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Journal:	*Paediatric and Perinatal Epidemiology*
Manuscript ID	PPE-2019-4111.R1
Manuscript Type:	Review Article
Date Submitted by the Author:	n/a
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Socioeconomic inequalities in mortality in children with congenital heart disease: a systematic review and meta-analysis

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Abstract

Background: The impact of socioeconomic status (SES) on congenital heart disease (CHD) related mortality in children is not well established.

Objectives: We aimed to systematically review and appraise the existing evidence on the association between SES (including poverty, parental education, health insurance, income) and mortality among children with CHD.

Data sources: Seven electronic databases (Medline, Embase, Scopus, PsycINFO, CINAHL, ProQuest Natural and Biological Science Collections), reference lists, citations and key journals were searched.

Study selection and data extraction: We included articles reporting original research on the association between SES and mortality in children with CHD if they were full papers published in the English language and regardless of 1) timing of mortality, 2) individual or area-based measures of SES, 3) CHD subtype; 4) age at ascertainment; 5) study period examined. Screening for eligibility, data extraction and quality appraisal were performed in duplicate.

Synthesis: Meta-analyses was performed to estimate pooled ORs for in-hospital mortality according to health insurance status.

Results: Of 1 388 identified articles, 28 met the inclusion criteria. Increased area-based poverty was associated with increased odds/risk of post-operative (n=1), neonatal (n=1), post-discharge (n=1), infant (n=1) and long-term mortality (n=2). Higher parental education was associated with decreased odds/risk of neonatal (n=1) and infant mortality (n=5), but not with long-term mortality (n=1). A meta-analysis of four US articles showed increased unadjusted odds of in-hospital mortality in those with government/public versus private health insurance (OR=1.40, 95% CI: 1.24, 1.56). The association between area-based income and CHD-related mortality was conflicting, with three of eight articles reporting significant associations.

Conclusions: This systematic review provides evidence that children of lower SES are at increased risk of CHD-related mortality. As these children are over-represented in the CHD population, interventions targeting socioeconomic inequalities could have a large impact on improving CHD survival.

1 BACKGROUND

The World Economic Forum considers widening global income inequality as the second most significant trend of worldwide concern.[1] Socioeconomic inequalities in health are established in all developed countries and have persisted over time.[2] Socioeconomic status (SES) affects many aspects of health, influencing the risk of morbidity, mental health, disability free life-years and life expectancy.[3-5] Socioeconomic inequalities in health are estimated to cost $1.02 trillion in the US and £980 billion in the European Union.[6,7]

Congenital heart disease (CHD) is the most common group of congenital anomalies, affecting almost 1% of births.[8,9] In western populations infant mortality is around 13%, but as high as 83% for subtypes such as hypoplastic left heart (HLH).[10] Access and uptake of care are potentially important predictors of CHD survival, and may be influenced by SES.[11,12] However, the overall association between SES and CHD-related mortality is rarely the focus of existing research, often being analysed as a secondary exposure or included only as potential confounding factor. Given that children of lower SES are over-represented amongst the CHD population,[8,13] reducing socioeconomic inequalities in CHD-related treatment and care could have a large impact on survival. Summarising the existing evidence will build the foundation for future strategies to reduce CHD-related mortality in infants and children, which was specifically outlined as a US public health priority by Healthy People 2020.[14]

The aim of this systematic review was to identify, summarise and appraise existing evidence on the association between SES and mortality among children with CHD.

2 METHODS

2.1 Search strategy

A comprehensive search strategy using the PICOS process[15] was developed for the following databases from their inceptions until 8th January 2018: Medline, Embase, Scopus, PsycINFO, CINAHL, ProQuest Natural and Biological Science Collections. Each database was searched using key words (e.g. "socioeconomic" or "income") and subject headings (e.g. exp Social Class/ and exp congenital heart disease/). Search terms are available in the supplementary materials. The titles and abstracts of identified citations were screened according to the inclusion criteria, and the eligible full articles were reviewed.

Key journals including Circulation, Congenital Heart Disease, Heart and Journal of the American Heart Association were searched using basic key words (e.g. "socioeconomic" and "congenital heart"). Citation searching of the reference lists and citing articles (via Google Scholar) of the included articles was performed to identify additional relevant articles.

KEB conducted all searches and screened the titles and abstracts of all the identified citations, and other authors each screened a 10% sample of the citations. Any discrepancies (n=3) in the included studies were discussed amongst all authors and agreement reached. This systematic review has been registered on the PROSPERO database (CRD42017054493).

2.2 Eligibility Criteria

Articles reporting original research on the association between SES and mortality in children with CHD were included: 1) regardless of the timing of mortality; 2) regardless of individual (e.g. paternal/maternal education) or area-based measures (i.e. based on post or zip-codes of residence, e.g. poverty level) of SES; 3) irrespective of the CHD subtype; 4) regardless of age at ascertainment; 5) if they were full papers published in the English language; 6) regardless of the study period examined.

Where articles were based on the same population and both articles reported the same outcomes (e.g. in-hospital mortality) and exposures (e.g. income), only the largest or most recent was included.

2.3 Data extraction

Information on the following study characteristics was extracted: study location, study period, type of mortality (e.g. in-hospital, post-operative), overall mortality rate, data sources (e.g. congenital anomaly register), type of SES (e.g poverty, income), measure of SES (e.g. census-block score), CHD subtypes (e.g. all subtypes, HLH). Health insurance was categorised as private, public (e.g. "Medicaid"), managed or other, (see Table 2 footnotes for article-specific definitions). Adjusted and unadjusted Odds Ratios (ORs), and Hazard Ratios (HRs) were extracted with their corresponding 95% confidence intervals (CIs) according to level of SES. Where they were not reported, crude ORs were estimated from frequencies. However, ORs were not calculated when mortality occurred after infancy as this would not sufficiently allow for case censorship (i.e. for cases with incomplete survival information). Authors were contacted if it was not possible to extract or estimate ORs, or if further information was required (n=6). All data were extracted by KEB and the articles were divided for additional independent data extraction by each of the co-authors. Data were entered into piloted data extraction forms.

2.4 Statistical analysis

Where three or more articles reported ORs for a specific combination of exposure and outcome (e.g. insurance status and in-hospital mortality), meta-analysis was performed. Random effects were incorporated using the inverse variance method to better account for heterogeneity between studies.[16] Heterogeneity between all studies was quantified using the I^2 statistic, where I^2>50% indicates significant heterogeneity.[17] Unadjusted and adjusted ORs were included

separately in any meta-analyses. Where it was not possible to pool ORs in a meta-analysis, the data were summarised narratively.

2.5 Quality appraisal

The Critical Appraisal Skills Programme (CASP) checklist for observational studies was used to assess the quality of the included studies,[18] although papers were not excluded based on these criteria. The CASP checklist consists of eight appraisal tools that are designed to be applied when reading and appraising research. The checklist includes questions on whether: the research is clearly focused, the cohort was recruited in an acceptable manner (e.g. no selection bias), the exposure was accurately measured, confounding factors were accounted for, the results are precise and believable, the results are applicable to the local population, the results fit with other studies, and there are implications for practice.

3 RESULTS

3.1 Search results

The literature search of electronic databases identified a total of 1 959 citations resulting in 1 388 citations after the removal of 571 duplicates (Figure 1). The screening of titles and abstracts of 1 388 citations revealed 97 articles eligible for full text review. After further exclusion of 67 articles (see reasons in Figure 1) and inclusion of articles identified in the reference lists of the included articles (n=1) or their citations (n=5), 36 articles met the inclusion criteria. Eight further articles were excluded because they were based on the same populations, leaving 28 articles for data extraction and analysis.

3.2 Characteristics of included studies

The following types of mortality were analysed: in-hospital (n=10),[19-28] infant (≤1 year, n=6),[21,29-33] neonatal (<28 days, n=2),[34,35] post-operative (n=2),[36,37] post-discharge (n=3),[24,25,38] intra-stage (n=2)[39,40] and long-term (>1 year, n=6)[41-46] (see Table 1 for study-specific definitions). Four measures of SES were reported in the included studies: area-based poverty (n=13),[21,29,30,32,35-41,43,44] parental (maternal[29,31,34,42,45,46] or paternal[33]) or area-based[32,43] education (n=9), individual health insurance status (n=8),[20,23-29] and area-based income (n=8).[19,22,24,25,28,29,32,43] The definitions for SES measures used in individual studies are given in Table 2. The included articles were based on US (n=22),[19,20,22-35,37,39,40,44-46] UK (n=5)[21,36,38,41,43] and Panama (n=1)[42] populations. Most articles included all CHD subtypes combined (n=21),[19-29,31-33,36,38,41-43,45,46] with the rest including cases of HLH or single ventricle (SV) defects (n=5),[30,35,37,39,40] atrioventricular septal defect (AVSD, n=1),[44] and a composite group of "critical" subtypes (n=1).[34] Cases were ascertained from congenital anomaly registers (n=11),[29-35,41,44-46] the Kids Inpatient Database (KIDS, n=4),[22,23,27,28] the SV Reconstruction (SVR) trial (n=2),[37,39] clinical databases (n=2),[21,38] the Pediatric Health Information system (n=2),[19,20] medical records or hospital discharges (n=7).[24-26,36,40,42,43] Many articles ascertained cases post-operatively (n=17),[19-28,30,36-40] with these tending to ascertain cases from medical records. All but one article ascertained cases in childhood.[43] Articles were published between 1999[33] and 2019,[21 28,36] whilst cases were ascertained between 1979[35] and 2015.[19,20,36]

3.3 Association between SES measures and CHD-related mortality

3.3.1 Area-based poverty

Four of five articles that considered all CHD subtypes combined [32,36,38,41,43] reported significant associations between area-based poverty and post-operative,[36] neonatal,[32] post-discharge,[38] infant,[32] and long-term mortality[41,43] (Table 2). The five UK studies[21,36,38,41,43] measured poverty using the English Index of Multiple Deprivation (IMD), a measure based on seven domains:

income, employment, health and disability, education, crime, barriers to housing and services and living environment, which is assigned based on postcode.[47] Both articles that analysed IMD as a continuous variable reported significant positive associations between poverty level and mortality (OR=1.06[36] and OR=1.13[43]). Two articles that analysed IMD as a categorical variable (quintiles[38] and tertiles[41]) reported significant differences in long-term and post-operative mortality but between the most and least deprived categories only (HR=1.22[41] and OR=1.72[38]). However one UK article reported no significant association between infant mortality and IMD quintile. The US article measured poverty using census-based score, assigned based on census block tract and derived from six measures: income, housing and occupational factors.[32] This article compared only the most versus least deprived decile finding statistically significant associations with neonatal, post-neonatal (after one month of age) and infant mortality (ORs= 1.48, 1.67 and 1.61, respectively).[32] Articles that reported ORs and HRs estimated from multivariable models generally reported slightly attenuated effect sizes (Table 2).

