11-digit code—2-digit state code, 3-digit county code, and 6-digit tract code—using the Census Geocoder.³⁰ We subsequently linked each 11-digit code to tract-level median income using the Census Bureau’s American Fact Finder.³¹ See Appendix A for details regarding the census as a data source and our methods of connecting census-derived data to the *RESTORE* dataset.

Statistical Analysis

Descriptive statistics were calculated for baseline characteristics and illness severity variables. Following U.S. census-level research recommendations, median income level was categorized into quartiles, which we have designated as Low Income, Low Middle Income, High Middle Income, and High Income.⁵ Because they reflect an ordinal progression, baseline characteristic and illness severity differences between quartiles were compared using the nonparametric Jonckheere-Terpstra test for ordinal and continuous variables and the Cochran-Armitage trend test for binary variables.³² Pearson’s chi square test was used to compare nominal variables (race and primary diagnosis). The Wilcoxon rank sum test was used to compare continuous variables between survivors and nonsurvivors. The association between PRISM III-12 and PARDS was assessed using the Spearman’s rank correlation coefficient.

Adjusting for PICU as a cluster variable, linear regression was used to model the effects of independent variables on PRISM III-12 scores using an exchangeable working assumption and cumulative logistic regression was used to model the effects of independent variables on PARDS severity using an independence working assumption. First, univariable models were created based on hypothesized associations between independent variables and each of the outcome variables. Next, multivariable models

were run including income quartiles as well as sociodemographic factors and primary diagnosis. Race and ethnicity were retained in final models to address potential confounding with income quartiles. Statistical analyses were performed using SAS (version 9.4; SAS Institute).

Results

Of the 2138 subjects who consented to *RESTORE* follow-up, 94% were matched to a census tract median income ($n = 2006$). Subjects were excluded from the current study if residential addresses were: unavailable ($n = 93$), incomplete ($n = 28$), did not sufficiently match a U.S. census tract ($n = 4$), were not U.S.-based ($n = 3$), or were connected to a medical facility ($n = 1$). Three additional subjects originally consented for follow-up withdrew from follow-up after PICU discharge, and thus were not included in this study. The median income for the census tracts represented in the sample was \$54,036 and the income distribution was positively skewed. Nonsurvivors were equally distributed across the income quartiles. Median income did not differ between the 43 subjects who died before PICU discharge and the 1963 who survived (\$55,837 vs. \$54,028; $p = 0.76$).

Differences between income quartiles were significant for all demographic characteristics and baseline health variables except gender, PRISM III-12 score, and risk of mortality (Table 1). Patients in the High Income quartile were more likely to be older, non-Hispanic white, and admitted to the PICU for pneumonia. Patients in the Low Income quartile were more likely to be black, of younger age, and have age-appropriate functional status (PCPC/POPC score = 1). They were also more likely to have a history of prematurity and asthma, and to be admitted for asthma or bronchiolitis. As income increased across the quartiles the proportion of subjects identifying as white also increased, while the proportion of subjects identifying as black decreased.

Illness Severity

PRISM III-12 scores were similar across income quartiles ($p = 0.57$; Table 3-1). Subjects who died before PICU discharge had higher PRISM III-12 scores (median = 13; interquartile range [IQR] = 8 – 21) compared with those who survived (median = 7; IQR = 3 – 12; $p < 0.001$). PRISM III-12 scores were independently associated with age group and primary diagnosis (Table 3-2). Compared with the reference age group (2 wk to < 1 yr), scores were 1.9 points higher for subjects 1 yr to < 3 yr, 2.1 points higher for subjects 3 yr to < 6 yr and 4.4 points higher for subjects 6 yr to < 18 yr. In addition, the Low Middle Income quartile had PRISM III-12 scores 1.0 points higher (95% confidence interval, 0.0 to 2.0; $p = 0.05$) compared to the Low Income quartile, though this is a small difference and overall there were no statistically significant differences among the four quartiles ($p = 0.29$). Race and ethnicity were not associated with PRISM III-12 but were retained in the multivariable analysis due to potential confounding with income. In a multivariable model controlling for age group, gender, race, ethnicity, and primary diagnosis, income quartile was not significantly associated with PRISM III-12 score ($p = 0.31$). Additional adjustment for functional status at baseline, history of prematurity, or history of asthma did not appreciably affect these results.

The two illness severity measures—PRISM III-12 and PARDS severity—were weakly correlated with one another (Spearman $r = 0.19$; $p < 0.001$). Subjects in the two oldest age groups (3 yr to < 6 yr and 6 yr to < 18 yr) had more than twice the odds of having severe PARDS than those in the reference age group (2 wk to < 1 yr). PARDS severity was significantly different across income quartiles ($p = 0.01$, Table 3-3). More subjects from the Low Income quartile were at risk for PARDS while more subjects from the High Income quartile had severe PARDS. The odds of dying before PICU discharge were more than five times as likely for subjects with severe PARDS as compared with

subjects who were at risk for PARDS (odds ratio = 5.39; 95% confidence interval, 2.51 to 11.57; $p < 0.001$). PARDS severity was independently associated with age group, gender, primary diagnosis, and the High Income quartile (Table 3-3). However, after controlling for age group, gender, race, ethnicity, and primary diagnosis, income quartile was not significantly associated with severe PARDS ($p = 0.96$). Additional adjustment for functional status at baseline, history of prematurity, or history of asthma did not appreciably affect these results.

Age was significantly associated with illness severity: younger children had less severe diagnoses (e.g. bronchiolitis), lower PRISM III-12 scores, and lower PARDS severity. Due to the strong association between age and illness severity, as well as the finding that there were more older children in the higher income quartiles, regression models were created for each age group separately. No statistically significant associations were found between income quartiles and either PRISM III-12 or PARDS for any of the age groups.

Discussion

In this geographically diverse cohort of children with acute respiratory failure, income was not associated with measures of illness severity upon PICU admission in multivariable models. Critically ill children are collectively characterized by physiological dysfunction to the extent that there are disturbances in the body's homeostasis.^{33,34} In the current study, when there was a significant independent relationship between a single income quartile and illness severity, the associated coefficient was small and not clinically relevant.

The fourth iteration of PRISM (PRISM IV), introduced in 2016, briefly addressed socioeconomic factors in its development and validation phase but excluded them from the algorithm.³⁵ PRISM scores over-predicted the mortality of the commercially-insured

and under-predicted the mortality of those with Medicaid or CHIP, which are associated with lower SES as both are entitlement programs based on household income. Unlike the PRISM III-12 score, PARDS focuses on illness severity within a single body system (respiratory). The weak correlation suggests that these two parameters are measuring different aspects of pediatric criticality and are independently relevant. Two retrospective studies using chart review, as opposed to prospectively collected data from recruited and consenting families, found an association between median income and illness severity.^{16,17} One of these studies took place in a predominantly Latino city¹⁷ and included race in regression models; the other did not report on race and was conducted in the Washington D.C./Baltimore area, which has a predominantly black population as compared with most other U.S. cities.¹⁶ These two homogenous and centralized populations differ from our geographically diverse population.

The present study included the following proportions by race compared with U.S. population proportions in 2011: white: 68.6% (study) vs 74.2% (U.S.); black: 21.2% (study) vs 12.6% (U.S.); multiracial: 5.0% (study) vs 2.7% (U.S.).³¹ In a secondary analysis of the *RESTORE* study, there were racial disparities in parental refusal of consent: as compared with white families, fewer black families were approached for consent and fewer black and Hispanic families consented.³⁶ A large secondary analysis ($n = 80,739$) using the Virtual PICU database (all U.S. PICUs) depicted a population racially disproportionate to that of the U.S.: 55.1% non-Hispanic white, 17.5% black, and 4.3% mixed race.³⁷ (The remaining categories and proportions were: 16.8% Hispanic, 2.9% Asian, and 3.4% unspecified). This may suggest that the *RESTORE* study's population was on par with the racial makeup of PICU populations, which tend to be *overrepresented* by minorities.

The income distribution of our study may not accurately represent the U.S. income spectrum: the sample's median income was lower compared to that of the entire U.S. in 2011 (\$61,619)³¹ but it included very few children from impoverished tracts. In 2011, the overall poverty rate for the U.S. was 15.0% and specifically for children living in poverty, 21.9%.³¹ The U.S. guidelines for living below the poverty threshold are calculated based on family size and while the family sizes for our study sample subjects are unknown, if each subject were to belong to a four-person household, only 5.9% of our sample would fall below the poverty threshold.

Income is a commonly used SES proxy, and at the census level can be analyzed at the state, city, tract, or block level, with census tracts comparable to neighborhoods and averaging 4,000 people, depending on population density.^{38,39} Epidemiological studies comparing the use of tracts vs. block groups when analyzing socioeconomic factors did not find significant advantages to examining populations at the block group level; however, tract- and block group-derived SES did not match ZIP Code-derived SES.⁴⁰⁻⁴²

Strengths and Limitations

This study presents a novel way of approximating SES in a secondary analysis of data from a rigorously conducted randomized controlled trial. Neither the parent study (*RESTORE*) nor this study was designed to test for causal effects of family income on illness severity measures. Furthermore, *RESTORE* did not include census-derived median income as a predetermined variable of interest, and a substantial amount of its parent-reported SES data was missing. The census-based methods described in this study were executed with accuracy and we believe they provide reasonable approximations to individual-level income data. However, the same dollar value for median income in a Midwestern small town versus a Northeastern large city may not

represent the same value and access to goods. In addition, our study only included residential addresses from about a third of PICU nonsurvivors and while they were equally distributed across the four income quartiles, we cannot be certain this pattern would have continued.

Our data reflected several trends that provide support for the use of this census-tract derived income method: children in the lowest income quartile were more likely to be black or Hispanic and have a history of asthma or prematurity; children in the highest income quartile were more likely to be white, with markedly lower rates of asthma or prematurity. These demographic and health-related trends are well documented in U.S. health disparity literature.^{43,44} It is possible that our census tract-derived median income variable did not reflect the substantial differences in income when stratified by racial identity.⁴⁵ Furthermore, due to discrimination and segregation, minorities experience more neighborhood-based poverty and less access to societal resources (e.g. quality education and housing), regardless of individual income level.⁴⁶

Self-reported income can be intentionally misreported, due to its association with the receiving of government aid and resources, taxes, and social status.⁴⁷ It is typically “missing not at random,” with high-income and low-income individuals withholding this information and skewing data.⁴⁸ Nonetheless, there is a margin of error of varying magnitude for each census-collected median income value related to missing data. An alternate SES measure, such as self-reported education level or insurance type, may have more substantially impacted illness severity because of associations with delay of care, healthcare access, lack of consistent primary care, and differences in recognizing and reacting to a developing illness course.

Conclusions

To our knowledge, this is the first paper that uses a novel method to explore the association between severity of illness and SES in a large, geographically diverse cohort of critically ill children. However, as we operationalized SES, it did not appear to have an association with presenting illness severity in children with acute respiratory failure. As more robust and reliable methods for measuring SES are developed, we may be able to better explain the mechanisms by which SES affects critical illness.

