Societal Costs of Sickle Cell Disease in the United States

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BACKGROUND

- An estimated 100,000 individuals live with sickle cell disease (SCD) in the United States (US), the majority of whom are African American or Hispanic American[1,2]
- SCD is a lifelong and costly inherited disorder caused by hemoglobin polymerization and red blood cell (RBC) sickling, which lead to chronic anemia, hemolysis, and episodic vaso-occlusive crises (VOCs)[3]
- The combination of chronic anemia, hemolysis, and vaso-occlusion contributes to a clinical disease course[4] characterized by markedly reduced patient-reported health-related quality of life (HRQOL),[5,6] disability, and a lifespan that is reduced by approximately 30 years compared with the general US population[3]
- Available data on the impact of SCD mortality and morbidity on lifetime earnings are limited, which may result in an underestimation of the true aggregate costs of this disease on patients, their families, and society by relying solely on estimates using direct health care costs

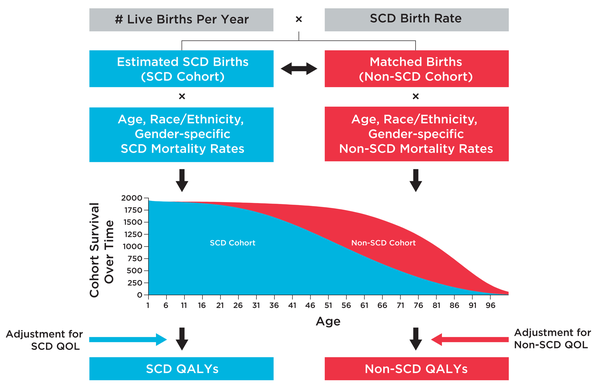
OBJECTIVE

- To estimate the lost lifetime income due to differences in life expectancy among patients with SCD in the US (SCD cohort); an age-, sex-, and race-matched cohort without SCD in the US (non-SCD cohort); and the general US population

METHODS

- To estimate the future impact of SCD on life expectancy and lifetime earnings, we developed a cohort simulation model using the R statistical program (R Core Team [2017]. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.r-project.org/) (**Figure 1**)

Figure 1. Model Concept



QALY, quality-adjusted life-year; QOL, quality of life; SCD, sickle cell disease.

- The model calculated the estimated life expectancy, quality-adjusted life-years (QALYs), and lifetime income for the SCD cohort, the non-SCD cohort, and a cohort that represented the general US population
  - The non-SCD cohort had the same demographics as the SCD cohort but had a different mortality risk profile
  - For comparison, life expectancy and income for a cohort that represents the general US population was also calculated
- **Table 1** lists the model inputs and sources

Table 1. Model Inputs and Sources

Description of Data Input	Population Value (Data Source)		
	SCD Cohort	Non-SCD Cohort	General US Population
Estimate of newborns with SCD derived from: • Number of newborns in US, 2015 • SCD rates per 1000 births	• Estimate of newborns based on CDC live births (3,978,497)[7] × Therrell rate (0.00049)[8]	• Same as SCD cohort	• NA
Life table derived from: • Published mortality rates by age group (2004-2008) • Observed SCD deaths from CDC MCOD file (2007-2016) • CDC National Vital Statistics Data	• Mortality rates for SCD derived from Paulukonis et al (2016)[9] • Observed deaths from CDC MCOD file[10]	• Mortality rates for non-SCD population (black and Hispanic) from CDC/NCHS, National Vital Statistics System, Mortality data for race and sex distribution for SCD population[11]	• Mortality rates for general population from CDC/NCHS, National Vital Statistics System, Mortality data for entire US population[11]
Estimate of QALYs: • Link visual analog pain for SCD children/ adolescents to EQ-5D • Link visual analog pain for SCD adults to EQ-5D • EQ-5D US normative values	• Algorithm linking pain to EQ-5D from Anie et al (2012)[12] • Pain scores and linked EQ-5D by age[13,14]	• EQ-5D normative values by age for US population[15]	• EQ-5D normative values by age for US population[15]
Calculate income losses: • Observed annual personal income by sex and race/ ethnicity (2014)	• US Bureau of Census: data for black males, black females, Hispanic males, Hispanic females[16]	• Same as SCD cohort	• US Bureau of Census: data for all US males, all US females[16]

CDC, Centers for Disease Control and Prevention; ED, emergency department; EQ-5D, EuroQol 5 Dimension; MCOD, multiple causes of death; NA, not applicable; NCHS, National Center for Health Statistics; QALY, quality-adjusted life year; SCD, sickle cell disease.