Six articles examined the association between poverty and mortality among cases of HLH or HLH and SV phenotypes.[29,30,35,37,39,40] Significant associations were reported between poverty and one year post-operative mortality[37] and intra-stage mortality.[39,40] While the risk of infant mortality was significantly increased for cases of HLH (OR=1.84), there was no significant association reported in another article for cases of critical univentricular CHD (p=0.76)[30] (Table 2). All of these articles were based on US populations and therefore measured poverty using US census-based scores. Two articles showed an increased odds of neonatal mortality in cases of HLH in those born in census block areas with <20% vs ≥20% of residents in poverty (ORs=1.64[30] and 1.21[35]), although neither reached statistical significance. A further article showed no evidence of an association between late phase HLH mortality and census-based poverty, despite showing an early-phase association.[37] One article examined AVSD only, identifying monotonically increasing long-term mortality rates with increasing poverty levels,

but this was not statistically significant (p=0.51).[44] Lastly, one article reported mortality rates for cases of critical biventricular and non-critical biventricular CHD; with a borderline significant association between infant mortality and area-based poverty being observed only for critical biventricular CHD (p=0.05 and 0.42, respectively).

3.3.2 Parental or area-based education

Articles that analysed all CHD subtypes combined reported significant associations between parental education with neonatal[32] and infant mortality, [29,31-33,42] but not with long-term mortality[43] (Table 2). One of those articles measured area-based education using the census score, reporting a stronger effect with infant mortality than in neonatal mortality (OR=1.75 vs 1.49).[32] Another article measured area-based education using the IMD, finding no significant effect with long-term mortality on the continuous scale.[43] The remaining articles measured individual-level parental education (maternal: n=3[29,31,42] and paternal: n=1[33]); all using different categorisations. Three of these articles reported significant effects in each category [31,33,42] and one reported significant effects for biventricular CHD but not for univentricular CHD, which had a smaller sample size.[29] An additional article reported decreasing mortality rates with increasing years of maternal education (<12, 12 and >12 years: 9.7%, 9.6% and 8.1%, respectively) but did not conduct a formal hypothesis test.[45] One article that analysed "critical" CHD reported no association between (individual-level) maternal education and neonatal mortality.[34] Another article reported no significant associations between maternal education and long-term mortality in cases of transposition of the great arteries, tetralogy of Fallot, HLH and coarctation of aorta, but the HRs provided were adjusted for mediators of the association (maternal age and birth weight for gestational age) which likely blocked the total effect of SES on mortality.[46] Indeed, log-rank tests showed significant differences in survival according to years of maternal education for transposition of the great arteries (p=0.002), and coarctation of aorta (p=0.046), but not for HLH (p=0.089) or tetralogy of Fallot (p=0.379).

3.3.3 Health insurance status

The unadjusted odds of in-hospital mortality were significantly greater with public compared to private health insurance in four articles,[20,25,26,28] although in one of these articles a significant effect was reported in neonatal but not post-neonatal mortality.[28] Pooling the ORs from these four articles, a meta-analysis showed a 40% significant increased odds of in-hospital mortality in those with government/ public compared to private health insurance (OR=1.40, 95% CI 1.24, 1.56) (Figure 2), with variation between the studies being low/medium (I^2=37.8%). After controlling for demographic and clinical factors, two[20,27] of three [20,23,27]articles reported significant increased odds of in-hospital mortality} Pooling the adjusted ORs in a meta-analysis there was a 13% increased odds of in-hospital mortality (OR=1.13, 95% CI: 0.98, 1.28; I^2=60.0%), which did not quite reach statistical significance.

With the exception of one article,[25] there were no significant associations (adjusted or unadjusted) between in-hospital mortality and "other" versus private health insurance.[23,26-28] But, pooling the unadjusted ORs in a meta-analysis, there was a 48% significant increased odds of in-hospital mortality in "other" versus private health insurance (OR=1.48, 95% CI 1.19, 1.77; I^2=5.2%).[25,26,28]

One article reported a significant increased odds of infant mortality in those insured with Medicaid versus those not insured with Medicaid (OR=1.16, 95% CI:1.03, 1.3), although the effect was not observed in cases of critical univentricular CHD (OR=1.00, 95% CI:0.72, 1.41).[29] Additionally there was no effect once the analysis was controlled for maternal age, maternal education, maternal race and/ or ethnicity, marital status. One article reported no significant associations between type of health insurance status and post-discharge mortality.[24]

3.3.4 Area-based income

Two articles reported decreasing in-hospital mortality rates with increasing area-based income: one reported significant increased odds associated with area-based incomes of ≤$32 808, $32 808– 41 437, $41 437– 53 982 versus >$53 982 (ORs= 1.57, 1.37, 1.29, respectively)[19] while the other reported a significant increased odds associated with area-based income of <$20k versus >$60k (OR=1.64) only.[25] Two articles reported no association between income and in-hospital mortality.[22,28] One article reported significant increased odds of neonatal and infant mortality (OR=1.41 and 1.78, respectively) in those living in areas associated with the most versus least disadvantaged decile of income.[32] While another article reported decreasing infant mortality rates over increasing categories of income for cases of critical CHD, there were no statistically significant associations reported.[29] The same article reported similar findings for non-critical CHD, but the mortality rate was greatest in the highest income category (7.4%).[29] In one article, ORs for post-discharge mortality decreased monotonically as income increased, but comparing even the lowest income category to the highest was not statistically significant.[24] One article examined survival five years after clinic appointments in adults in London, finding a non-significant decrease in mortality as income z-score increased.[43]

3.4 Quality assessment

All included articles addressed clearly focussed issues. Cohorts were always recruited in an acceptable way, generally using hospital records or congenital anomaly register data. These data sources were also used to accurately ascertain information on the exposure (SES). National death registrations and hospital records were used to adequately ascertain deaths in the included studies. Four articles that adjusted for ethnicity/nativity were deemed to satisfy the CASP's criteria for accounting for important confounding factors. Studies that adjusted for variables such as CHD severity, extra-cardiac anomalies, and gestational age at delivery were not deemed

to satisfy these criteria as these are mediators not confounders. All studies had adequately complete follow-up and appropriate follow-up times for the type of exposure (e.g. in-hospital mortality). Three articles did not report 95% CIs and so it was not possible to assess the precision of their effect estimates.[22,44,45] The remaining studies had acceptable levels of precision, although three articles had wider 95% CIs than other studies due to the relative rarity of their outcomes of interest (Table 1).[24,38,39]

4 COMMENT

4.1 Main findings

This systematic review and meta-analysis identified 28 articles that reported the association between SES and CHD-related mortality. There was consistent evidence that higher levels of area-based poverty, lower levels of parental/area-based education and public as opposed to private health insurance were associated with an increased risk of CHD-related mortality. The evidence regarding the association between area-based income and CHD-related mortality was less consistent. Socioeconomic inequalities were found in: post-operative, in-hospital, intra-operative, neonatal, post-discharge, infant and long-term mortality, although there was some indication that there was a stronger effect in early versus later phase mortality. This systematic review will build the foundation for future strategies to reduce CHD-related mortality in infants and children, addressing public health strategic plans to tackle health inequalities, including a Strategic Review of Health inequalities in England[3] and an US public health priority by Healthy People 2020.[14]

4.2 Interpretation

Socioeconomic inequalities in CHD-related mortality were found in: overall, in-hospital, intra-stage and post-discharge mortality which suggests that there are several potential mechanisms. Differences in case mix between the most versus least deprived are one possible mechanism.

In some populations, prenatal diagnosis of CHD is less common in those living in higher poverty.[48] This may affect case mix if severe cases are undiagnosed and therefore more likely to continue to term in those of lower compared to higher SES. Moreover, there is some evidence that UK women of lower SES are less likely to terminate a pregnancy after a prenatal diagnosis of a congenital anomaly.[49] However, in a recent French cohort, there was little evidence of an association between maternal occupation and prenatal diagnosis or termination of pregnancy following a prenatal diagnosis of CHD. [50] Additionally, several of the included articles reported socioeconomic inequalities in CHD-related mortality for single CHD subtypes, which suggests the associations existed independently of case mix.[30,37]

Two articles reported stronger effect sizes in infant compared to neonatal mortality, which may suggest that socioeconomic inequalities in CHD survival increase with child's age.[30,32] This may indicate that there is a larger deprivation gap in post-discharge mortality, given that most operations occur within infancy.[12] However, Peterson et al (2017) reported a slightly smaller effect size in post-neonates versus neonates and Twedell et al (2012) reported an effect in early but not late phase mortality.[37] Two articles reported smaller effect sizes in their association between maternal education and long-term mortality, than in the other studies that examined early-life mortality.[45,46] The lack of consensus indicates a need for more research to pinpoint exactly where on the care pathway socioeconomic inequalities in CHD-related mortality occur.