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TABLE 3-1. Baseline Characteristics and Illness Severity Measures According to Income Quartiles

Characteristics	Low Income^a (<i>n</i> = 501)	Low Middle Income^a (<i>n</i> = 502)	High Middle Income^a (<i>n</i> = 501)	High Income^a (<i>n</i> = 502)	<i>p</i>^b
Age at PICU admission					
Median (IQR), yr	1.4 (0.3-6.1)	1.5 (0.3-7.0)	1.8 (0.4-7.9)	3.5 (0.6-10.3)	<0.001
<i>n</i> (%)					<0.001
2 wk to < 1 yr	231 (46.1)	226 (45.0)	190 (37.9)	158 (31.5)	
1 yr to < 3 yr	98 (19.6)	80 (15.9)	100 (20.0)	80 (15.9)	
3 to < 6 yr	46 (9.2)	61 (12.2)	58 (11.6)	66 (13.2)	
6 to < 18 yr	126 (25.2)	135 (26.9)	153 (30.5)	198 (39.4)	
Male, <i>n</i> (%)	297 (59.3)	277 (55.2)	256 (51.1)	274 (54.6)	0.07
Race, <i>n</i> (%)					<0.001

White	238 (47.6)	347 (69.5)	380 (76.0)	411 (82.0)	
Black/African American	201 (40.2)	105 (21.0)	74 (14.8)	45 (9.0)	
Multiracial	41 (8.2)	25 (5.0)	17 (3.4)	18 (3.6)	
Other^c	20 (4.0)	22 (4.4)	29 (5.8)	27 (5.4)	
Hispanic ethnicity, <i>n</i> (%)	164 (32.9)	146 (29.4)	73 (14.7)	53 (10.6)	<0.001
Age-appropriate functional status at baseline, <i>n</i> (%)^d	397 (79.2)	363 (72.3)	366 (73.1)	340 (67.7)	<0.001
History of prematurity (< 36 wk postmenstrual age), <i>n</i> (%)	85 (17.0)	79 (15.7)	74 (14.8)	62 (12.4)	0.04
History of asthma (prescribed bronchodilators or steroids), <i>n</i> (%)	97 (19.4)	73 (14.5)	74 (14.8)	63 (12.6)	0.005
PRISM III-12 score, median (IQR)	7 (3-11)	8 (3-13)	7 (3-12)	8 (3-13)	0.57
Risk of mortality, median (IQR)	3 (1-8)	4 (1-14)	3 (1-10)	4 (1-12)	0.78
Died before discharge, <i>n</i> (%)	10 (2.0)	11 (2.2)	12 (2.4)	10 (2.0)	0.95

Primary diagnosis, <i>n</i> (%)					<0.001
Pneumonia	145 (28.9)	161 (32.1)	165 (32.9)	211 (42.0)	
Bronchiolitis	146 (29.1)	155 (30.9)	150 (29.9)	102 (20.3)	
Acute respiratory failure related to sepsis	62 (12.4)	63 (12.6)	61 (12.2)	78 (15.5)	
Asthma or reactive airway disease	68 (13.6)	39 (7.8)	43 (8.6)	36 (7.2)	
Aspiration pneumonia	28 (5.6)	28 (5.6)	32 (6.4)	33 (6.6)	
Other^e	52 (10.4)	56 (11.2)	50 (10.0)	42 (8.4)	
PARDS^f, <i>n</i> (%)					0.01
At risk	87 (17.4)	80 (15.9)	76 (15.2)	67 (13.4)	
Mild	125 (25.0)	101 (20.1)	122 (24.4)	106 (21.1)	
Moderate	136 (27.2)	166 (33.1)	129 (25.8)	147 (29.3)	
Severe	153 (30.5)	155 (30.9)	174 (34.7)	182 (36.3)	

IQR, interquartile range; PRISM III-12, Pediatric Risk of Mortality-III score from first twelve hours in the PICU; PARDS, Pediatric Acute Respiratory Distress Syndrome.

Not all column percentages sum to 100% due to rounding. Data are complete except for missing race ($n = 14$) and Hispanic ethnicity ($n = 7$).

^a Low Income < \$35,878; Low Middle Income = \$35,878 - \$54,036; High Middle Income = \$54,037 - \$80,357; High Income > \$80,357.

^b p values for comparison between the income quartiles were calculated using the Jonckheere-Terpstra test for ordinal and continuous variables, the Cochran-Armitage trend test for binary variables, and the Pearson's chi square test for nominal variables.

^c Asian, Native Hawaiian or Other Pacific Islander, American Indian or Alaskan Native.

^d Age-appropriate functional status at baseline was defined as Pediatric Cerebral Performance Category (PCPC) = 1 and Pediatric Overall Performance Category (POPC) = 1.²¹

^e Other diagnoses include: acute chest syndrome/sickle cell disease, acute respiratory failure post bone marrow transplant, chronic lung disease (cystic fibrosis or bronchopulmonary dysplasia), laryngotracheobronchitis (croup/tracheitis), pertussis, pulmonary edema, pulmonary hemorrhage, thoracic trauma (pulmonary contusion or inhalation burns).

^f PARDS severity was defined using the 2015 Pediatric Acute Lung Injury Consensus Conference (PALICC) criteria: at risk (OI, < 4.0 or OSI, < 5.0); mild (OI, 4.0 to < 8.0 or OSI, 5.0 to < 7.5); moderate (OI, 8.0 to < 16.0 or OSI, 7.5 to < 12.3); severe (OI, ≥ 16.0 or OSI, ≥ 12.3).²³

TABLE 3-2. Predictors of Illness Severity as Measured by PRISM III-12

Variables	Unadjusted Models		Multivariable Model	
	β (95% CI) ^a	p^b	β (95% CI)	p
Age (ref = 2wk to <1yr)		0.002		0.008
1yr to <3yr	1.9 (1.1, 2.7)	<0.001	1.1 (0.3, 1.8)	0.004
3yr to <6yr	2.1 (0.9, 3.4)	<0.001	1.0 (-0.4, 2.3)	0.15
6yr to <18yr	4.4 (3.3, 5.6)	<0.001	2.8 (1.6, 4.0)	<0.001
Female gender (ref = male)	0.7 (0.0, 1.3)	0.07	0.2 (-0.5, 0.9)	0.57
Race ^c (ref = white)		0.37		0.42
Black/African American	0.1 (-0.9, 1.0)	0.85	-0.1 (-0.9, 0.7)	0.79
Multiracial	0.4 (-1.4, 2.1)	0.67	0.6 (-1.1, 2.3)	0.47
Other	1.0 (0.1, 2.1)	0.07	0.8 (-0.1, 1.6)	0.07

Hispanic ethnicity ^c (ref = non-Hispanic)	-0.8 (-1.7, 0.1)	0.10	-0.3 (-1.1, 0.5)	0.49
Primary diagnosis (ref = bronchiolitis)		0.002		0.007
Pneumonia	2.4 (1.4, 3.4)	<0.001	1.1 (0.0, 2.3)	0.04
Acute respiratory failure related to sepsis	8.5 (7.5, 9.6)	<0.001	7.1 (6.0, 8.2)	<0.001
Asthma or reactive airway disease	4.4 (3.1, 5.7)	<0.001	2.8 (1.4, 4.1)	<0.001
Aspiration pneumonia	4.3 (3.4, 5.3)	<0.001	2.9 (1.5, 4.3)	<0.001
Other	3.8 (2.6, 5.1)	<0.001	2.6 (1.2, 4.1)	<0.001
Income quartile ^d (ref = Low)		0.29		0.31
Low Middle	1.0 (0.0, 2.0)	0.05	0.9 (-0.1, 1.9)	0.08
High Middle	0.6 (-0.4, 1.6)	0.26	0.3 (-0.7, 1.3)	0.55
High	0.8 (0.0, 1.6)	0.06	0.1 (-0.5, 0.8)	0.69

PRISM III-12, Pediatric Risk of Mortality-III score from first twelve hours in the PICU; CI, Confidence Interval.

Higher PRISM scores are associated with greater illness severity.

^a $\beta > 0$ indicates higher level of PRISM compared to the reference group.

^b Variables significant at $p < 0.20$ in unadjusted analyses were included in the multivariable analysis.

^c Race and ethnicity were included in the multivariable analysis to control for potential confounding with income.

^d Income quartile was included in the multivariable analysis because it is the predictor variable of interest.

TABLE 3-3. Predictors of Illness Severity as Measured by PARDS

Variables	Unadjusted Models		Multivariable Model	
	OR (95% CI) ^a	<i>p</i> ^b	OR (95% CI) ^a	<i>p</i>
Age (ref = 2wk to <1yr)		<0.001		<0.001
1yr to <3yr	1.45 (1.13, 1.85)	0.003	1.45 (1.13, 1.86)	0.003
3yr to <6yr	2.70 (1.96, 3.72)	<0.001	2.74 (2.02, 3.73)	<0.001
6yr to <18yr	2.56 (2.02, 3.24)	<0.001	2.54 (1.90, 3.38)	<0.001
Female gender (ref = male)	1.25 (1.06, 1.47)	0.01	1.18 (0.97, 1.42)	0.09
Race ^c (ref = white)		0.83		0.90
Black/African American	0.90 (0.73, 1.12)	0.35	0.96 (0.76, 1.22)	0.74
Multiracial	0.93 (0.61, 1.40)	0.72	1.07 (0.71, 1.61)	0.76
Other	0.90 (0.63, 1.29)	0.58	0.86 (0.57, 1.31)	0.48
Hispanic ethnicity (ref = non-Hispanic)	0.86 (0.71, 1.04)	0.13	0.96 (0.78, 1.19)	0.74
Primary diagnosis (ref = bronchiolitis)		0.02		0.07
Pneumonia	2.11 (1.74, 2.55)	<0.001	1.31 (1.05, 1.64)	0.02
Acute respiratory failure related to sepsis	1.98 (1.46, 2.69)	<0.001	1.17 (0.79, 1.73)	0.44
Asthma or reactive airway disease	1.23 (0.93, 1.61)	0.13	0.64 (0.46, 0.88)	0.006
Aspiration pneumonia	1.72 (1.19, 2.47)	0.004	1.00 (0.70, 1.43)	0.99
Other	1.85 (1.28, 2.67)	0.001	1.13 (0.77, 1.64)	0.53
Income quartile (ref = Low)		0.10		0.96
Low Middle	1.14 (0.92, 1.41)	0.23	1.05 (0.84, 1.32)	0.67
High Middle	1.17 (0.93, 1.47)	0.17	1.04 (0.82, 1.31)	0.78
High	1.35 (1.07, 1.70)	0.01	1.07 (0.81, 1.41)	0.64

PARDS, Pediatric Acute Respiratory Distress Syndrome; OR, Odds Ratio; CI, Confidence Interval.

PARDS severity was defined using the 2015 Pediatric Acute Lung Injury Consensus Conference (PALICC) criteria.²³ Higher scores are associated with greater illness severity.

^a Odds ratio > 1 indicates greater risk of having a higher level of PARDS compared to the reference group.

^b Variables significant at $p < 0.20$ in unadjusted analyses were included in the multivariable analysis.

^c Race and ethnicity were included in the multivariable analysis to control for potential confounding with income.

Appendix A: The United States census as a data source and methods for connecting census and subject data

The mission of the United States (U.S.) Census Bureau is to “serve as the leading source of quality data about the nation’s people and economy.”¹ As mandated by Article I, Section 2 of the U.S. Constitution, the census counts each U.S. resident every ten years; in addition to achieving the most accurate population count, the census asks residents a series of demographic questions, including number of people living in the household and self-identified race. The census survey has existed in both short and long form, but in 2005 the American Community Survey (ACS) was created to replace the long form; the ACS is administered annually to 3.5 million American residents, roughly 1% of the total U.S. population. The ACS is the primary source for socioeconomic status-related information on both population and neighborhood levels. Based on this demographic and socioeconomic collected information, federal funds are then allocated to schools, hospitals, public works, and roads.² Data for both the decennial census survey and the ACS are obtained via internet, mail, phone, and in-person, with response rates for both near 95%.

The census divides the U.S. into geographically smaller meaningful units, allowing for a variety of data analyses at the ZIP Code, tract, and block group levels. The United States Postal Service (USPS) created ZIP Codes—Zone Improvement Plan Codes— in order to make mail delivery more efficient, but they can span large areas comprised of socioeconomically heterogeneous populations. Census tracts, on the other hand, are “small, relatively permanent statistical subdivisions of a county” and are “designed to be homogeneous with respect to population characteristics, economic status, and living conditions.”³

Each *RESTORE* subject is represented by a unique identification number, which is linked to a residential address, including street number and name, city, state, and ZIP Code. Residential addresses were initially reviewed for misspellings (e.g. Walnut Streat) and edited as needed. We created “Dataset A,” which included the street number and name, city, state, and ZIP code for each *RESTORE* subject. Dataset A was loaded into the Census Geocoder where each residential address was matched with measures of latitude and longitude as well as a 2-digit state code, 3-digit county code, and 6-digit tract code.⁴ These three numerical strings were concatenated to form a unique 11-digit code. Residential addresses that returned either a “no match” or a “non-exact match” were checked against the *RESTORE* study’s original case report forms (CRFs). Online searches often revealed misspellings or transposed numbers originating from the CRFs. Dataset A was continuously cleaned and loaded into the Geocoder until all residential addresses were linked to an 11-digit code.