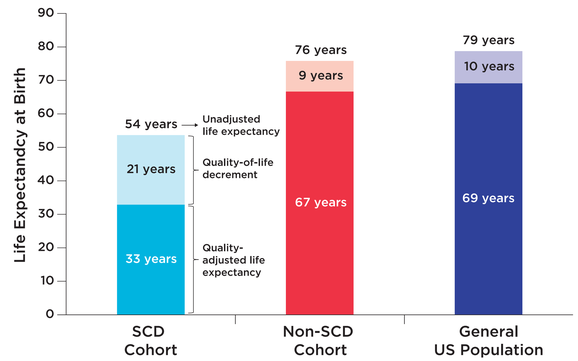
- SCD birth rates were estimated using published data from Therrell[8] (**Table 1**)
- A Poisson regression was generated from published mortality rates for patients with SCD[9] and was supplemented with data from the Centers for Disease Control and Prevention (CDC) Multiple Causes of Death (MCOD) database[10] to create age-specific life tables for a cohort of individuals born with SCD (SCD cohort; **Table 1**)
  - Published life tables from the CDC[11] were used to develop age-specific mortality rates for a matched cohort without SCD (non-SCD cohort) and the general US population
  - Results were pooled across race/ethnicity categories because of the small numbers of non–African Americans with SCD
- Published utility weights for individuals with SCD[12-14] and for the general US population[15] were used to estimate the impact of SCD on HRQOL (**Table 1**)
- The US Bureau of Labor Statistics Supplemental Survey of Annual Personal Income[16] was used to calculate the expected annual personal income based on age, sex, and race/ethnicity (**Table 1**)
- The model used undiscounted values for future premature mortality and wage losses; analyses of mortality rates and prevalence used Monte Carlo sampling to characterize uncertainty
  - Mortality rates were estimated for the 95% uncertainty interval based on 2.5% and 97.5% of the results distribution over 200 iterations of the model

RESULTS

Projected Life Expectancy

- The model estimates a birth cohort of 1950 newborns with SCD
- Model estimates for life expectancy at birth and QALYs for the SCD and matched non-SCD cohort and the general US population are shown in **Figure 2**

Figure 2. Projected Life Expectancy and Quality-Adjusted Life Expectancy at Birth



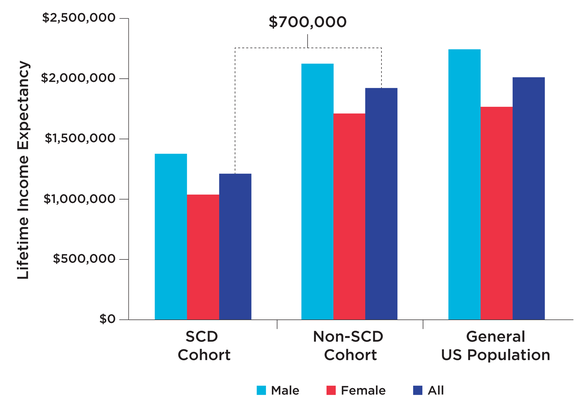
SCD, sickle cell disease.

- The projected life expectancy for the SCD cohort was 54 years, which is 22 years less than the life expectancy for the matched non-SCD cohort (76 years) and 25 years less than for the general US population (79 years)
- The estimated quality-adjusted life expectancy for the SCD cohort was 33 years, which was 34 years less than the life quality-adjusted life expectancy for the matched non-SCD cohort (67 years) and 36 years less than that for the general US population (69 years)

Projected Lifetime Income

- The projected lifetime income for the SCD and matched non-SCD cohorts and general US population by sex is shown in **Figure 3**

Figure 3. Projected Lifetime Income by Sex (US Dollars)



SCD, sickle cell disease.

- The estimated lifetime income for an individual in the SCD cohort was approximately $1,227,389 compared with $1,921,574 for an individual in the matched non-SCD cohort and just over $2 million in the general US population
  - Our estimates represent the current values of future income lost, with income inflation being canceled out by the need to discount future earnings
- Therefore, an individual with SCD is estimated to lose approximately $700,000 in lifetime income versus an individual without SCD, because of the early mortality associated with SCD

CONCLUSIONS

- This analysis demonstrated that individuals with SCD experienced markedly reduced life expectancy, diminished quality-adjusted life expectancy, and significantly lower lifetime earning than individuals without SCD
- Individuals with SCD were estimated to live 22 years less than a matched cohort of individuals without SCD, and when adjusted for diminished quality of life, the quality-adjusted life expectancy for individuals with SCD was less than half of those without SCD
- This reduced life expectancy translates into approximately $700,000 in lost lifetime earnings for individuals born with SCD versus those without SCD, equating to $1.4 billion in lifetime income lost for the 1950 individuals born in the US with SCD, because of premature mortality
  - These losses in lifetime earnings represent only a fraction of the total societal costs because this analysis does not include any direct medical costs or other societal costs (eg, lost educational potential, lost workdays due to caregivers caring for their affected children, or patient time spent in the hospital or the emergency department), nor does it account for additional challenges in finding and maintaining active employment because of SCD
- Limitations of this analysis included correcting the CDC MCOD for underreporting to estimate SCD prevalence, using adjacent age groups as a proxy for age groups with undefined death rates, exclusion of fatigue and other important SCD symptoms in utility estimates leading to an overestimate of SCD QALYs, and using current death rates for SCD to estimate future deaths
- This study shows the substantial societal consequences of SCD beyond the resources required to provide medical care for these patients, underscoring the urgent need to develop disease-modifying therapies that can improve the underlying morbidity and mortality of individuals living with SCD

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Disclosures

- **Irene Agodoa:** Global Blood Therapeutics: employment, equity ownership; **Deborah Lubeck:** Global Blood Therapeutics: research funding; **Nickhill Bhakta:** nothing to disclose; **Mark Danese:** Global Blood Therapeutics: consultant and research funding; **Kartik Pappu:** Global Blood Therapeutics: employment, equity ownership; **Robin Howard:** Global Blood Therapeutics: employment, equity ownership; **Michelle Gleeson:** Global Blood Therapeutics: consultant and research funding; **Marc Halperin:** Global Blood Therapeutics: consultant and research funding; **Sophie Lanzkron:** nothing to disclose
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