Due to delays in seeking treatment and being referred to pediatric cardiology, children with CHD on Medicaid are more likely to experience delayed diagnosis and treatment,[11,12] which may increase the risk of emergency as opposed to elective admission, and therefore the risk of in-hospital mortality. It is not clear whether these mechanisms (delays in diagnosis and treatment) are related to insurance status specifically, or another domain of SES captured by the insurance status variable. Given that inequalities in mortality were also observed in two UK

studies, where universal access to healthcare is enabled via the National Health Service, and with other proxies of SES, the association may not to be solely related to the insurance status.

Loss to follow-up or non-attendance at clinics increases the risk of mortality in adults with CHD,[43] and occurs more commonly in those of lower SES.[43] There is less research regarding attendance at clinics for CHD in childhood, although research in Canada suggests loss to follow-up increases with age.[51] Failure to attend follow-up and clinical appointments could therefore drive inequalities in post-discharge and longer-term mortality. Further research investigating why children with CHD get lost in follow-up is necessary in order to develop interventions to improve follow-up, which is potentially one of few modifiable risk factors for mortality. The majority of studies included in this review examined early outcomes in children with CHD, but there is an emerging population of adults with CHD. Socioeconomic inequalities in CHD-related mortality need to be further investigated in adults.

4.3 Strengths of the review

A major strength of this systematic review was the use of a rigorous search strategy to identify relevant articles. The search strategy was developed and pre-tested using Medline, refined and retested until the authors were confident that it was appropriately inclusive. We also searched the reference lists of all included articles, articles that had cited the included article and core journals in the field, which is proven to increase the ascertainment of relevant articles.[52] A sample of citations was screened by all authors to ensure consistency in study inclusion. All data was double extracted to ensure accuracy in the reported results. Authors were contacted where more information was required during data extraction. Four measures of SES (regardless of variable categorisation), six types of mortality and any combination of CHD subtypes were included in order to incorporate all available evidence. We also used an established quality assessment tool as part of the critical appraisal process.

4.4 Limitations of the review

There were several limitations in this systematic review resulting from limitations in the available evidence. With one exception, all studies were performed in high income western countries (22/28 in the USA), meaning the findings are not likely to be generalizable to lower-income populations. The associations between CHD-related mortality and health insurance and maternal education in particular may not directly apply to non-US populations with different health services and education systems. However, these variables act as proxy measures of SES, representing several domains, and are still meaningful when investigating socioeconomic inequalities.

Despite relatively large sample sizes, the power of some studies to identify a significant association was decreased due to the relative rarity of specific types of mortality. Furthermore, CHD among live births are over-represented in more deprived groups,[8,13] which means that the comparison group can consist of lower numbers, again reducing power. Additional meta-analyses for poverty levels, parental education and area-based income may have increased the power and detected significant associations. However, it was not possible to perform because the categorisations of these exposure variables were not directly comparable between studies.

The included articles used area-based as opposed to individual-based measures of poverty and income, which can result in ecological fallacy; the area-based measures assume that all individuals living in a small area (approximately 1500 people) have the same level of deprivation, but in reality, variation in deprivation exists even in small areas. Additionally, more rural areas with combinations of high and low levels of deprivation may be coded as mid-ranking deprivation, which is then unrepresentative of the majority of individuals within that area.[53] Articles that used individual-level measures of SES (education and insurance status) had more consistent findings than studies investigating area-level income as an exposure. Although poverty was also measured on the area level, the reviewed studies tended to compare only the

most and least deprived (e.g. <20% vs ≥20% in poverty) which perhaps resulted in fewer misclassifications compared to the studies on income, which used multiple categories. We cannot rule out however, that area-based income is a less important factor in socioeconomic inequalities in CHD survival.

5 CONCLUSIONS

This systematic review provides evidence of socioeconomic inequalities in CHD-related mortality. Higher degree of poverty, lower level of parental education and public as opposed to private health insurance were associated with an increased the risk of CHD-related mortality. Given that individuals of lower SES are over-represented amongst those with CHD, it is important to understand why these inequalities occur in order to develop evidence-based interventions to target the deprivation gap. Further research is also required to pinpoint exactly when in the care pathway socioeconomic inequalities in CHD-related mortality occur. Ultimately, this may reduce CHD-related mortality and decrease health care costs.

Acknowledgements

We thank Titus Chan for providing further information upon request and Dr Nicola Heslehurst for her helpful comments on the manuscript. We also thank Dr Emma Slack for running the literature searches for 2018/19 using the predefined search strategy and screening a 10% sample of the citations for 2018/19.

Contributor's Statement

Dr Best obtained funding, conceptualised and designed the study, did the literature search and led the review process, reviewed all included papers, carried out the statistical analysis, drafted and revised the manuscript.

Drs Vieira and Glinianaia made substantial contribution to study design, data acquisition (paper reviewing, data extraction), analysis or interpretation of data, and critically reviewed and revised the manuscript.

Prof. Rankin supervised, conceptualised and designed the study, contributed to paper reviewing, data extraction and interpretation, and critically reviewed the manuscript for important intellectual content.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Figure legends

FIGURE 1 PRISMA Flow diagram of study selection

FIGURE 2 Forest plot showing association between public vs private health insurance and in-hospital mortality

FIGURE 3 Forest plot showing association between "other" vs private health insurance and in-hospital mortality.

Supplementary materials

eTable 1 Search strategy

REFERENCES

1. World Economic Forum. Outlook on the global agenda. 2014; Available from: https://www.weforum.org/reports/outlook-global-agenda-2014.
2. Bleich SN, Jarlenski MP, Bell CN, LaVeist TA. Health Inequalities: Trends, Progress, and Policy. *Annual Review of Public Health* 2012; 33:7-40.
3. Marmot M. Fair Society, Healthy Lives. The Marmot Review Executive Summary. 2010; Available from: http://www.cpa.org.uk/cpa_documents/FairSocietyHealthyLivesExecSummary.pdf.
4. Reiss F. Socioeconomic inequalities and mental health problems in children and adolescents: A systematic review. *Social Science & Medicine* 2013; 90:24-31.
5. Lynch JW, Smith GD, Kaplan GA, House JS. Income inequality and mortality: importance to health of individual income, psychosocial environment, or material conditions. *British Medical Journal* 2000; 320:1200.
6. Mackenbach JP, Meerding WJ, Kunst AE. Economic costs of health inequalities in the European Union. *Journal of Epidemiology & Community Health* 2011; 65:412-419.
7. Schoeni RF, Dow WH, Miller WD, Pamuk ER. The Economic Value of Improving the Health of Disadvantaged Americans. *American Journal of Preventive Medicine* 2011; 40:S67-S72.
8. Agha MM, Glazier RH, Moineddin R, Moore AM, Guttmann A. Socioeconomic status and prevalence of congenital heart defects: does universal access to health care system eliminate the gap? *Birth Defects Research Part A- Clinical and Molecular Teratology* 2011; 91:1011-1018.
9. Van der Linde D, Konings EE, Slager MA, Witsenburg M, Helbing WA, Takkenberg JJ, et al. Birth prevalence of congenital heart disease worldwide: a systematic review and meta-analysis. *Journal of the American College of Cardiology* 2011; 58:2241-2247.
10. Best K, Rankin J. Long-term survival for individuals born with congenital heart disease: A systematic review and meta-analysis. *Journal of the American Heart Association* 2016; 5:e002846.
11. Perlstein MA, Goldberg SJ, Meaney FJ, Davis MF, Kluger CZ. Factors influencing age at referral of children with congenital heart disease. *Archives of Pediatrics & Adolescent Medicine* 1997; 151:892-897.
12. Chang R-KR, Chen AY, Klitzner TS. Factors associated with age at operation for children with congenital heart disease. *Pediatrics* 2000; 105:1073-1081.
13. Knowles RL, Ridout D, Crowe S, Bull C, Wray J, Tregay J, et al. Ethnic and socioeconomic variation in incidence of congenital heart defects. *Archives of Disease in Childhood* 2016; 102:496-502.
14. U.S. Department of Health and Human Services. Healthy People 2020. [cited 2018]; Available from: https://www.healthypeople.gov/node/4829/data_details.
15. PubMed Health. PICO Framework. 2018; Available from: https://www.ncbi.nlm.nih.gov/pubmedhealth/PMHT0029906/.
16. Egger M, Smith GD, Altman DG. *Systematic reviews in health care*. BMJ Publishing group; 2001.

17. Higgins J, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *British Medical Journal* 2003; 327:557.

18. Better Value Healthcare Ltd. Critical Appraisal Skills Programme. 2018; Available from: http://www.casp-uk.net/casp-tools-checklists.

19. Anderson BR, Fieldston ES, Newburger JW, Bacha EA, Glied SA. Disparities in Outcomes and Resource Use After Hospitalization for Cardiac Surgery by Neighborhood Income. *Pediatrics* 2018; 141:e20172432.

20. Chan T, Barrett CS, Tjoeng YL, Wilkes J, Bratton SL, Thiagarajan RR. Racial variations in extracorporeal membrane oxygenation use following congenital heart surgery. *Journal of Thoracic and Cardiovascular Surgery* 2018; 156:306-315.

21. Knowles RL, Ridout D, Crowe S, Bull C, Wray J, Tregay J, et al. Ethnic-specific mortality of infants undergoing congenital heart surgery in England and Wales. *Archives of Disease in Childhood* 2019.

22. Benavidez OJ, Gauvreau K, Jenkins KJ. Racial and ethnic disparities in mortality following congenital heart surgery. *Pediatric Cardiology* 2006; 27:321-328.

23. Benavidez OJ, Gauvreau K, Nido PD, Bacha E, Jenkins KJ. Complications and Risk Factors for Mortality During Congenital Heart Surgery Admissions. *The Annals of Thoracic Surgery* 2007; 84:147-155.

24. Chang RK, Rodriguez S, Lee M, Klitzner TS. Risk factors for deaths occurring within 30 days and 1 year after hospital discharge for cardiac surgery among pediatric patients. *American Heart Journal* 2006; 152:386-393.