“Dataset B” was created by downloading median income for every census tract in the United States from the Census Bureau’s “American Fact Finder.”⁵ This dataset also included the 11-digit code for each tract. Microsoft Excel was used to link the two datasets by merging queries on the 11-digit code. Fifty subjects chosen at random were manually geocoded and individually matched to median income via “American Fact Finder” in order to perform an accuracy check.

Appendix A references

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CHAPTER 4

ASSOCIATION OF SOCIOECONOMIC STATUS WITH RESOURCE USE AND QUALITY OF LIFE IN CHILDREN WITH ACUTE RESPIRATORY FAILURE AFTER INTENSIVE CARE DISCHARGE

Abstract

Importance: Socioeconomic factors may impact healthcare resource use and health-related quality of life, but the extent to which they are associated with recovery post-pediatric critical illness is currently unknown.

Objective: The purpose of this study is to examine the associations between socioeconomic status, resource use, and health-related quality of life in a cohort of children recovering from acute respiratory failure requiring intensive care hospitalization.

Design: Secondary analysis of data from children with acute respiratory failure who were enrolled in the *RESTORE* clinical trial and whose parents consented for follow-up.

Setting: Thirty-one pediatric intensive care units in the United States.

Participants: Of those families who provided follow-up interview data ($n = 960$), 99.8 % ($n = 958$) matched to census tract data. Eight hundred and thirty-eight families completed health-related quality of life questionnaires.

Exposure: Socioeconomic status was estimated by matching the residential address of each study subject to census tract-based median income.

Main Outcome(s) and Measure(s): Resource use included the presence of in-home care, the number of healthcare providers and medications prescribed for routine use, newly prescribed homecare medical equipment, visiting the emergency department, and hospital readmission. Health-related quality of life was measured with one of two parent-report instruments depending on child age.

Results: The median census tract income of 958 matched subjects was \$58,482 (IQR: \$39,265-\$87,816). There was no association among income quartiles and illness severity. Compared with high-income children, low-income children had fewer healthcare providers ($\beta = -0.4$; $P = .004$) and less newly prescribed homecare medical equipment (OR = 0.4; $P < .001$). Young low-income children had physical ability scores 8.6 points

lower as compared with high-income children ($P = .01$). Health-related quality of life was lower for young children who had more healthcare providers and prescribed medications. For older children, health-related quality of life was lower if they had been prescribed medications, visited the emergency department, or had a hospital readmission.

Conclusions and Relevance: Many children recovering from acute respiratory failure have ongoing healthcare resource use. More children in the lowest income quartile visited the ED or had a hospital readmission, but they also had fewer healthcare providers managing their care, fewer medications prescribed, and were less likely to have new homecare medical equipment.

As a result of lower mortality rates, pediatric critical care providers are increasingly focused on post-discharge morbidity and, relatedly, improving the quality of life for survivors.¹⁻⁴ Recovery after critical illness can profoundly impact the entire family, particularly if the child's health has not returned to baseline and necessitates new healthcare needs after hospital discharge.⁵ While the majority of survivors are reported to have returned to their baseline health,⁶⁻¹² a portion of these children will develop new morbidities requiring healthcare resources and may experience diminished health-related quality of life (HRQL).¹³⁻¹⁵ Patient and family perceptions of health are critical to understanding the effectiveness of care and identifying who is at risk for altered HRQL.¹⁶⁻¹⁹

Data supports an inverse association between resource use and HRQL: an increase in resource use is associated with a decrease in quality of life.²⁰⁻²² The utilization of healthcare resources has financial implications for the entire family, regardless of socioeconomic status (SES), but differences in SES may affect the association between resource use and HRQL. SES, measured by various proxies, typically relate to a family's financial state and is generally positively associated with health outcomes—as SES increases, health outcomes improve.²³⁻²⁹ Resource use and its associations with SES and HRQL have not been sufficiently studied in a large group of pediatric critical care survivors.^{10,30-33} Here we quantify post-discharge resource use, examine the association of SES with resource use and HRQL, and examine the impact of resource use on HRQL in a cohort of children with acute respiratory failure, six months after intensive care discharge.

Methods

Parents/guardians of 2138 subjects from the Randomized Evaluation of Sedation Titration for Respiratory Failure (*RESTORE*) study consented to follow-up and 2002

subjects survived to hospital discharge (ClinicalTrials.gov NCT00814099).^{34,35} A random sample of 1360 eligible subjects, stratified by site and age group (<2, 2-4, 5-7, 8-12, and 13-18 years old), was selected for follow-up.^{36,37} Each consenting family was contacted at 6 months ($\pm$ 1 month) after the child's hospital discharge to complete interviews assessing outcomes that included healthcare resource utilization and HRQL. A priori secondary outcomes—HRQL, functional status, and post traumatic stress disorder—in this cohort were not found to be significantly different between the control and intervention arms in the *RESTORE* trial.³⁴ Our sample of analysis consists of subjects whose families completed follow-up interviews and whose residential address could be linked to a census tract.

Data Collection

Baseline data included demographic variables, past medical history, and preexisting conditions collected at *RESTORE* enrollment. Functional status was established at enrollment, hospital discharge, and six-month follow-up using the Pediatric Overall Performance Category (POPC) and Pediatric Cerebral Performance Category (PCPC) scales.³⁸ Additional clinical variables included the PRISM III-12 score,³⁹ severity of pediatric acute respiratory distress syndrome (PARDS) on post intubation day 0/1,⁴⁰ greatest number of dysfunctional organ systems during PICU hospitalization⁴¹, and duration of mechanical ventilation. PARDS severity was defined using the 2015 Pediatric Lung Injury Consensus Conference criteria. In addition to respiratory dysfunction (present in all enrolled children), dysfunction could have been present in the follow systems: cardiovascular, neurologic, hematologic, hepatic, or renal.⁴¹ PRISM III-12 and PARDS severity can both indicate baseline severity of illness on PICU admission. Number of dysfunctional organ systems and duration of mechanical

ventilation provide measures of patient criticality throughout the duration of the PICU stay.

Because 63% of families who completed follow-up interviews declined to provide annual income,³⁶ an approximation of SES was derived from census tract-level “median annual income by presence of own children under 18 years of age” from the year 2011 (the midpoint of the *RESTORE* trial). We then categorized median income values into quartiles, following U.S. census-level research recommendations,²⁷ and designated them as Low Income, Low Middle Income, High Middle Income, and High Income. Measurements of SES at the neighborhood level are feasible to collect and have been shown to be representative of individual data.⁴²⁻⁴⁶

Follow-up

Parents/guardians were interviewed six months after PICU discharge and reported on their education level and relationship status. Resource use variables were also self-reported and included care provided in the home by a healthcare professional or assistive personnel, the number and types of healthcare professionals providing ongoing consultation and care, medications prescribed for routine chronic use, new homecare medical equipment, emergency department (ED) visits, and hospital readmission. HRQL was assessed using one of two measures: the Infant Toddler Quality of Life Questionnaire-97 (ITQOL-97)⁴⁷ for children 2 years and younger and the Pediatric Quality of Life Inventory, Version 4.0 Generic Core Scales (PedsQL)⁴⁸ for children older than 2 years. The ITQOL, primarily used in children 2 years and younger but employed if developmental age made completing the PedsQL difficult, assesses 12 unique concepts such as general health, physical abilities, growth and development, pain and discomfort, and temperament and moods. The PedsQL evaluates HRQL in physical, emotional, social, and school domains. For both HRQL instruments, item

responses for each concept were scored, summed, and converted to a 0-100 scale where 0 = worst health and 100 = best health.

Statistical Analysis

To compare differences in clinical and resource use variables according to income quartile, the Cochrane-Armitage trend test was used for binary variables, the Pearson's chi square test for nominal variables, and the Jonckheere-Terpstra test for ordinal and continuous variables. Adjusting for PICU as a cluster variable, linear and logistic regression was used to model the effects of independent variables on continuous HRQL and binary resource use variables using an exchangeable working assumption. Cumulative logit regression was used for ordinal resource use and HRQL variables using an independence working assumption. In all models, a three-degree of freedom test was used to assess overall significance for income quartile with outcome variables. Regression models adjusted for age category, having a preexisting condition, PARDS severity, worst MODS, duration of mechanical ventilation, and functional status. Backward stepwise regression was used to test if resource use was associated with HRQL, represented by the growth and development domain for the ITQOL and the total score for the PedsQL. Statistical analyses were performed using SAS (version 9.4; SAS Institute).

Results

Of the 1360 subjects that were eligible and selected for *RESTORE* follow-up and matched to census tract data, 958 (70%) of families completed healthcare resource interviews and 750 of these (55%) completed HRQL questionnaires (352 completed the ITQOL and 398 completed the PedsQL) (Figure 4-1). There were no significant differences in median income between subjects that were preliminarily eligible and those selected for follow-up ($P = .23$). However, of those eligible and selected, there were

differences in the median income between the families that completed follow-up and those that did not (\$58,482 vs \$46,442; $P < .0001$). Baseline and hospital course characteristics for the study sample are summarized in Table 4-1. Preexisting conditions were present in one-third of the study population, the most common of which were asthma, seizure disorder, and neurologic/neuromuscular disorders. Most children were discharged to home ($n = 872$) and were at home at the time of follow-up ($n = 932$). There was no association among income quartile and preexisting conditions ($P = .83$), PRISM III-12 score ($P = .51$), PARDS severity ($P = .16$), or duration of mechanical ventilation ($P = .32$).

As presented in Table 4-2, resource use six months after PICU discharge was significantly different according to income quartile for the number of active healthcare providers ($P < .001$), prescription medications ($P < .001$), new equipment post PICU discharge ($P = .003$), and emergency department visits ($P = .04$). The majority of children ($n = 606$, 63%) used medical equipment in the home, with more than half of those children ($n = 353$, 58%) using *new* medical equipment (not used prior to PICU admission). Within six months after discharge, 41% ($n = 386$) visited an emergency department and 34% ($n = 328$) were readmitted to the hospital. Compared with children in the highest quartile, more children in the lowest income quartile visited the ED ($n = 78$ vs $n = 101$) or had a readmission ($n = 72$ vs $n = 92$). However, children in the lowest quartiles were less likely to have new medical equipment in the home. Types of medical equipment are shown in eTable 4-1.

In a multivariable model controlling for age group, preexisting conditions, PARDS severity, highest number of dysfunctional organs, duration of mechanical ventilation, and functional status at discharge, income quartile was significantly associated with number of healthcare providers providing on-going care, new medical equipment, and hospital

readmission (Table 4-3). Children in the lowest income quartile had fewer healthcare providers and were less likely to have new medical equipment as compared with those in the highest income quartile. While emergency department visits were not significantly associated with income quartile overall ($P = .10$), the odds of visiting the ED were approximately 50% higher for children in the lowest three income quartiles as compared with those in the highest income quartile. The odds of having a readmission were approximately 70% higher for children in the High Middle income quartile as compared with those in the High income quartile. Functional status at discharge was strongly predictive of most resource use variables, with those with some degree of disability more than three times as likely to have in-home healthcare.