25. Klitzner TS, Lee M, Rodriguez S, Chang R-KR. Sex-related disparity in surgical mortality among pediatric patients. *Congenital Heart Disease* 2006; 1:77-88.

26. DeMone JA, Gonzalez PC, Gauvreau K, Piercey GE, Jenkins KJ. Risk of death for Medicaid recipients undergoing congenital heart surgery. *Pediatric Cardiology* 2003; 24:97-102.

27. Chan T, Lion KC, Mangione-Smith R. Racial disparities in failure-to-rescue among children undergoing congenital heart surgery. *Journal of Pediatrics* 2015; 166:812-818.e811-814.

28. Peterson JK, Chen Y, Nguyen DV, Setty SP. Current trends in racial, ethnic, and healthcare disparities associated with pediatric cardiac surgery outcomes. *Congenital Heart Disease* 2017; 12:520-532.

29. Pace ND, Oster ME, Forestieri NE, Enright D, Knight J, Meyer RE. Sociodemographic factors and survival of infants with congenital heart defects. *Pediatrics* 2018; 142:e20180302.

30. Hirsch JC, Copeland G, Donohue JE, Kirby RS, Grigorescu V, Gurney JG. Population-based analysis of survival for hypoplastic left heart syndrome. *Journal of Pediatrics* 2011; 159:57-63.

31. Kucik JE, Cassell CH, Alverson CJ, Donohue P, Tanner JP, Minkovitz CS, et al. Role of health insurance on the survival of infants with congenital heart defects. *American Journal of Public Health* 2014; 104:e62-70.

32. Kucik JE, Nembhard WN, Donohue P, Devine O, Wang Y, Minkovitz CS, et al. Community socioeconomic disadvantage and the survival of infants with congenital heart defects. *American Journal of Public Health* 2014b; 104:e150-157.

33. Kuehl KS, Loffredo CA, Ferencz C. Failure to diagnose congenital heart disease in infancy. *Pediatrics* 1999; 103:743-747.

34. Fixler DE, Xu P, Nembhard WN, Ethen MK, Canfield MA. Age at referral and mortality from critical congenital heart disease. *Pediatrics* 2014; 134:e98-e105.

35. Morris SA, Ethen MK, Penny DJ, Canfield MA, Minard CG, Fixler DE, et al. Prenatal diagnosis, birth location, surgical center, and neonatal mortality in infants with hypoplastic left heart syndrome. *Circulation* 2014; 129:285-292.

36. Kempny A, Dimopoulos K, Uebing A, Diller GP, Rosendahl U, Belitsis G, et al. Outcome of cardiac surgery in patients with congenital heart disease in England between 1997 and 2015. *PLoS One* 2017; 12:e0178963.

37. Tweddell JS, Sleeper LA, Ohye RG, Williams IA, Mahony L, Pizarro C, et al. Intermediate-term mortality and cardiac transplantation in infants with single-ventricle lesions: Risk factors and their interaction with shunt type. *Journal of Thoracic and Cardiovascular Surgery* 2012; 144:152-159.

38. Crowe S, Ridout DA, Knowles R, Tregay J, Wray J, Barron DJ, et al. Death and emergency readmission of infants discharged after interventions for Congenital Heart Disease: a national study of 7643 infants to inform service improvement. *Journal of the American Heart Association* 2016; 5:e003369.

39. Ghanayem NS, Allen KR, Tabbutt S, Atz AM, Clabby ML, Cooper DS, et al. Interstage mortality after the Norwood procedure: Results of the multicenter Single Ventricle Reconstruction trial. *Journal of Thoracic and Cardiovascular Surgery* 2012; 144:896-906.

40. Taylor LC, Burke B, Donohue JE, Yu S, Hirsch-Romano JC, Ohye RG, et al. Risk Factors for Interstage Mortality Following the Norwood Procedure: Impact of Sociodemographic Factors. *Pediatric Cardiology* 2016; 37:68-75.

41. Best KE, Tennant PWG, Rankin J. Survival, by Birth Weight and Gestational Age, in Individuals With Congenital Heart Disease: A Population-Based Study. *Journal of the American Heart Association* 2017; 6:e005213.

42. Castro F, Zúñiga J, Higuera G, Donderis MC, Gómez B, Motta J. Indigenous Ethnicity and Low Maternal Education Are Associated with Delayed Diagnosis and Mortality in Infants with Congenital Heart Defects in Panama. *PLoS One* 2016; 11.

43. Kempny A, Diller G-P, Dimopoulos K, Alonso-Gonzalez R, Uebing A, Li W, et al. Determinants of outpatient clinic attendance amongst adults with congenital heart disease and outcome. *International Journal of Cardiology* 2016; 203:245-250.

44. Miller A, Siffel C, Lu C, Riehle-Colarusso T, Frías JL, Correa A. Long-Term Survival of Infants with Atrioventricular Septal Defects. *Journal of Pediatrics* 2010; 156:994-1000.

45. Nembhard WN, Xu P, Ethen MK, Fixler DE, Salemi JL, Canfield MA. Racial/ethnic disparities in timing of death during childhood among children with congenital heart defects. *Birth Defects Research Part A- Clinical and Molecular Teratology* 2013; 97:628-640.

46. Wang Y, Liu G, Druschel CM, Kirby RS. Maternal race/ethnicity and survival experience of children with congenital heart disease. *Journal of Pediatrics* 2013; 163:1437-1442.e1431-1432.

47. Official statistics. English Indices of deprivation. 2015 [cited 2018]; Available from: https://www.gov.uk/government/statistics/english-indices-of-deprivation-2015.

48. Hill GD, Block JR, Tanem JB, Frommelt MA. Disparities in the prenatal detection of critical congenital heart disease. *Prenatal Diagnosis* 2015; 35:859-863.

49. Smith LK, Budd JLS, Field DJ, Draper ES. Socioeconomic inequalities in outcome of pregnancy and neonatal mortality associated with congenital anomalies: population based study. *British Medical Journal* 2011; 343:d4306.

50. Khoshnood B, Lelong N, Andrieu T, Houyel L, Bonnet D, Jouannic JM, et al. Assessing sociodemographic differences (or lack thereof) in prenatal diagnosis of congenital heart defects: a population-based study. *BMJ Open* 2016; 6:e009353.

51. Mackie AS, Ionescu-Ittu R, Therrien J, Pilote L, Abrahamowicz M, Marelli AJ. Children and adults with congenital heart disease lost to follow-up. *Circulation* 2009; 120:302-309.

52. Papaioannou D, Sutton A, Carroll C, Booth A, Wong R. Literature searching for social science systematic reviews: consideration of a range of search techniques. *Health Information and Libraries Journal* 2010; 27:114-122.

53. Pampalon R, Hamel D, Gamache P. Health inequalities in urban and rural Canada: Comparing inequalities in survival according to an individual and area-based deprivation index. *Health & Place* 2010; 16:416-420.

54. Jenkins KJ. Risk adjustment for congenital heart surgery: the RACHS-1 method. *Seminars in Thoracic & Cardiovascular Surgery: Pediatric Cardiac Surgery Annual* 2004; 7:180-184.

TABLE 1 Description of included articles

Author	Study location	Study period	Deaths/ Cases	Type of mortality	Inclusion criteria Surgical/ all, CHD subtypes, age	Data sources	Measure of Socioeconomic status	Information on Unadjusted & Adjusted results
Anderson et al 2018[19]	27 US states	Cardiac procedures between 2005 and 2015	2933/86 104 (3.4%)	In-hospital	Surgical cases only (cardiac transplantation excluded) All CHD subtypes Cases aged ≤18 years	Pediatric Health Information System database and the US Census Bureau	Income	ORs unadjusted and adjusted for age category, sex, prematurity, other comorbid chronic condition, RACHS-1 category, hospital, patient, year, race, payer, state, and urban designation.
Benavidez et al 2006[22]	19 states in USA (AZ, CA, CO, CT, FL, HI, KS, MA, MD, MO, NJ, NY, PA, SC, TN, TX, UT, VA, and WI)	Hospital discharges in 2000	348/8483 (4.1%)	In-hospital	Surgical cases only All CHD subtypes Cases aged ≤18 years	Kids Inpatient Database	Income	ORs unadjusted and adjusted for (RACHS-1) risk category, age category, prematurity, non-cardiac structural anomalies, and multiple cardiac procedure.

Author	Study location	Study period	Deaths/ Cases	Type of mortality	Inclusion criteria Surgical/ all, CHD subtypes, age	Data sources	Measure of Socioeconomic status	Information on Unadjusted & Adjusted results
Benavidez et al 2007[23]	19 states in USA (AZ, CA, CO, CT, FL, HI, KS, MA, MD, MO, NJ, NY, PA, SC, TN, TX, UT, VA, and WI)	Hospital discharges in 2000	416/10 032 (4.1%)	In-hospital	Surgical cases only All CHD subtypes Cases aged ≤18 years	Kids Inpatient Database	Health insurance	OR adjusted for RACHS-1, gender, race and volume.
Best et al 2017[41]	North of England	Births between 1985-2003	652/5070	Long-term (before 2008)	All cases All CHD subtypes	Northern Congenital Abnormality Survey	Poverty (Index of Multiple Deprivation)	HRs unadjusted and adjusted for year of birth, gestational age at delivery, birth weight, extra-cardiac anomalies, maternal age at delivery, sex, plurality, CHD severity.
Castro et al 2016[42]	Panama, Central America	Cases born between 2010 and 2014	284/954 (29.8%)	Long-term (up to age five)	All cases All CHD subtypes	Medical records National database of mortality	Maternal education	OR unadjusted and adjusted for ethnicity, maternal age, delivery institution type, Non-cardiac anomalies, severity of defect.

Author	Study location	Study period	Deaths/ Cases	Type of mortality	Inclusion criteria Surgical/ all, CHD subtypes, age	Data sources	Measure of Socioeconomic status	Information on Unadjusted & Adjusted results
Chan et al 2015[27]	USA	Hospital discharges in 2003, 2006 or 2009	1147/38801 (3.0%)	In-hospital	Surgical cases only All CHD subtypes Cases ≤18 years old	Kids Inpatient Database	Health insurance	OR adjusted for sex, age category, surgical complexity, prematurity, non-cardiac structural defects, emergent admission, and year.
Chan et al 2018[20]	27 US states	Cardiac procedures between 2004 and 2015	4254/ 130,860 (3.3%)	In-hospital	Surgical cases only All CHD subtypes Cases aged ≤18 years	Pediatric Health Information System database and the US Census Bureau	Health insurance	ORs unadjusted and adjusted for sex, age, surgical complexity, surgical era, prematurity, complex chronic conditions, hospital surgical volume, preoperative mechanical ventilation and medications, and pre- and postoperative cardiopulmonary resuscitation
Chang et al 2006[24]	California, USA	Hospital discharge data between 1989 and 1999	148/23 897 (0.6%)	In-hospital, Post-discharge (within 1 year)	Surgical cases only All CHD subtypes Cases ≤18 years old	State-wide hospital discharge data Death registration data	Income, health insurance	OR unadjusted

Author	Study location	Study period	Deaths/ Cases	Type of mortality	Inclusion criteria Surgical/ all, CHD subtypes, age	Data sources	Measure of Socioeconomic status	Information on Unadjusted & Adjusted results
Crowe et al 2016[38]	England & Wales	Cardiac procedures between 2005 and 2010	246/7643 (3.2%)	Post discharge (within 1 year)	Surgical cases only All CHD subtype	National Congenital Heart Disease Audit and Pediatric Intensive Care Network	Poverty (Index of Multiple Deprivation)	OR unadjusted
DeMone et al 2003[26]	California, Illinois, Washington, Pennsylvania, Massachusetts, USA	Hospital discharges in 1996	227/4729 (4.8%)	In-hospital	Surgical cases only All CHD subtypes Cases ≤18 years old	Hospital discharge data	Health insurance	OR unadjusted and adjusted for risk category and age category, prematurity, non-cardiac anomalies.
Fixler et al 2014[34]	Texas, USA	Cases born between 1996-2007	69/178 (38.8%)	Neonatal	All cases Cases of critical CHD	Texas birth defects registry state birth and death records	Maternal education	OR unadjusted and adjusted for maternal ethnicity, maternal age, diagnosis, gender, birth weight, gestation age, birth era, extra-cardiac defects prenatal diagnosis.

Author	Study location	Study period	Deaths/ Cases	Type of mortality	Inclusion criteria Surgical/ all, CHD subtypes, age	Data sources	Measure of Socioeconomic status	Information on Unadjusted & Adjusted results
Ghanayem et al 2012[39]	North America	Norwood procedure between May 2005 to Dec 2008	50/426 (11.7%)	Intra-stage	Surgical cases only HLH	Subjects randomized in the multicentre SVR trial who survived to discharge from the hospital after the Norwood procedure are included in this analysis.	Poverty (US census based score)	OR unadjusted and adjusted for site.
Hirsch et al 2011[30]	Michigan, USA	Cases born between 1992 and 2005	111/406 (27.3%)	Infant	Surgical cases only HLH	Michigan birth defects registry Death Statistics Master File that includes state mandated reporting of all deaths	Poverty (US census based score)	OR unadjusted
Kempny et al 2016[43]	London, UK	Hospital follow up between 1991 and 2008	366/4461 (8.2%)	Long-term (between 2008 to 2013)	All cases All CHD subtypes Adult patients	CHD at a tertiary centre	Poverty: Index of Multiple Deprivation (IMD, z score), IMD score, IMD income, IMD employment	HR unadjusted

Author	Study location	Study period	Deaths/ Cases	Type of mortality	Inclusion criteria Surgical/ all, CHD subtypes, age	Data sources	Measure of Socioeconomic status	Information on Unadjusted & Adjusted results
							IMD health, IMD education	
Kempny et al 2017[36]	England, UK	Cardiac surgery between 1997-2015	2423/57293	Post-operative (within 6 months)	Surgical cases only All CHD subtypes All ages included	Hospital episode statistics	Poverty (Index of Multiple Deprivation (IMD, z score))	OR unadjusted
Klitzner et al 2006[25]	California, USA	Hospital discharges between 1989 and 1999	1505/25402 (5.9%)	In-hospital, post-discharge (within 30 days)	Surgical cases only All CHD subtypes Cases <18 years old at death	Hospital notes Death registry data	Income, health insurance	OR unadjusted

Author	Study location	Study period	Deaths/ Cases	Type of mortality	Inclusion criteria Surgical/ all, CHD subtypes, age	Data sources	Measure of Socioeconomic status	Information on Unadjusted & Adjusted results
Knowles et al 2019[21]	England and Wales	Cases born between 2006 to 2009.	449/5350 (8.4%)	In-hospital, Infant	Surgical cases only All CHD subtypes	National CHD Audit and Paediatric intensive care unit admission records	Poverty (Index of Multiple Deprivation)	OR adjusted for ethnicity, sex, gestation, prenatal diagnosis, CHD subtype, extra-cardiac anomalies, weight at admission, age at admission,
Kucik et al 2014b[32]	Arizona, New Jersey, New York, Texas, USA	Cases born between 1999 and 2007	1942/9853 (19.7%)	Infant	All cases Common truncus arteriosus, transposition of the great vessels, tetralogy of Fallot, atrioventricular septal defect, aortic valve stenosis, HLH, and coarctation of the aorta notified to four birth defect registries	Four birth defect registries State-specific birth-infant death files	Income, poverty (US census based score), maternal education	OR unadjusted
Kucik et al 2014[31]	Florida, USA	Cases born between 1998 and 2007	1443/43411 (3.3%)	Infant	All cases All CHD subtypes	Florida Birth Defects Registry Death certificates	Maternal education, health insurance	OR unadjusted and adjusted for community-level indicator and adjusted for birth weight, sex, maternal age, maternal

Author	Study location	Study period	Deaths/ Cases	Type of mortality	Inclusion criteria Surgical/ all, CHD subtypes, age	Data sources	Measure of Socioeconomic status	Information on Unadjusted & Adjusted results
								nativity, maternal education, parity, state, and birth period.
Kuehl et al 1999[33]	Baltimore and Washington, USA	Cases born between 1981 and 1989	800/4390 (18.2%)	Infant	All cases All CHD subtypes	The Baltimore Washington infant study	Paternal education	OR unadjusted
Miller et al 2010[44]	Metropolitan Atlanta, USA	Cases born between 1979 and 2003	111/338 (32.8%)	Long-term (age 25)	All cases Atrioventricular septal defect	Metropolitan Atlanta Birth Defects Program National death index records	Poverty (US census based score)	Mortality rate only (unadjusted)
Morris et al 2014[35]	Texas, USA	Cases born between 1999 and 2007	/463	Neonatal	All cases HLH	Cases & deaths: Texas Birth Defects Registry and Texas vital records	Poverty, maternal education	OR unadjusted
Nembhard et al 2013[45]	Texas, USA	Cases born between 1999 and 2007	2767/30015 (9.2%)	Long-term (age 10)	All cases All CHD subtypes	Texas Birth Defect Registry and vital statistics	Maternal education	Mortality rate only (unadjusted)

Author	Study location	Study period	Deaths/ Cases	Type of mortality	Inclusion criteria Surgical/ all, CHD subtypes, age	Data sources	Measure of Socioeconomic status	Information on Unadjusted & Adjusted results
Pace et al 2018[29]	North Carolina, USA	Cases born between 2004 and 2013	1307/15533 (8.4%)	Infant	All cases All CHD subtypes Age<1 at diagnosis	North Carolina Birth Defects Monitoring Program	Maternal education, health insurance, Income, poverty	OR unadjusted and HR adjusted for maternal age, maternal education, maternal race and/ or ethnicity, marital status, health insurance
Peterson et al 2017[28]	USA (44 states)	CHD discharges 2012	391/13130	In-hospital	Surgical cases only All CHD subtypes Age< 18 years	Kids Inpatient database	Income, health insurance	OR- not clear if adjusted
Taylor et al 2016[40]	Michigan, USA	Cases born between Jan 2000 and June 2009	32/273 (11.7%)	Intra-stage	Surgical cases only HLH, single right ventricle malformations	Cases & deaths: Medical records	Poverty (US census based Z score)	OR unadjusted

Author	Study location	Study period	Deaths/ Cases	Type of mortality	Inclusion criteria Surgical/ all, CHD subtypes, age	Data sources	Measure of Socioeconomic status	Information on Unadjusted & Adjusted results
Tweddell et al 2012[37]	15 centres in USA	Norwood procedure between May 2005 and July 2008	178/547 (32.5%)	Post-operative ("early" within 1 year and "late" within 1-4 years)	Surgical cases only HLH and single right ventricle	Cases & deaths: multicentre SVR trial who survived to discharge from the hospital after the Norwood procedure are included in this analysis.	Poverty (US census based score)	HR adjusted for phenotype, gestational age at delivery, genetic syndrome.
Wang et al 2013[46]	New York State, USA	Cases born between 1983 and 2006	/8181	Long-term (before January 1st 2008)	All cases HLH, coarctation of aorta, tetralogy of Fallot, transposition of the great vessels	New York State Congenital Malformations Registry and death certificate data	Maternal education	OR unadjusted

Infant= <1 year, Neonatal = <28 days, Intra-stage=after Norwood procedure discharge and before the stage II procedure, OR=Odds ratio, HR-hazard ratio. CHD=congenital heart disease, RACHS-1=Risk adjustment in Congenital Heart Surgery (a risk adjusted method comprised of: cardiac procedures grouped into six risk categories, age, gestational age and non-cardiac anomalies[54]). AZ=Arizona, CA=California, CO=Colorado, CT=Connecticut, FL=Florida, HI=Hawaii, KS= Kansas, MA=Metropolitan Atlanta, MD=Maryland, MO=Missouri, NJ=New Jersey, NY=New York, PA=Philadelphia, SC=South Carolina, TN=Tennessee, TX=Texas, UT=Utah, VA=Virginia, and WI=Wisconsin.