As shown in Table 4-4, in a multivariable model controlling for the same covariates noted above, HRQL in young children was associated with income quartile for the ITQOL subscore measuring physical abilities: scores were 8.6 points lower for children in the lowest income quartile as compared with children in the highest income quartile. While particular income quartiles were associated with the pain and discomfort and the temperament and moods domains, they were not statistically significantly different overall. Functional status at discharge was highly predictive of most of the ITQOL domains, and those with severe disability/vegetative state scored 44.5 points lower on the physical disabilities domain than those with age-appropriate functional status. For the growth and development domain, as level of disability increased, scores decreased.

In older children whose parents completed the PedsQL, income quartile was not associated with the total score or any of the subscores (Table 4-5). Age category was highly significantly associated with most PedsQL scores, with those in the youngest age category having higher scores than the other three age categories. In total score as well

as all subscores, children in the 8 to <13 year old age category consistently had the lowest scores of all age categories. In terms of functional status, children with moderate disability had the worst PedsQL scores in all domains compared with all other levels of functional status.

In a backward stepwise regression model controlling for income quartile, age category, preexisting condition, PARDS severity, duration of mechanical ventilation, highest number of dysfunctional organs, and functional status, two of the six resource use variables were associated with lower scores on the ITQOL's growth and development domain: scores were 2 points lower for each additional healthcare provider ($P < .001$) and 2.6 points lower for each prescribed medication ($P = .004$). In another backward stepwise regression model controlling for the same covariates, three of the six resource use variables were associated with lower PedsQL total scores: 1.6 points lower for each prescribed medication ($P = .04$), 4.4 points lower if the child had visited the ED ($P = .05$), and 5.8 points lower if the child had a readmission ($P = .02$).

Discussion

Among children recovering from acute respiratory failure, there are differences in post-PICU resource use and quality of life according to different income levels but it is unknown whether these differences impact continued recovery post PICU hospitalization. Quality of life was affected in the ITQOL's physical abilities domain with respect to income quartiles whereas there were no differences for children whose families completed the PedsQL. Overall, these findings indicate that income-based differences in resource use and diminished HRQL exist post critical illness. It is well established that even low income children who have healthcare coverage face more barriers to healthcare access and reliable, regular sources of care.^{26,28,29} The financial

and time constraints associated with low SES may preclude the ability of parents to garner healthcare resources for their child post critical illness.

A portion of children in each income quartile did not see a pediatrician in the six months after PICU discharge (10% in the lowest quartile and 19% in the highest quartile). More children in the lowest income quartile visited the ED and were readmitted to the hospital, but they had fewer healthcare providers and less new medical equipment: did these low income children have an illness that could have been prevented with better primary or subspecialty care, as their resource utilization (e.g. providers and equipment) was less than that of the higher income children? Alternatively, do these low-income children have resource needs that are not being met? One study that followed healthcare utilization for two years after PICU discharge found that one-fifth of the patients were referred to a specialist alone and one half were readmitted to the hospital, the majority of these to the PICU.⁴⁹ It is possible that better care coordination post PICU discharge could help identify patients at risk for readmissions or preventable health problems. Even if resource utilization within the first six months after discharge is minimal, post-PICU sequelae may take time to emerge and require attentive care on the part of providers, particularly for children who are continually developing in physical, cognitive, and emotional domains.^{50,51}

Measures of HRQL can reveal critical developments in a patient's state of health not detected by assessed clinical variables or physiological endpoints. Health in general, as well as growth and development, for young children did not differ by income quartile in the present study, but physical abilities were rated significantly lower for low income children whose parents completed the ITQOL. PICU survivors can be discharged with or subsequently develop impairments in physical functioning that may relate to illness course, treatments, or both.^{51,52} Controlling for illness course variables, a large study

conducted in French ICUs found that only the physical functioning items on the HRQL instrument were significantly lower for low SES adults.⁵³ Furthermore, there were no differences in mortality rates or length of stay in the same study. Because the low-income group in our study also had fewer healthcare providers and less new equipment in the home, it is possible that a socioeconomic difference in healthcare access is contributing to diminished parent-reported physical abilities. Specifically, physical rehabilitation or adequate physical activity could be lacking.

Both HRQL instruments demonstrated that higher scores were associated with children having fewer medications prescribed indefinitely, suggesting that these medications indicate ongoing health issues that substantially affect a child's day-to-day life, not to mention the family's. Interestingly, having in-home healthcare and newly prescribed medical equipment were not associated with HRQL after adjustment for other factors. For younger children whose parents completed the ITQOL, having more healthcare providers was associated with lower scores on the growth and development domain, but this was not the case for the PedsQL total score for older children. It is possible that older children could have had ongoing health issues for longer periods of time, and families have become accustomed to actively seeing healthcare providers in order to maintain their children's health or that a child's age affects the family's perceived burden of having more healthcare providers.

Strengths and Limitations

While the census-based methods described in this study were executed with accuracy, they may not reflect the actual income of each family. However, studies have shown that neighborhood-level income data can provide a reasonable approximation to individual-level income data.⁴²⁻⁴⁶ Our data reflected several trends that provide support for the use of this census-tract derived income method: children in the lowest income

quartile were more likely to be black or Hispanic and have a history of asthma; children in the highest income quartile were more likely to be white, with lower rates of asthma. Fewer low-income families who consented to follow-up actually completed it, potentially because of perceived burden of follow-up or the tendency to change residential locations due to housing instability. These demographic and health-related trends are well documented in U.S. health disparity literature, though less follow-up of lower income subjects is also a limitation of this study.^{54,55} It is possible that an alternative measure of SES, such as health insurance status, may have more significantly impacted resource use and HRQL due to its association with healthcare access and lack of consistent primary care. While HRQL was assessed six months after PICU discharge, we cannot be certain that the HRQL outcomes are directly *caused* by critical illness or the PICU care and treatment. No baseline HRQL measurements were available to evaluate potential changes in HRQL and subsequent associations with SES.

Conclusion

Six months after PICU discharge, many children recovering from acute respiratory failure have ongoing healthcare resource use. More children in the lowest income quartile visited the ED or had a hospital readmission, but after controlling for illness and functional status characteristics, children in the lowest income quartile had fewer healthcare providers managing their care, had fewer medications prescribed indefinitely, and were less likely to have new homecare medical equipment. PICU survivors require ongoing vigilance in order to identify emerging health concerns. Follow-up care of PICU survivors could help identify those children in need of healthcare resources and those at risk for decreased health-related quality of life.

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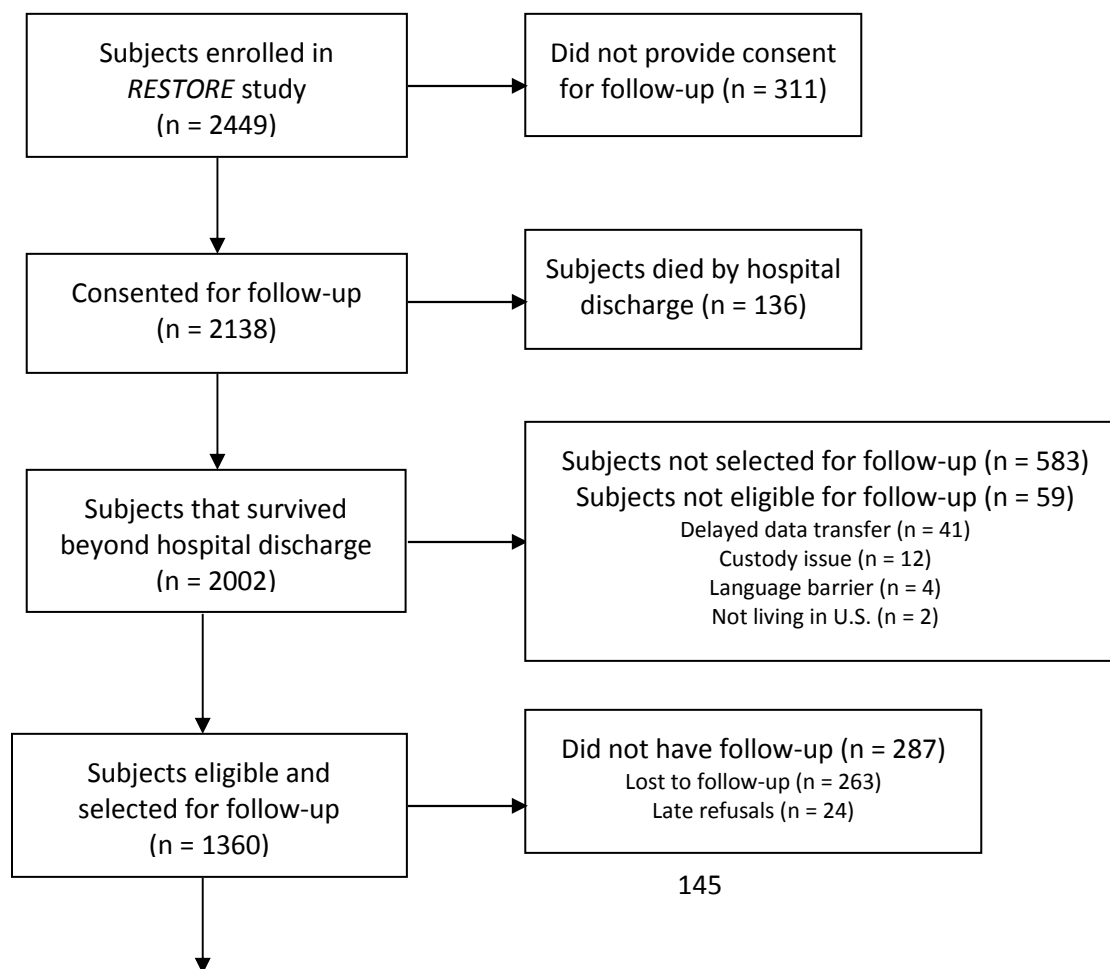
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Figure 4-1. Flow Diagram for Subjects Included in Current Study.



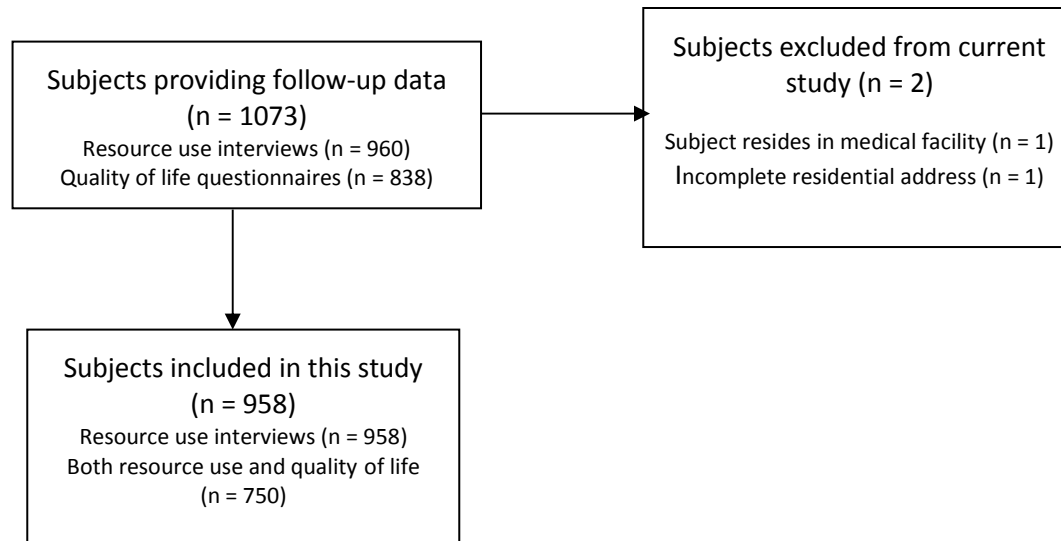


Table 4-1. Patient and Family Characteristics

Characteristics	All Subjects (n = 958)
Patient	
Age at PICU admission, median (IQR), yr	1.8 (0.4 – 7.9)
Age category, n (%)	
2 wk to <1 yr	357 (37)
1 to <3 yr	179 (19)
3 to <6 yr	132 (14)
6 to <18 yr	290 (30)
Female, n (%)	443 (46)
Race, n (%)	
White	687 (72)
Black/African American	171 (18)
Other ^a	94 (10)
Ethnicity, n (%)	
Non-Hispanic or Latino	746 (78)
Hispanic or Latino	208 (22)
Census tract-based household income, median, \$	58,482
Income quartile, \$	
Low Income	< 39,265
Low Middle Income	39,265 – 58,482