TABLE 2 Effect estimates for association between CHD-related mortality and area-based poverty, parental education, health insurance status and area-based income

Author	CHD subtypes	Mortality type	Exposure categories	% Mortality	OR (95% CI)	Adjusted OR (95% CI)
Area-based poverty[c]						
Knowles et al (2019)[21]	All	In-hospital	Q1 (most deprived)		1.18 (0.77, 1.80)	0.94 (0.60, 1.48)
			Q2		1.58 (1.03, 2.42)	1.33 (0.86, 2.06)
			Q3		0.88 (0.53, 1.45)	0.87 (0.52, 1.46)
			Q4		1.01 (0.61, 1.67)	1.04 (0.63, 1.71)
			Q5 (least deprived)		1 (ref)	1 (ref)
Kempny et al (2017)[36]	All	Post-operative	IMD rank (continuous)	-	1.06 (1.02, 1.11)[b]	-
Twedell et al (2012)[37] *(late phase)*	HLH & right SV		Census-based score (continuous-per 5 points)	-	0.88 (0.57, 1.35)	-
Twedell et al (2012)[37] *(early phase)*	HLH & right SV		Census-based score (continuous-per 5 points)	-	1.27 *(1.07, 1.51)*[a]	1.28 (1.06, 1.56)[a]
Hirsch et al (2011)[30]	HLH	Neonatal	≥20% in poverty	26.0	*1.64 (0.9, 3.0)*	-
			<20% in poverty	17.6	*1 (ref)*	
Morris et al (2014)[35]	HLH		≥20% in poverty	25.4	*1.21 (0.78, 1.87)*	-
			<20% in poverty	29.2	*1 (ref)*	
Kucik et al (2014b)[32]	All		D1 (most deprived)	13.3	*1.48 (1.08, 2.02)*	1.43 (1.00, 2.06)[a]
			D10 (least deprived)	9.4	*1 (ref)*	1 (ref)
Kucik et al (2014b)[32]	All	Post-neonatal	D1 (most deprived)	12.0	*1.67 (1.17, 2.39)*	1.62 (1.06, 2.47)[a]
			D10 (least deprived)	7.5	*1 (ref)*	1 (ref)
Crowe et al (2015)[38]	All	Post-discharge	Q1 (most deprived)	3.6	1.72 *(1.08, 2.73)* [b]	-
			Q2	3.3	1.56 *(0.95, 2.55)* [b]	
			Q3	3.3	1.58 *(0.94, 2.63)* [b]	
			Q4	3.5	1.69 *(1.0, 2.84)* [b]	
			Q5 (least deprived)	2.1	1 (ref)	
Ghanayem et al (2012)[39]	HLH	Intra-stage	≥13% in poverty	12.4	3.71 (1.37, 10.0) [b]	-
			5.4-13% in poverty	16.9	5.33 (2.03, 14.0) [b]	
			<5.4% in poverty	3.7	1 (ref)	

Taylor et al (2016)[40]	HLH, SV		Census-based Z score (continuous)	-	1.11 (1.0, 1.11) [b]	-
Hirsch et al (2011)[30]	HLH	Infant	≥20% in poverty <20% in poverty	45.3 31.0	*1.84 (1.17, 2.91)* *1 (ref)*	-
Knowles et al (2019) [21]	All		Q1 (most deprived) Q2 Q3 Q4 Q5 (least deprived)		1.30 (0.96, 1.76) 1.54 (1.13, 2.11) 0.99 (0.69, 1.42) 1.21 (0.86, 1.72) 1 (ref)	1.08 (0.78, 1.49) 1.33 (0.97, 0.83) 1.07 (0.75, 1.53) 1.27 (0.90, 1.79) 1 (ref)
Kucik et al (2014b)[32]	All		D10 (most deprived) D1 (least deprived)	16.2 23.7	*1.61 (1.25, 2.06)* *1 (ref)*	1.51 (1.15, 2.00) 1 (ref)
Pace et al (2018)[29]	Critical Univentricular		Q1 (least deprived) Q2 Q3 Q4 (most deprived)	38.6 36.6 39.3 39.2	-	-
Pace et al (2018)[29]	Critical Biventricular		Q1 (least deprived) Q2 Q3 Q4 (most deprived)	12.7 17.0 18.0 18.0	-	-
Pace et al (2018)[29]	Noncritical Biventricular		Q1 (least deprived) Q2 Q3 Q4 (most deprived)	5.7 5.8 6.2 6.0	-	-
Miller et al (2010)[44]	AVSD	Long-term	≥20% in poverty 10-19.9% in poverty 5-9.9% in poverty 0-4.9% in poverty	62.3 60.4 57.9 56.9	-	-
Kempny et al (2016)[43]	All		IMD score (continuous/ SD)	-	1.13 (1.10, 1.17)	-
Best et al (2017)[41]	All		T1 (most deprived) T2 T3 (least deprived)	-	1.22 (1.01, 1.45) [a,b] 1.12 (0.89, 1.28) [b] 1 (ref)	1.19 (0.98, 1.45) [a,b] 1.08 (0.90, 1.28) [b] 1 (ref)
Parental education						
Fixler et al (2014)[34]	"Critical" CHD	Neonatal	<12 years 12 years >12 years	-	0.89 (0.74, 1.08) [b] 1 (ref) 0.80 (0.67, 1.01) [b]	0.96 (0.78, 1.23) [b] 1 (ref) 0.91 (0.69, 1.21) [b]

Kucik et al (2014b)[32]	All		D1 (least educated) D10 (most educated)	-	*1.49 (1.0, 2.03)* *1 (ref)*	1.34 (0.93, 1.92)[a] 1 (ref)
Castro et al (2016)[42]	All	Infant	<6 years ≥6 years	-	1.78 (1.38, 2.29)[a] 1 (ref)	1.95 (1.45, 2.62)[a] 1 (ref)
Kucik et al (2014)[31]	All		<12 years 12 years >12 years	-	*1.26 (1.10, 1.44)* *1 (ref)* *0.75 (0.66, 0.84)*	-
Kuehl et al (1999)[33] (Paternal)	All		<12 years ≥12 years	-	1.62 (1.2, 2.1) 1 (ref)	-
Kucik et al (2014b)[32]	All		D1 (least educated) D10 (most educated)	-	*1.75 (1.38, 2.26)* *1 (ref)*	1.51 (1.15, 2.00)[a] 1 (ref)
Pace et al (2018)[29]	Critical Univentricular		<12 years 12 years >12 years	40.7 38.9 37.7	*1.13 (0.72, 1.77)* *1.05 (.69, 1.59)* 1 (ref) *(ref)*	0.90 (0.59, 1.37)[a] 0.96 (0.67, 1.37)[a] 1 (ref)
Pace et al (2018)[29]	Critical Biventricular		<12 years 12 years >12 years	19.4 17.4 13.9	*1.49 (1.04, 2.14)* *1.31 (0.93, 1.84)* 1 (ref)	1.36 (0.91, 2.03)[a] 1.25 (0.88, 1.78)[a] 1 (ref)
Pace et al (2018)[29]	Noncritical Biventricular		<12 years 12 years >12 years	6.8 7.2 5.0	*1.38 (1.15, 1.67)* *1.47 (1.24, 1.76)* 1 (ref)	1.21 (0.96, 1.51)[a] 1.33 (1.10, 1.60)[a] 1.0 (ref)
Pace et al (2018)[29]	All CHD		<12 years 12 years >12 years	9.2 9.4 7.1	*1.33 (1.14, 1.55)* *1.36 (1.18, 1.57)* 1 (ref)	-
Wang et al (2013)[46]	TGA	Long-term	<12 years 12 years >12 years	30.5 36.3 27.6	-	0.95 (0.79, 1.14)[a] 1 (ref) 0.99 (0.81, 1.21)[a]
Wang et al (2013)[46]	ToF		<12 years 12 years >12 years	21.6 21.2 19.1	-	1.09 (0.88, 1.36)[a] 1 (ref) 1.00 (0.82, 1.22)[a]
Wang et al (2013)[46]	HLH		<12 years 12 years >12 years	61.5 71.3 65.7	-	1.04 (0.86, 1.25)[a] 1 (ref) 0.99 (0.84, 1.16)[a]
Wang et al (2013)[46]	CoA		<12 years 12 years >12 years	25.0 25.6 21.2	-	1.07 (0.86, 1.34)[a] 1 (ref) 0.86 (0.7, 1.06)[a]

Nembhard et al (2013)[45]	All		<12 years 12 years >12 years	9.7 9.6 8.1	-	-
Kempny et al (2016)[43]	All		IMD Education score (continuous)	-	0.97 (0.87, 1.08)[a]	
Insurance status[e]						
Chan et al (2015)[27]	All	In-hospital	Private Public Other	-	-	1 (ref) 1.24 (1.08, 1.43) 1.30 (0.97, 1.75)
Chan et al (2018)[20]	All		Private Public	2.6 3.8	1 (ref) *1.48 (1.38, 1.58)*	1 (ref) 1.17 (1.08, 1.27)
Benavidez et al (2007)[23]	All		Private Public Other	-	-	1 (ref) 0.9 (0.7, 1.2) 0.8 (0.5, 1.2)
DeMone et al (2003)[26]	All		Private Public Managed Other	3.8 6.4 3.8	*1 (ref)* *1.72 (1.21, 2.45)* *0.98 (0.66, 1.47)* *1.31 (0.84, 2.05)*	1 (ref) 1.67 1.06
Klitzner et al (2006)[25]	All		Private Public Managed Other	5.2 6.5 5.2 8.8	1 (ref) 1.22 *(1.03, 1.44)* 1.06 *(0.89, 1.26)* 1.75 *(1.37, 2.24)*	-
Peterson et al (2017) *(neonates only)*[28]	All		Private Public Other	-	1 (ref) 1.51 [1.13, 2.03] 1.49 [0.94, 2.36]	-
Peterson et al (2017) *(post-neonates only)*[28]	All		Private Public (Other	-	1 (ref) 1.24 [0.82, 1.89] 1.09 [0.62, 1.92]	-
Klitzner et al (2006)[25]	All	In-hospital & post-discharge	Private Public Managed Other	-	1 (ref) 1.22 *(1.03, 1.44)* 1.79 *(1.37, 1.80)* 1.07 *(0.9, 1.27)*	-
Chang et al (2006)[24]	All	Post-discharge	Private Public Managed Other	0.72 0.57 0.63 0.79	1 (ref) *0.78 (0.51, 1.21)* *0.87 (0.55, 1.37)* *1.09 (0.44, 2.74)*	-