High Middle Income	58,483 – 87, 816
High Income	> 87,816
Functional status at baseline, n (%) ^b	
Age-appropriate	716 (75)
Mild disability	78 (8)
Moderate disability	70 (7)
Severe disability or vegetative state	94 (10)
History of prematurity (< 36 wk postmenstrual age)	138 (14)
Any preexisting condition, n (%)	323 (34)
Asthma (prescribed bronchodilators or steroids)	135 (14)
Seizure disorder (prescribed anticonvulsant medication)	88 (9)
Neurologic/neuromuscular disorder	83 (9)
Cancer	51 (5)
Bronchopulmonary dysplasia	20 (2)
Immunodeficiency (unrelated to cancer)	13 (1)
Sickle cell disease	7 (<1)
Cystic fibrosis	6 (<1)
Insulin-dependent diabetes	1 (<1)
Primary admitting diagnosis, n (%)	
Pneumonia or aspiration pneumonia	412 (43)
Bronchiolitis	248 (26)

Acute respiratory failure related to sepsis	115 (12)
Asthma or reactive airway disease	83 (9)
Other acute illnesses ^c	77 (8)
Other chronic illnesses ^d	23 (2)
Admission PRISM III-12 score, median (IQR)	7 (3 – 12)
PARDS severity, n (%) ^e	
At risk/mild	344 (36)
Moderate	287 (30)
Severe	327 (34)
Number of organ systems with dysfunction median (IQR) ^f	2 (1 – 3)
Duration of mechanical ventilation, d, median (IQR)	6 (4 – 11)
Functional status at hospital discharge, n (%)	
Age-appropriate	660 (70)
Mild disability	106 (11)
Moderate disability	78 (8)
Severe disability or vegetative state	101 (11)
Functional status at six-month follow up, n (%)	
Age-appropriate	671 (71)
Mild disability	96 (10)
Severe disability	73 (8)

Moderate disability	107 (11)
Severe disability or vegetative state	

Family

Parent education level, n (%)

Some high school	82 (9)
High school grad/GED	173 (18)
Some college/technical school	208 (22)
College graduate/post graduate school	215 (22)

Parent relationship status, n (%)

Married	463 (48)
Never been married	137 (14)
Partnered	59 (6)
Other ^g	84 (9)

Abbreviations: PICU, pediatric intensive care unit; IQR, interquartile range; PRISM III-12, Pediatric Risk of Mortality III score from first 12 hours in the PICU; PARDS, pediatric acute respiratory distress syndrome; GED, general education diploma.

Not all column percentages sum to 100% due to rounding.

^a Other includes Asian, Native Hawaiian or Other Pacific Islander, American Indian or Alaskan Native, and Multiracial.

^b Functional status is measured by the Pediatric Cerebral Performance Category.³⁸

^c Other acute diagnoses include acute respiratory failure related to multiple blood transfusions, laryngotracheobronchitis (croup/tracheitis), pertussis, pneumothorax, pulmonary edema, pulmonary hemorrhage, and thoracic trauma (pulmonary contusion or inhalation burns).

^d Other chronic diagnoses include acute chest syndrome/sickle cell disease, acute respiratory failure post bone marrow transplant, chronic lung disease (cystic fibrosis or bronchopulmonary dysplasia), and pulmonary hypertension (not primary).

^e PARDS severity was defined using the 2015 Pediatric Acute Lung Injury Consensus Conference (PALICC).⁴⁰

^f Multiple organ dysfunction includes dysfunction in at least one of the following systems in addition to respiratory: cardiovascular, neurologic, hematologic, hepatic, or renal. Subjects could have only respiratory dysfunction

^g Other includes divorced, separated, and deceased.

Table 4-2. Post Intensive Care Resource Use According to Income Quartiles

Healthcare Resources	Low Income (n = 240)	Low Middle Income (n = 239)	High Middle Income (n = 239)	High Income (n = 240)	P^a
In home healthcare, n (%)	68 (29)	64 (27)	62 (26)	73 (31)	.73
Registered Nurse	44 (18)	41 (17)	41 (17)	59 (25)	
Nurse's aid	4 (2)	5 (2)	6 (3)	3 (1)	
Licensed Practical Nurse	3 (1)	5 (2)	4 (2)	3 (1)	
Physical/Occupational Therapist	26 (11)	28 (12)	25 (10)	24 (10)	
Other ^b	11 (5)	18 (8)	17 (7)	9 (4)	
Active healthcare providers, median (IQR)	2 (1-3)	2 (1-3)	2 (1-4)	2 (1-4)	<.001
Pediatrician, n (%)	216 (90)	216 (90)	196 (82)	195 (81)	
Pulmonologist, n (%)	55 (23)	66 (28)	73 (31)	78 (33)	
Neurologist, n (%)	30 (13)	35 (15)	44 (18)	42 (18)	
Cardiologist, n (%)	35 (15)	22 (9)	19 (8)	31 (13)	
Gastroenterologist, n (%)	22 (9)	21 (9)	28 (12)	38 (16)	
Occupational/physical therapist, n (%)	22 (9)	21 (9)	47 (20)	39 (16)	
Medical equipment in home, n (%)	143 (61)	163 (69)	142 (60)	158 (66)	.71
New equipment post PICU discharge ^c	74 (52)	85 (52)	88 (62)	106 (67)	.003
Prescribed medications, median (IQR)	2 (1-4)	2 (1-4)	3 (1-5)	3 (1-5)	<.001
Emergency department visit, n (%)	101 (43)	104 (44)	103 (43)	78 (33)	.04
Readmission, n (%)	92 (38)	66 (28)	98 (41)	72 (30)	.42

Abbreviations: IQR, interquartile range; PICU, pediatric intensive care unit.

^a *P* values for comparison between the income quartiles were calculated using the Cochran-Armitage trend test for binary variables, the Pearson's chi square test for nominal variables, and the Jonckheere-Terpstra test for ordinal and continuous variables.

^b Other includes counselor, neuropsychologist, speech therapy, respiratory therapy, vision therapy, and wound care.

^c Column percentages were calculated based on the number of subjects using medical equipment in the home for that income quartile.

Table 4-3. Predictors of Resource Use Six Months After Pediatric Intensive Care Unit (PICU) Discharge (n = 958)

Covariates	In home healthcare OR (95% CI)	Number of active healthcare providers β (95% CI)	New medical equipment OR (95% CI)	Number of prescribed medications β (95% CI)	ED visit OR (95% CI)	Readmission OR (95% CI)
Income quartiles (ref = High)						
Low	0.9 (0.6, 1.3)	-0.4* (-0.6, -0.1)	0.4** (0.3, 0.7)	-0.2 (-0.5, 0.1)	1.5* (1.1, 2.2)	1.4 (0.8, 2.4)
Low Middle	0.8 (0.5, 1.3)	-0.4* (-0.6, -0.1)	0.5* (0.3, 0.8)	-0.2 (-0.6, 0.1)	1.5* (1.1, 2.1)	0.8 (0.6, 1.2)
High Middle	0.8 (0.5, 1.2)	-0.03 (-0.3, 0.3)	0.7 (0.4, 1.1)	0.04 (-0.3, 0.4)	1.5* (1.1, 2.1)	1.7* (1.1, 2.4)
Age (ref = 2wk to <1yr)						
1yr to <3yr	0.9 (0.5, 1.7)	0.03 (-0.3, 0.3)	0.4** (0.3, 0.7)	-0.2 (-0.6, 0.2)	0.6* (0.4, 0.9)	0.6* (0.4, 0.8)
3yr to <6yr	0.2** (0.1, 0.4)	-0.1 (-0.5, 0.3)	0.4** (0.3, 0.6)	-0.1 (-0.6, 0.4)	0.5* (0.3, 0.9)	0.4** (0.2, 0.6)
6yr to <18yr	0.4** (0.2, 0.6)	-0.1 (-0.4, 0.1)	0.7 (0.4, 1.2)	0.4* (0.1, 0.8)	0.5** (0.3, 0.7)	0.4** (0.2, 0.6)
Preexisting condition	1.9** (1.4, 2.6)	0.1 (-0.1, 0.4)	0.4** (0.3, 0.6)	1.5* (1.2, 1.8)	1.4 (0.98, 2.0)	2.6** (1.7, 3.9)
PARDS on day 0/1 ^a (ref = at risk/mild)						
Moderate	0.8 (0.5, 1.1)	0.01 (-0.4, 0.4)	0.8 (0.5, 1.1)	0.1 (-0.2, 0.5)	1.1 (0.8, 1.6)	0.9 (0.6, 1.3)
Severe	0.8 (0.5, 1.1)	-0.1 (-0.4, 0.2)	0.6* (0.4, 0.9)	0.1 (-0.3, 0.5)	1.0 (0.8, 1.3)	0.9 (0.7, 1.2)
Organ system dysfunction ^b	1.04 (0.9, 1.2)	0.1* (0.01, 0.2)	1.1 (0.99, 1.3)	0.07 (-0.1, 0.2)	1.1 (0.95, 1.3)	1.2 (0.98, 1.4)
Duration of mechanical ventilation, per day	1.05** (1.03, 1.1)	0.03** (0.01, 0.05)	1.04** (1.02, 1.1)	0.03 (-0.001, 0.1)	1.003 (0.99, 1.03)	1.02* (0.99, 1.05)
Functional status at discharge (ref = age-appropriate)						
Mild disability	3.8** (2.4, 6.2)	0.9** (0.5, 1.4)	0.6 (0.4, 1.1)	0.9** (0.4, 1.3)	1.3 (0.9, 2.0)	1.6* (1.1, 2.5)
Moderate disability	4.5** (2.6, 7.7)	1.7** (1.2, 2.3)	0.7 (0.4, 1.0)	1.1** (0.6, 1.7)	2.6** (1.6, 4.2)	2.0* (1.1, 3.5)
Severe disability or vegetative state	7.6** (4.0, 14.2)	1.5** (1.2, 1.8)	1.1 (0.6, 1.8)	2.2** (1.7, 2.7)	1.3 (0.9, 2.0)	2.7** (1.7, 4.2)

Abbreviations: ED, emergency department; OR, odds ratio; CI, confidence interval; PARDS, pediatric acute respiratory distress syndrome.

* $P < .05$

** $P < .001$

^a PARDS severity was defined using the 2015 Pediatric Acute Lung Injury Consensus Conference (PALICC) criteria.⁴⁰

Organ system dysfunction was measured continuously; every subject had respiratory dysfunction and dysfunction in up to five additional organ systems.⁴¹

Table 4-4. Predictors of Health-Related Quality of Life (ITQOL) in Young Children Six Months After PICU Discharge (n = 352)

Covariates	Overall health OR (95% CI)	Physical abilities β (95% CI)	Growth and development β (95% CI)	Pain and discomfort β (95% CI)	Temperament and moods β (95% CI)	General health β (95% CI)
Income quartiles (ref = High)						
Low	0.6 (0.3, 1.0)	-8.6* (-15.5, -1.8)	-0.8 (-5.1, 3.5)	8.2* (2.9, 13.5)	-4.3* (-7.1, -1.4)	1.1 (-3.2, 5.4)
Low Middle	0.7 (0.4, 1.1)	3.8 (-3.1, 10.8)	1.7 (-2.0, 5.5)	0.7 (-3.3, 4.7)	-0.98 (-3.8, 1.8)	-0.8 (-6.4, 4.8)
High Middle	0.6 (0.3, 1.1)	2.7 (-4.5, 9.9)	-2.6 (-6.4, 1.1)	0.02 (-5.4, 5.5)	-1.6 (-5.1, 1.8)	-3.4 (-8.1, 1.2)
Age at follow-up (ref = <1yr)						
1yr to <2yr	0.9 (0.6, 1.1)	-0.8 (-7.1, 5.6)	-1.8 (-5.9, 2.3)	2.3 (-1.6, 6.2)	0.3 (-2.6, 3.2)	-2.0 (-5.3, 1.3)
2yr to <6yr	0.4 (0.2, 1.0)	-7.9 (-29.4, 13.6)	-4.0 (-14.8, 6.8)	-3.8 (-16.1, 8.5)	-2.5 (-8.2, 3.1)	-4.0 (-12.0, 4.0)
Preexisting condition	0.5* (0.3, 0.9)	-6.6 (-18.9, 5.7)	-4.9 (-11.4, 1.6)	3.1 (-3.5, 9.7)	-0.9 (-5.0, 3.1)	-5.5 (-11.1, 0.1)
PARDS on day 0/1* (ref = at risk/mild)						
Moderate	0.7 (0.4, 1.2)	1.6 (-4.3, 7.4)	-2.2 (-6.6, 2.3)	0.02 (-5.5, 5.5)	-1.8 (-4.6, 1.0)	-3.0 (-7.8, 1.6)
Severe	0.9 (0.6, 1.5)	-0.5 (-9.6, 8.6)	-1.6 (-7.5, 4.3)	-1.9 (-6.0, 2.3)	-3.5* (-6.2, -0.8)	-3.3 (-6.6, -0.05)
Organ system dysfunction ^b	1.03 (0.8, 1.3)	1.8 (-0.7, 4.3)	2.1* (0.2, 3.9)	1.1 (-0.6, 2.9)	0.4 (-0.7, 1.5)	-0.007 (-1.5, 1.4)
Duration of mechanical ventilation, per day	0.97 (0.9, 1.03)	-0.4 (-0.97, 0.2)	-0.2 (-0.6, 0.3)	0.1 (-0.5, 0.6)	0.04 (-0.2, 0.3)	-0.3 (-0.6, 0.05)
Functional status at discharge (ref = age-appropriate)						
Mild disability	0.3 (0.1, 1.2)	-16.4 (-33.7, 0.9)	-13.5* (-21.8, -5.2)	-4.0 (-14.3, 6.3)	-0.3 (-6.7, 6.1)	-6.0 (-16.9, 4.9)
Moderate disability	0.2** (0.1, 0.5)	-18.9** (-27.8, -10.0)	-22.6** (-33.1, -12.2)	1.6 (-5.7, 8.8)	-2.2 (-7.9, 3.6)	-13.2** (-20.7, -5.8)
Severe disability or vegetative state	0.2** (0.1, 0.5)	-44.5** (-66.8, -22.1)	-26.8* (-42.8, -10.8)	-9.9 (-24.1, 4.4)	-10.0* (-19.3, -0.7)	-12.3* (-21.5, -3.1)

Abbreviations: PICU, pediatric intensive care unit; OR, odds ratio; CI, confidence interval; PARDS, pediatric acute respiratory distress syndrome.

Higher scores indicate better health-related quality of life.

* $P < .05$

** $P < .001$

^a PARDS severity was defined using the 2015 Pediatric Acute Lung Injury Consensus Conference (PALICC) criteria.⁴⁰

^b Organ system dysfunction was measured continuously; every subject had respiratory dysfunction and dysfunction in up to five additional organ systems.⁴¹

Table 4-5. Predictors of Health-Related Quality of Life (PedsQL) in Children Ages 2 - 17 Six Months After PICU Discharge (n = 398)

Covariates	Total score β (95% CI)	Physical health β (95% CI)	Psychosocial health β (95% CI)	Emotional functioning β (95% CI)	Social functioning β (95% CI)	School functioning β (95% CI)
Income quartiles (ref = High)						
Low	-4.0 (-9.8, 1.7)	-2.6 (-9.7, 4.5)	-4.8 (-10.7, 1.0)	-5.9 (-12.8, 1.1)	-3.4 (-10.6, 3.8)	-7.5 (-15.8, 0.9)
Low Middle	-2.8 (-8.1, 2.4)	-3.9 (-11.0, 3.2)	-2.5 (-7.4, 2.4)	-3.3 (-9.6, 3.1)	-0.4 (-6.1, 5.3)	-8.6* (-15.6, -1.6)
High Middle	-2.8 (-7.43, 1.7)	-1.8 (-7.2, 3.5)	-3.5 (-8.0, 1.1)	-6.0* (-11.9, -0.2)	-1.5 (-7.2, 4.2)	-4.2 (-10.3, 1.9)
Age at follow-up (ref = 2yr to <5yr)						
5yr to <8yr	-8.2* (-13.0, -3.3)	-7.8* (-14.3, -1.2)	-8.2** (-12.9, -3.5)	-8.7** (-13.8, -3.5)	-4.9 (-10.3, -.6)	-8.6* (-16.5, -0.7)
8yr to <13yr	-12.9** (-20.0, -5.8)	-12.3* (-20.9, -3.7)	-13.0** (-19.4, -6.6)	-13.3** (-20.7, -5.8)	-9.3* (-16.1, -2.5)	-14.6** (-22.7, -6.6)
13yr to < 17yr	-9.7** (-13.7, -5.6)	-10.9** (-16.6, -5.2)	-8.8** (-12.5, -5.1)	-9.4** (-14.1, -4.7)	-3.7 (-8.2, 0.8)	-11.6** (-18.4, -4.9)
Preexisting condition	-6.6** (-2.8, -10.5)	-10.0** (-15.3, -4.7)	-4.4* (-7.6, -1.2)	-0.6 (-4.3, 3.2)	-5.7* (-10.0, -1.4)	-8.2** (-13.0, -3.5)
PARDS on day 0/1 ^a (ref = at risk/mild)						
Moderate	-2.4 (-6.8, 2.1)	-2.8 (-8.0, 2.4)	-2.6 (-7.4, 2.3)	-0.8 (-6.7, 5.0)	-5.1* (-9.7, -0.6)	-0.4 (-7.8, 7.0)
Severe	-0.2 (-3.9, 3.6)	1.3 (-4.0, 6.6)	-1.3 (-4.9, 2.2)	-1.4 (-5.2, 2.5)	-3.4 (-7.4, 0.7)	2.3 (-3.4, 8.0)
Duration of mechanical ventilation, per day	-0.02 (-0.4, 0.4)	-0.2 (-0.6, 0.3)	0.08 (-0.3, 0.4)	0.03 (-0.3, 0.4)	0.2 (-0.3, 0.7)	0.02 (-0.4, 0.5)
Organ system dysfunction ^b	-1.6 (-3.2, -0.1)	-1.9 (-3.6, -0.2)	-1.3 (-3.1, 0.4)	-0.5 (-2.9, 1.8)	-1.7 (-3.4, 0.04)	-2.3 (-4.4, -0.2)
Functional status at discharge (ref = age-appropriate)						
Mild disability	-9.1* (-13.5, -4.6)	-13.5** (-19.4, -7.6)	-5.8* (10.4, -1.2)	-0.6 (-6.7, 5.5)	-11.1** (-16.1, -6.1)	-8.7* (-16.8, -0.5)
Moderate disability	-24.3* (-30.1, -18.5)	-36.2** (-44.5, -28.0)	-17.0** (-24.0, -10.0)	-1.6 (-7.9, 4.8)	-29.0** (-36.3, -21.6)	-23.4** (-34.1, -12.6)
Severe disability or vegetative state	-16.0 (-39.7, 7.6)	-31.5 (-75.3, 12.3)	-5.2 (-15.4, 4.9)	10.8** (5.2, 16.3)	-28.6* (-53.4, -4.1)	21.8** (14.0, 29.7)

Abbreviations: PICU, pediatric intensive care unit; CI, confidence interval; PARDS, pediatric acute respiratory distress syndrome.

Higher scores indicate better health-related quality of life.

* $P < .05$

** $P < .001$

^a PARDS severity was defined using the 2015 Pediatric Acute Lung Injury Consensus Conference (PALICC) criteria.⁴⁰

^b Organ system dysfunction was measured continuously; every subject had respiratory dysfunction and dysfunction in up to five additional organ systems.⁴¹

eTable 1. Medical equipment use before PICU admission and after PICU discharge (n = 958)

Type	Equipment in Home ^a (n = 606)	Used Pre-PICU ^b (n = 253)	New Post-PICU ^c (n = 353)
Pulmonary			
Nebulizer	382 (40)	210 (22)	172 (18)
Home oxygen	107 (11)	61 (6)	46 (5)
Pulse oximeter	87 (9)	51 (5)	36 (4)
Suction	82 (9)	53 (6)	29 (3)
Cough assist	35 (4)	16 (2)	19 (2)
Vest airway clearance	30 (3)	17 (2)	13 (1)
system			
CPAP/BiPAP	22 (2)	7 (<1)	15 (2)
Tracheostomy	21 (2)	4 (<1)	17 (2)
Mechanical ventilation	21 (2)	4 (<1)	17 (2)
Other	25 (3)	9 (<1)	16 (2)
Nutrition			
Feeding tube ^d	178 (19)	103 (11)	75 (8)
Tube feedings	139 (15)	82 (9)	57 (6)
TPN	10 (1)	4 (<1)	6 (<1)
Mobility			
Wheelchair	86 (9)	58 (6)	28 (3)
Crutches/cane/walker	40 (4)	19 (2)	21 (2)
Braces (back, arms, or legs)	30 (3)	19 (2)	11 (1)
Other	23 (2)	19 (2)	4 (<1)
Home IV	56 (6)	17 (2)	39 (4)
Patient transfer			
Hospital bed	38 (4)	28 (3)	10 (1)
Mechanical lift	19 (2)	14 (1)	5 (<1)
Bathing/toileting	33 (3)	19 (2)	14 (1)

Abbreviations: CPAP/BIPAP, continuous positive airway pressure or bilevel positive airway pressure; TPN, total parenteral nutrition; IV, intravenous line.

^a 63% of the study sample (606/958) were using at least one type of equipment within six months after discharge. 28% (273/958) were using more than one type of equipment.

^b The column represents equipment that was used prior to the PICU admission and also within six months after discharge.

^c 37% of the study sample (n = 353/958) are using at least one piece of new equipment within six months after discharge.

^d This includes subjects with feeding tubes placed, which could be used for feedings and/or medications. It is possible that a feeding tube is in place but is not being used.

CHAPTER 5

DISCUSSION AND CONCLUSION

Socioeconomic status (SES) is a ubiquitous term and a commonly used variable in research, but its measurement heterogeneity presents challenges in establishing consensus around its meaning and when comparing across studies. Nonetheless, factors represented by SES may interact with or directly contribute to the illness course that leads to a PICU admission and the recovery period after discharge. Physical, cognitive, emotional, and social morbidities experienced by pediatric critical illness survivors, and faced by their families, can substantially impact all aspects of daily life as well as financial circumstances. Emerging healthcare research, especially in the last decade, has increasingly called attention to how socioeconomic factors are implicated in one's state of health and overall health outcomes, but pediatric critical care studies do not routinely consider these socioeconomic factors. Healthcare access and healthcare utilization in the United States (U.S.) are particularly associated with SES in part because of the lack of universal healthcare and the complex interconnectedness of healthcare coverage, employment status, occupation type, and income. Despite being a wealthy, developed country, health outcomes in the U.S. are suboptimal compared to those of similar countries, which further emphasizes the importance of studying the outcomes of the sickest children residing there. Critical illness that could have been prevented (when in a more innocuous stage) and a subsequent recovery that encounters unmet healthcare needs potentially have long-lasting effects on a child's functioning, their family, the healthcare system, and society at large. This dissertation contributed to knowledge regarding the current measurement practices surrounding SES

and how a proxy for SES—census derived median income—relates to presenting severity of illness and the post-discharge outcomes of health-related quality of life (HRQL) and resource use in a cohort of children hospitalized and mechanically ventilated for acute respiratory failure.