Pace et al (2018)[29]	Critical Univentricular	Infant	Public (Medicaid) Not Medicaid	38.5 38.4	*1.00 (0.72, 1.41)* 1 (ref)	0.85 (0.61, 1.19)[a] 1 (ref)
Pace et al (2018)[29]	Critical Biventricular		Public (Medicaid) Not Medicaid	18.4 14.3	*1.35 (1.03, 1.78)* 1 (ref)	0.99 (0.73, 1.36) [a] 1 (ref)
Pace et al (2018)[29]	Noncritical Biventricular		Public (Medicaid) Not Medicaid	6.3 5.5	*1.15 (1.00, 1.33)* 1 (ref)	0.98 (0.83, 1.16) [a] 1 (ref)
Pace et al (2018)[29]	All CHD		Public (Medicaid) Not Medicaid	8.7 7.6	*1.16 (1.03, 1.30)* 1 (ref)	
Area-based income[fb]						
Kucik et al (2014b)[32]	All	Neonatal	D1 (most disadvantaged) D10 (least disadvantaged)	12.0 8.2	1.41 (1.00, 1.98) 1 (ref)	1.39 (0.93, 2.07)[a] 1 (ref)
Anderson et al (2018)[19]	All	In-hospital	≤$32 808 $32 808– 41 437 $41 437– 53 982 >$53 982	3.5 3.0 2.9 2.2	1.57 (1.37, 1.79) 1.37 (1.21, 1.53) 1.29 (1.15, 1.46) 1 (ref)	1.15 (1.01, 1.31) 1.12 (0.99, 1.27) 1.10 (0.98, 1.24) 1 (ref)
Benavidez et al (2006)[22]	All		<$25k $25-34.9k $35-44k ≥$45kk	- 	0.72 1.2 1.06 1 (ref)	0.65 1.03 0.96 1 (ref)
Klitzner et al (2006)[25]	All		<$20k $20-40k $40-60k >$60k	7.1 6.0 5.5 4.5	1.64 *(1.14, 2.36)* 1.36 *(0.98, 1.88)* 1.23 *(0.88, 1.73)* 1 (ref)	-
Peterson et al (2017) *(neonates only)*[28]	All		<$38.9k $39-47.9k $48-62.9k ≥$63k	- 	1.06 [0.68, 1.63] 0.92 [0.62, 1.36] 0.68 [0.42, 1.11] 1 (ref)	-
Peterson et al (2017) *(post-neonates only)*[28]	All		<$38.9k $39-47.9k $48-62.9k ≥$63k	- 	1.23 [0.59, 2.56] 1.43 [0.76, 2.68] 1.63 [0.86, 3.08] 1 (ref)	-
Chang et al (2006)[24]	All	Post-discharge	<$20k $20-40k $40-60k >$60k	0.8 0.7 0.5 0.1	*6.97 (0.92, 52.8)* *5.80 (0.81, 41.6)* *4.25 (0.58, 31.2)* *1 (ref)*	-

Kucik et al (2014b)[32]	All	Infant	D1 (most disadvantaged) D10 (least disadvantaged)	23.7 14.8	*1.78 (1.37, 2.31)* 1 (ref)	1.49 (1.11, 1.99)[a] 1 (ref)
Pace et al (2018)[29]	Critical Univentricular		<$35k $35–69 9k $70–99.9k ≥$100 000	41.1 38.8 29.2 14.3	1 (ref) *0.91 (0.63, 1.31)* *0.59 (0.30, 1.17)* *0.24 (0, 1.56)*	
Pace et al (2018)[29]	Critical Biventricular		<$35k $35–69 9k $70–99.9k ≥$100 000	17.9 16.2 11.7 18.5	1 (ref) *0.89 (0.66, 1.20)* *0.61 (0.34, 1.10)* *1.04 (0.40, 2.76)*	
Pace et al (2018)[29]	Noncritical Biventricular		<$35k $35–69 9k $70–99.9k ≥$100 000	6.5 5.8 4.7 7.4	1 (ref) *0.89 (0.76, 1.04)* *0.71 (0.51, 0.98)* *1.18 (0.71, 1.96)*	
Kempny et al (2016)[43]	All	Long-term	IMD income score (/SD)	-	0.9 (0.8, 1.01)[a]	

IMD=Index of Multiple Deprivation, T=tertile, Q=Quintile, D=Decile, HLH=hypoplastic left heart, SV=Single Ventricle, AVSD=atrioventricular septal defect, CoA= Coarctation of Aorta, ToF=Tetralogy of Fallot, TGA= Transposition of the Great Arteries, SD= standard deviation, Neonatal= <28 days, Post-neonatal= ≥28 days, Infant= ≤1 year, Post-operative, Post-discharge and Long-term mortality were defined separately by each of the included studies (for specific definitions refer to Table 1).

Estimates in italics were not reported in the article but were estimated from the raw data provided.

[a] Hazard ratio as opposed to Odds ratio.

[b]Odds Ratios/ Hazard Ratios were inverted to be interpreted as odds of mortality with increasing levels of deprivation.

[c] All US studies (n=7) used the census-based score to measure area-based poverty level, a measure of poverty assigned based on census block tract and derived from six measures: income, housing and occupational factors[30,32,35,37,39,40,44]. A higher census-based score indicates higher level of deprivation,[37] whereas a higher census-based Z score indicates a greater level of deprivation[40]. All of the UK articles (n=5)[36,38,41,43 21] used the English Index of Multiple Deprivation (IMD), a measure based on seven domains: income, employment, health and disability, education, crime, barriers to housing and services and living environment, which is assigned based on postcode[47]. A higher IMD score indicates higher level of deprivation, whereas a lower IMD rank indicates a greater level of deprivation. ORs corresponding to IMD rank and census Z score were therefore inverted to be interpreted on the same scale as IMD score and census score.

[d] Area-based education was analysed as a continuous variable (n=1, derived from the education domain of the English IMD)[43] or categorised into deciles (n=1, derived from the US census-based score)[32]. Individual level education was categorised into maternal years in education (n=4)[29,31,34,42,45,46] or categorised into paternal years in education (n=1)[33].

[e] The following definitions of health insurance categories were provided: Chan et al (2018):"Public" insurance was defined as government insurance.[20] DeMone et al (2003): "Private" insurance (referred to in the article as commercial insurance) included Blue Cross/Blue Shield, non-Blue Cross/Blue Shield commercial carriers, and self-insurance. "Public" insurance (referred to in the article as Medicaid) included Medi-Cal, Medicaid, Medicaid managed care, and Medicaid health maintenance organization/ preferred provider organization. "Managed" insurance included any health maintenance organization, preferred provider organization, or preferred health provider not associated with Medicaid (but included those associated with Blue Cross/commercial and employer funded). "Other" insurance included Medicare, self-pay, free-care, health care service contractors, and other employer-funded sources.[26] Klitzner et al (2006):"Private" insurance was defined as traditional indemnity insurance, "Public" insurance included Medicaid and other government-sponsored programs, "Managed" care included health maintenance organizations and preferred provider organizations, and others.[25] Chan et al (2015): "Private" insurance included both fee-for-service and managed care; "Public" insurance (referred to in the article as Medicaid) included both fee-for-service and Medicaid managed care. "Other" insurance was defined as other forms of payment, including Medicare and self-pay.[27] Peterson et al (2017): Public insurance (referred to in the article as Medicaid) included Medicare combined with Medicaid. "Other" insurance was defined as self-pay, no charge and other types of insurance.[28] Pace et al (2018): "Public" insurance was referred to in the article as Medicaid.[29] Chang et al (2006) "Private" insurance was defined as traditional indemnity insurance, "managed" care included health maintenance organization and preferred provider organization, "public" insurance included Medicaid and other government-sponsored programs. "Other" insurance was not defined.[24]

[f] All US articles (n=6) used the census-based score to measure average area-based income.[19,22,24,25,29,31] The UK article analysed the income z-score derived from IMD[43] where a higher score indicates higher average income