Summary and Overall Goals

The three papers comprising this dissertation collectively achieved the following objectives: 1) exploring the literature on current use and measurement of SES in pediatric health research and revealing wide variability in SES measures used as well as issues surrounding measurement, 2) examining the association between SES and illness severity within the first day of a pediatric intensive care unit (PICU) hospitalization for acute respiratory failure, and 3) examining the association of SES with health-related quality of life (HRQL) and healthcare resource use in a subgroup of PICU survivors six months after discharge. The extensive scoping review conducted in the first paper (Chapter 2) demonstrated a lack of consensus for measuring SES in pediatric health research, but most measures were explicitly or implicitly related to income, which informed our decision to use census tract-level income in both secondary analyses (Chapters 3 and 4). The scoping review further showed a tendency for studies to omit a rationale justifying the choice of SES measure, but studies that did provide a rationale contributed to our consideration of available, feasible, and logical SES measures to employ in the absence of complete individual-level SES data. Because all subjects in Chapter 4 were part of the sample in Chapter 3, we used the same census income variable in Chapter 4 so that we could compare findings between these two papers.

Major Findings

Major Findings: Socioeconomic Status

Socioeconomic status (SES), a nuanced concept that can include access to resources, financial standing, educational level, prestige, and occupational opportunities, is routinely part of studies crossing many disciplines but its measurement varies.¹⁻⁷ A latent variable, SES is represented by a wide variety of proxies, such as annual income or insurance status, but regardless of the proxy, research has continually shown a gradient effect between SES and health outcomes: higher SES is associated with better health.⁸⁻¹³ However, the mechanisms by which SES is impacting health outcomes are not well understood.

Because SES is conceptualized and measured differently in individual studies, comparison between studies can be challenging and thus potential trends in how SES affects health can be more difficult to identify. There are most likely multiple SES mechanisms—and interactions between mechanisms—through which SES affects health, but unfortunately we do not yet adequately understand these processes and cannot design interventions or shape policy accordingly. Our scoping review revealed the heterogeneity of contemporary SES measurement practices in pediatric healthcare research and the overwhelming lack of connection between the SES measure used and the health outcome investigated. In other words, studies are using a variety of measures, which may not be inherently problematic, depending on a study's objectives and issues of feasibility when collecting SES data. However, we know that correlation between SES measures can be low or moderate, suggesting that they measure distinct characteristics and cannot be used interchangeably or conceptualized equivalently.¹³ Postulating a connection between a particular SES measure and health outcome that draws from the literature and/or theoretical frameworks would strengthen the interpretation of a study's findings and conclusions.

Significant income inequalities among individuals in the U.S. and widening gaps in health outcomes warrant the study of SES as a concept and its related mechanisms.¹⁴⁻¹⁶ The Gini coefficient, used as an SES measure in two studies (Chapter 2), is a measure of income inequality ranging from 0 to 1, where 0 indicates that everyone in a given area has the same income and 1 indicates that a single person has all the income and everyone else has no income. In the thirty-four countries comprising the Organization for Economic Cooperation and Development (OECD)—countries that account for the majority of the world’s trading and investment endeavors—the U.S. has one of the highest Gini coefficients in recent years, demonstrating that the richest households have grown faster economically than the poorer.¹⁷ Income inequality within neighborhoods has been shown to have an impact on health outcomes, independently of individual level SES.^{18,19} In children in particular, one study found that Gini coefficient-measured neighborhood inequality was associated with higher rates of hospitalization for ambulatory care sensitive conditions (ACSCs), conditions where hospitalization could have been prevented from primary care interventions.²⁰ The SES proxy we used in Chapters 3 and 4—median income for households with children under the age of 18—did not directly aim to capture income *inequality* in a given census tract, but it’s possible a measure such as the Gini coefficient could have illuminated differences in presenting illness severity (Chapter 3) and post discharge outcomes (Chapter 4).

Our study populations were not designed to specifically represent the U.S. population economically, but they did include subjects from 41 states in Chapter 3 and 38 states in Chapter 4, with an overall median income of \$54,036 and \$58,482, respectively. For the same census tract variable used in both of these papers—median income representing families with children under the age of 18—the median income in the U.S. in 2011 was \$61,619.²¹ Despite a lower median income for both of our papers’

samples, both papers' income distributions were positively skewed, which is typical for U.S. income distributions.²² The overall U.S. poverty rate in 2011 was 15%, but for families with children under 18 years old, it was 22%.²³ Considering that the U.S. poverty guidelines cutoff for a family of four in 2011 was \$22,350, 5.9% of the sample in Chapter 3 would be considered in poverty, and 4.8% in Chapter 4. Both of our studies' income distributions, therefore, did not include an accurate reflection of the number of children in poverty, in general.

It is well established across research disciplines that low SES subjects are less likely to participate in studies, a point made in several studies included in the scoping review (Chapter 2).²⁴⁻²⁶ Relatedly, low SES subjects are more frequently lost to follow-up, with posited reasons including financial limitations that inhibit the ability to travel to study sites, time constraints, perceived burden in participating, and a tendency to change residences or mailing addresses.^{27,28} Furthermore, studies have shown that subjects lost to follow-up may be sicker than those who complete follow-up. These characteristics of lost to follow-up cohorts could prevent important research from being conducted on a vulnerable group with significant needs and thus hinder the generalizability of findings.²⁹⁻³¹ Our positively skewed income distributions and lack of below poverty level census-tracts in Chapter 3 may reflect the phenomenon of an underrepresentation of low SES subjects enrolling in studies while Chapter 4's sample, with a slightly higher median income than Chapter 3's sample, may reflect the SES-related trends of who consents to and completes follow-up.

Despite the fact that compared with white families fewer black families were approached for consent, and fewer consented for the *RESTORE* study,³² they still comprised a sizeable portion of the sample (503/2449, 21%) as compared with the U.S. population's racial makeup in 2011, which was 13% black.²¹ Of those who were eligible

for study participation (n = 3,438), 26% were black (n = 886). The sample included in Chapter 3 (n = 2,006) was 21% black while in Chapter 4 (n = 958) it was 18% black, both of which depict an overrepresentation as compared with the U.S. population but one that is similar to typical PICU populations.³³

Both of the data based papers in this dissertation demonstrated a race-income gradient: as income [quartile] increased, so did the proportion of white subjects; as income quartile decreased, so did the proportion of black subjects. This trend is reiterated in the U.S. health disparity literature but it does not, however, endorse an operationalizing of SES *with* race.^{34,35} Nine of the 228 studies included in Chapter 2's scoping review *did* operationalize SES with race, but this only further undermines the process of detangling the confounding mechanisms operating in both SES and race. We do know that median income greatly differs between races as categorized by the U.S. census: \$35,635 for black households, \$55,992 for white, and \$70,815 for Asian.²¹ If using an area-based measure of income like we did, it may be advantageous to stratify by race to account for these rather stark differences. Aside from income inequality, more research is needed to identify and describe the mechanisms responsible for health outcome disparities related to racial identity, including systemic racism and discrimination.^{35,36}

The use of a census-based measure of SES in Chapters 3 and 4 was a feasible way to approximate income in a cohort where individual level data was unavailable, but there are other SES measure options that warrant further study. Few of the 52 unique singular measures and 20 composite measures described in Chapter 2 were connected to an evidence-based reason for choosing one over another. Regardless of the measure—area-based versus individual level—SES measures used in studies that span multiple geographical areas do not typically adjust for area differences. One

contemporary measure that is currently being studied by the U.S. Census Bureau is the Supplemental Poverty Measure (SPM), which may more accurately represent poverty as it considers geographical differences in cost of living, the receiving of government assistance, and necessary expenditures for basic needs. This differs from the commonly used “poverty threshold” or “poverty line,” which is a measure developed in the 1960’s entirely based on food expenditures and only adjusted for inflation.³⁷

Few studies conducted in the PICU directly investigate the impact of SES-related factors on health outcomes. More specifically, in a scoping review of all randomized controlled trials (RCTs) taking place in the PICU through 2013, only three of the 248 included studies reported on SES.³⁸ Studies from 2013 up to the present are added to a corresponding online database, but no study included SES as a predictor variable in statistical models.³⁹ When SES *is* included in RCTs in general, more often than not it is “controlled for” in the statistical models. PICU-based RCTs are critically important for advancing knowledge in the care of the most vulnerable children but we do not know enough about socioeconomic factors that may directly impact presenting health as well as post-discharge outcomes, or interactions these factors may have with common clinical variables in intensive care units. In the follow-up phase, the *RESTORE* study⁴⁰ did ask SES-related questions but the majority of consenting parents/guardians declined to provide their annual income (63%) and 29% did not provide highest level of education.⁴¹ This contributed to our alternative method of operationalizing SES in Chapters 3 and 4, but it also leads to contemplating if there are better ways to inquire about SES-related factors that would encourage responses instead of inhibiting them.

Major Findings: Illness Severity

The PICU admits and treats children afflicted by a variety of illnesses and injuries, and while length of stay and illness severity have not significantly fluctuated over the years, mortality rates have plummeted.⁴² Composite, prognostic scores like the Pediatric Risk of Mortality (PRISM) score were designed to predict mortality within the first day of PICU admission, but they have also been used to characterize illness severity, and more recently, to predict morbidity.⁴³⁻⁴⁵ Several studies have shown that critically ill children of lower SES have higher illness severity, but to our knowledge, no study has investigated this association in prospectively conducted study in PICUs across the U.S.^{46,47}

We found no association between illness severity—measured by the PRISM III-12 score and Pediatric Acute Respiratory Distress Syndrome (PARDS) severity—and census-tract median income quartile when controlling for socio-demographic factors and primary diagnosis. While we were surprised at the lack of associations, we believe this could have occurred for multiple reasons. As mentioned above, it's possible that census tract median income did not capture the SES mechanism(s) that would have contributed to differences in illness severity along the SES gradient. An SES measure such as insurance status may have demonstrated these differences, as the theoretical argument for connecting SES with illness severity could relate to issues of healthcare access, inadequate or nonexistent primary care, and delay of care.^{48,49} Other factors, such as environmental exposures that affect respiratory function and distance to primary care provider offices or healthcare facilities, could have had an impact on illness severity that was not captured by census tract median income. Lastly, it is possible that the families of children who did enroll in *RESTORE* were more similar to one another in terms of seeking or delaying hospital care, and that the critical illness courses began and progressed similarly *in spite of* differences in income level and not *because of* these

differences. We do not know the census tract median income of the families who were eligible and/or approached but did not consent to the *RESTORE* study.

The two prior studies that also used census measures of income to investigate its effect on illness severity took place in Los Angeles, CA and Washington D.C., respectively. In the Washington D.C. study, low SES children were admitted to the PICU with higher illness severity as compared to children of higher SES.⁴⁶ In addition, for every \$10,000 increase in income, PICU admission rates in general fell by 9%. While a race variable was not included in this study, Washington D.C. is known to have a sizeable non-White population, including at the time that study was conducted, but issues of income and race confounding were not addressed. We know that PICUs admit a disproportionate number of minorities, but we do not know if they independently admit a disproportionate number of low-income children. The second study, conducted in Los Angeles, enrolled more than 5,000 children, 57.8% of which were Latino and 70.1% of which had government insurance.⁴⁷ They also found that median income was associated with higher illness severity, but the spread of income is omitted and it is unclear if univariate models tested the association between income and illness severity, or if models always included the race/ethnicity variables. Not only did these two studies take place in racially/ethnically more homogenous areas than our geographically widespread studies, but the cost of living and value of a dollar were more consistent between patients of those two single-metropolitan area studies. Lastly, both of these retrospective studies drew from PICU databases and/or the electronic health record, rather than prospectively enrolling families, so it is possible that the ability to include all PICU patients admitted in a certain time period gave a more accurate representation of the PICU population itself, accompanied by a range of incomes.

In our first study (Chapter 3), PRISM III-12 and PARDS were weakly correlated (Spearman $r = 0.19$; $p < 0.001$), indicating that the two measures represent distinctive aspects of “illness severity.” PRISM III-12 quantifies dysfunction in multiple body systems whereas PARDS is specific to respiratory dysfunction. While all children in the *RESTORE* study shared a condition—acute respiratory failure—their etiologies, baseline health, and other characteristics differed, contributing to an array of clinical presentations. The weak correlation highlights the potential importance of representing a variable like illness severity with multiple indicators.

Major Findings: Resource Use and Health-Related Quality of Life

While the majority of children in our last study were discharged to home—as opposed to another hospital or facility—and were also living at home at the time of six-month follow-up, many of them had ongoing healthcare needs. Because one-third of the study sample had preexisting conditions at baseline, it is not surprising that these children saw healthcare providers or were prescribed medications. But these children did not account for all of the resource use we quantified and described in Chapter 4. Nearly two-thirds of the study sample had at least one piece of medical equipment in the home at the time of follow-up, but perhaps what is more striking is how many children had at least one piece of medical equipment that was *new* post-PICU discharge ($n = 353$). Equipment type was most often pulmonary in nature but a substantial number of children were using new equipment that appears discordant with expected sequelae of acute respiratory failure, including mobility assistance (e.g. wheelchair) and nutrition assistance (e.g. tube feedings). What specific features of critical respiratory illness and its accompanying care contribute to non-respiratory healthcare resource needs? It’s important that future studies follow PICU survivors so that this question can someday be answered.

There were differences in resource use when categorizing children by income quartile, despite no trend by income quartile for PRISM III-12 scores, PARDS severity, or duration of mechanical ventilation. Relatedly, when controlling for the above illness variables as well as age group, preexisting condition, MODS, and functional status in a multivariable model, differences in resource use remained: low-income children had fewer healthcare providers and were less likely to have new medical equipment at home when compared with the high-income children. Illness severity was comparable between income quartiles in both of our studies (Chapters 3 and 4), so we may have expected resource use to also be comparable. It is possible that the low-income children were less sick during the follow-up period, but more of them visited the ER and were readmitted to the hospital than the high-income children, so this seems less probable. One can use ER services regardless of ability to pay or insurance type (or lack thereof), but healthcare access issues may come into play more when needing to make healthcare provider appointments. In addition, families of lower financial means may have less time or ability to follow through with appointments if these require missed work, childcare for other children, or unaffordable copays. If not consistently seeing healthcare providers, it is not surprising then that the low-income children in this study had less new medical equipment in the home, as some equipment could require a prescription or provider's orders. At the very least, families may not know what equipment would help their child's health if not recommended during a provider appointment.

Unlike resource use, there were few differences in HRQL scores when comparing across income quartiles for either instrument (ITQOL or PedsQL) used in our last study (Chapter 4). Age group and functional status were significantly associated with most PedsQL subscores but only functional status was consistently associated with most ITQOL subscores. For young children whose families completed the ITQOL,

income quartile and the physical abilities subscore were overall significantly associated, with the low-income quartile scoring 8.6 points lower than that of the high income quartile (the reference category). Many studies evaluate HRQL in PICU survivors at various time points after discharge (typically between 3 and 12 months),⁵⁰⁻⁵⁹ but few consider socioeconomic factors when building regression models and generating results.⁶⁰ While we cannot compare findings between similar pediatric studies with regards to SES, several studies have found impairments in physical domains but not psychological or emotional domains. One study that evaluated HRQL three months and twelve months after PICU discharge found that PedsQL total scores and physical functioning scores were significantly lower compared to those of healthy norms, though the scores did improve between the two time points.⁶¹ A large French ICU-based study found that only the physical functioning items on the HRQL instrument were significantly lower for low SES adults.⁶² In our study, it is possible that differences in income could have contributed to diminished HRQL in the physical domain, but we do not know in particular which abilities were affected as the ITQOL physical abilities questions encompass sleeping, grasping, rolling over, and feeding among others. Critical care studies that enrolled adults recovering from acute respiratory distress syndrome (ARDS) found that physical limitations have partly arisen due to issues in lung function.⁶³⁻⁶⁴ While evaluating specific physical sequelae was beyond the scope of our study, questions that emerged from our HRQL findings do point to the need for following up clinically with PICU survivors.

Limitations

The limitations of this dissertation include methodological challenges associated with the study designs, the post hoc use of a singular area-based measure of SES, and potential study sampling biases. The scoping review in the first study was employed

because a more narrowly focused question was not possible, but the broad literature search undertaken does not require studies to be of a particular quality. For this reason, we may have included studies that were methodologically problematic and should not have influenced our choice of using a census-derived income variable in the subsequent two papers. Nonetheless, our purpose in conducting a scoping review was to evaluate a variety of studies to better understand common contemporary practices of conceptualizing and operationalizing SES, and we feel confident that we achieved this objective.

As with all secondary data analyses, there are limitations when the original study's research questions did not set out to answer what is being investigated post-hoc. Census tract-derived median income was not a predetermined variable of interest in the *RESTORE* study, though the study did include the collection of SES variables (annual household income and highest educational level) for those families that consented to follow-up. In addition, the geographical size of a census tract may still be large enough (read: heterogeneous) that a singular median income did not accurately reflect the actual income of the enrolled subjects' families. In addition, the value of a dollar in one part of the U.S differs from that in another part of the U.S., meaning that cost of living and purchasing power can vary. Using data spanning 31 PICUs across the U.S. was deemed a strength of the two data-based studies included in this dissertation, however.

Based on the study designs of Chapters 3 and 4, we were unable to establish causal relationships between variables, so we cannot definitively state that low income directly resulted in lower resource use or lower rated physical abilities, for example. The gradient found between particular races and income quartiles, as well as a greater number of subjects with a history of asthma or prematurity found in the lowest quartiles

(Chapter 3), do lend support to the usage of census tract income as a proxy for individual-level income.^{34,35}

The *RESTORE* study was rigorous in its evaluation of PICUs, auditing of these PICUs throughout the study period, its data collection monitoring, as well as adherence to policies protecting human subjects in research. Despite the high caliber of the parent study that provided the data we used in our secondary analyses (Chapters 3 and 4), it is possible that there were sampling biases during the enrollment phase, as evidenced by the differences in approach for consent and actual consent when analyzed by race.³² The samples for both of our studies do, however, reflect the positive skew typically seen in income distributions, but they may not reflect the usual population of the PICU on certain socio-demographic characteristics.

Future Directions

This dissertation raised new questions about the conceptualization and measurement of SES, a complex term that is represented by an array of indicators in. The specific SES mechanisms that affect health are not yet fully understood but we do know that research does consistently find statistically significant associations between SES and health outcomes (Chapter 2). For this reason, we recommend taking a careful and evidence-based approach to choosing SES measures that are feasible to collect and relevant within the context and objectives of a given study.

Studies analyzing area-based measures of SES alongside individual-level SES for the same population have shown that using area-based measures of SES introduces bias when estimating coefficients.⁶⁵⁻⁶⁷ One of these studies, however, found that the area-based measure was more likely to control for the confounding between SES and race because of the effect of one's neighborhood on health. Future studies could concurrently investigate area-based and individual-level SES measures for a pediatric

critical care population to evaluate the performance of each one independently and in comparison to one another.

This dissertation's investigation of the association of SES with illness severity, and with post-discharge resource use and HRQL, has unveiled new insights into how a large cohort of children mechanically ventilated for acute respiratory failure present to the PICU and how they are managing six months after discharge (Chapters 3 and 4). The long-term goal associated with this dissertation is to build a program of research that focuses on identifying the individual and/or interacting socioeconomic mechanisms that affect the health outcomes of children hospitalized in the PICU. How do these SES mechanisms impact outcomes such as health-related quality of life, healthcare utilization, psychological health, emotional wellbeing, and cognition? The ultimate objective of this program of research will be to design interventions targeting these SES mechanisms, optimizing those that promote health and mitigating the impact of those that compromise it.

In addition to the need for future research, analyzing the SES-health outcomes connection can also be observed and investigated during clinical encounters with patients. A physician-led team recommends screening for social determinants of health (SDOH)—which are associated with SES—during appointments, asking questions that relate to childcare needs, food insecurity, and literacy, for example.⁶⁸ A screening tool like this would be one way for physicians and nurse practitioners to regularly assess the needs of pediatric patients and their families so that connections to the right resources can be made.

For survivors of critical illness in particular, it was concerning that not all of the children in the follow-up phase had seen a healthcare provider in the six months after PICU discharge, and 12% (115/958) saw a specialist but not a pediatric provider

(Chapter 4). Most hospitalizations include discharge instructions that involve following up with at least one healthcare provider, even when a full recovery is expected. Pediatric critical care involves invasive technology and potent medications, the long-term effects of which are not well understood. What health challenges await a child that has survived critical illness, and what contributes to those challenges, is largely uncharted territory, but we do know that a significant number of survivors do go on to develop morbidities that may or may not relate to their admitting diagnosis.^{69,70} Like any other child, a child discharged from the PICU has developmental milestones to meet; being assessed by their regular pediatric provider seems warranted to assess for any changes in the developmental trajectory and to promptly intervene if necessary. But unlike most children, those discharged from the PICU may need to be more closely followed because of unpredictable outcomes that arise from critical illness, critical care, or a combination of these.

Critical care providers and researchers have shifted their focus from mortality rates to the needs of survivors.³¹ Thus far, the Post Intensive Care Syndrome (PICS) framework has guided post-ICU discharge care and intervention testing in the adult population⁷¹ and most recently, it has been adapted for the pediatric population.⁷² The PICS-p framework consists of four health domains in which impairments can occur: physical, cognitive, emotional, and social. Post PICU recovery is not well characterized, but this framework combined with research that follows survivors and evaluates their health in these domains is needed. The parents in the lowest income quartile rated their children's physical abilities as significantly lower than those in the highest income quartile (Chapter 4), but before we can analyze the potential differences caused by income level we must first understand why and how physical health could be impacted post-PICU hospitalization.

It is unknown how consistently follow-up care is provided for all PICU survivors—aside from what is reported on through research—but from the current state of the literature it appears that few protocols are in place related to who should see these children, when, and what evaluations should be done. Our last study (Chapter 4) revealed that most PICU survivors see a specialist and/or their primary pediatric provider within the six months after discharge, but some do not. More research has been done around follow-up of adult ICU survivors, with a nurse-conducted scoping review of critical care follow-up clinics finding that the use of a diary to prevent or aid psychological ramifications of an ICU stay was the most supportive of interventions.⁷³ Interdisciplinary ICU follow-up clinics that address PICS complications in adults are more common in Europe than in the U.S., but to our knowledge, a similar clinic model has not been established exclusively for all PICU survivors.^{74,75} An Oregon-based hospital created a interdisciplinary follow-up clinic for survivors of neurological insults—mostly TBI—in order to fill the gap that existed in evaluating and treating post-discharge morbidities.⁷⁶ These clinics are typically created and run by a team of physicians, nurses, and pharmacologists, mirroring the interprofessional nature of critical care. We hope that more institutions will establish follow-up clinics with an approach that involves all healthcare team members and seeks to assess PICU survivors in physical, cognitive, emotional, and social domains, and connects them with the resources that could support recovery and prevent further morbidity.

Conclusion

This dissertation explored contemporary measurement practices for SES in pediatric health research and, using a proxy for representing SES in a large pediatric clinical trial, illuminated the relationship between SES and illness severity, resource use, and HRQL. The scoping review conducted in the first paper provided a framework for

choosing and implementing the use of an SES measure as the primary predictor variable of interest in the remaining two papers. In addition to investigating the role of SES in presenting illness severity and post-discharge outcomes, this dissertation has highlighted the importance of purposefully and justifiably using SES measures in studies and for following PICU survivors to address the health outcomes of critical care and related needs that emerge.

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