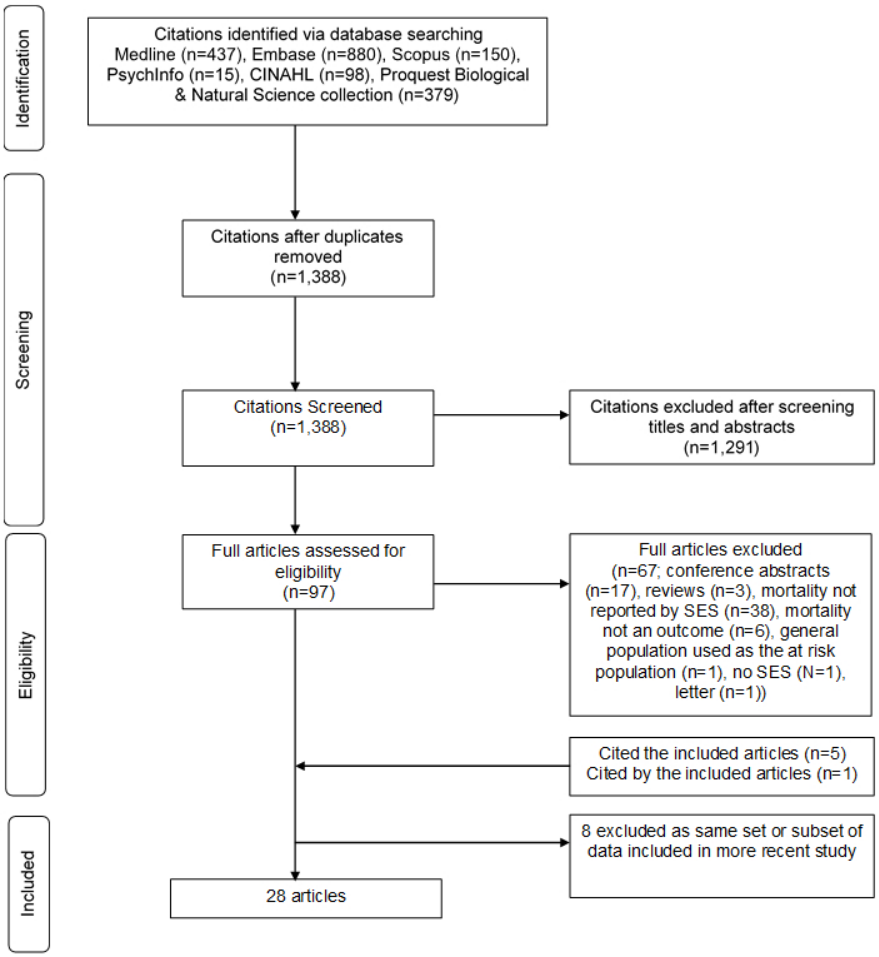

FIGURE 1

190x254mm (96 x 96 DPI)

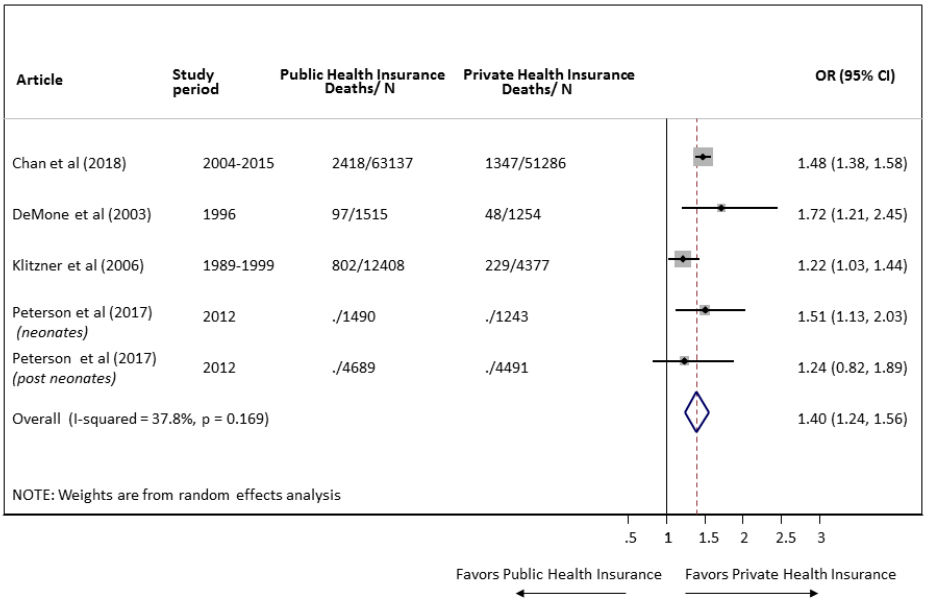

FIGURE 2

254x190mm (96 x 96 DPI)

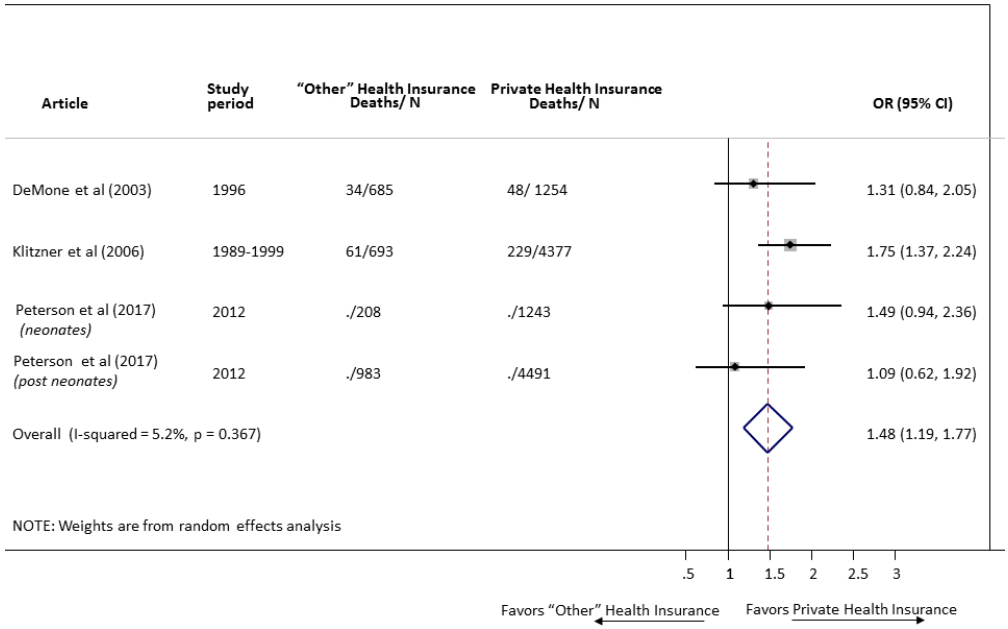

FIGURE 3

254x190mm (96 x 96 DPI)

Supplementary material

eTable 1 Search strategy

Database	Operator	Search terms
Embase		exp Social Class/ or exp Socioeonomic Factors/ or exp Income. Or exp Poverty/ or (socio-economic or socioeconomic).ti,ab or sociodemographic.ti,ab or (inequalit* or inequit*).ti,ab or disparit*.ti,ab or deprivation.ti,ab.
	AND	exp congenital heart disease/ or exp congenital heart malformation/ or (congenital and (heart or cardiac or cardiovascular)).ti,ab.
	AND	exp perinatal mortality/ or exp fetus mortality/ or exp mortality/ or exp mortality risk/ or exp premature mortality/ or exp surgical mortality/ or exp embryo mortality or exp mortality rate/ or exp hospital mortality/ or exp newborn mortality/ or exp prenatal mortality/ or exp infant mortality/ or exp survival rate/ or exp survival index/ or exp short term survival/ or exp survival time/ or exp survival prediction/ or exp survival/ or exp long term survival/ or exp morbidity/ or exp perinatal morbidity/ or exp newborn morbidity or (survival or mortalit* or death* or complication* or outcome*).ti,ab. or exp death/ or exp perinatal death/ or exp fetus death/ or exp embryo death/ or exp newborn death/ or exp catheter complication/ or exp peroperative complication/ or exp postoperative complication/ or exp preoperative complication or exp complication/
	AND	Limit to humans and English language
Medline		exp Social Class/ or exp Socioeconomic Factors/ or exp Income/ or exp Poverty/ or (socio-economic or socioeconomic).ti,ab or sociodemographic.ti,ab or (inequality or inequit&).ti,ab or disparit*.ti,ab or deprivation.ti,ab
	AND	exp Heart Defects, Congenital/ or (congenital and (heart or cardiac or cardiovascular)).ti,ab
	AND	exp Death/ or exp Perinatal Death/ or exp Fetal Death/ or exp Infant Death/ or exp Survival/ or exp Surviva Rate/ or exp intraoperative Complications/ or Postoperative Complications/ or (survival or mortalit* or death*).ti,ab or (complication* or outcome*).ti,ab or exp Morbidity/ or exp Mortality, Prematyre/ or exp Fetal Mortality/ or exp Child Mortality/ or exp Infant Mortality/ or exp Hospital Mortality/ or exp Mortality/
	AND	Limit to humans and English language
Scopus		(((social class) OR (socioeconomic factors) OR poverty OR sociodemographic OR inequality* or disparit* of deprivation of depriv*) AND ((congenital) AND (heart OR cardiac or cardiovascular) AND (mortality OR survival OR death* OR complication))
Psychinfo		exp Social Class/ or exp Sociocultural Factors/ or exp Family Socioeconomic Level/ or exp Socioeconomic Status/ or expl

		income level/ or exp upper income level/ or exp "income(economic)"/ or exp middle income level/ or exp lower income level/ or exp poverty areas/ or exp poverty/ or (socio-economic or socioeconomic).ti,ab or sociodemographic.ti,ab. or (inequalit*or inequit*).ti,ab or disparit*.ti,ab or deprivation.ti,ab
	AND	(congenital and (hear or cardiac or cardiovascular)).ti,ab
	AND	exp "Death and Dying"/ or exp Mortality Rate/ or exp morbidity/ or exp postsurgical complications/ or treatment outcomes/ or (survival or mortalit* or death* or complication* or outcome*).ti,ab
ProQuest Natural Science Collection and Proquest Biological Science Collection		All((social class OR socioeconomic factors or income or poverty or cosmographic or inequality or disparit or deprivation or depriv*) and ((congenital) and (heart or cardiac or cardiovascular)) and mortality or survival or death* or complication*))
	AND	Limit to conference papers & proceedings, dissertations & theses, Reports, Scholarly Journals, Working Papers, Annual Report, Article, Commentary, Conference Paper Conference Proceeding Correction/ Retraction, Editorial, Essay, Evidence Based Healthcare, Feature, General Information, Government and Official Document, Industry Report, Letter to the Editor , Literature Review. Reference Document, Report, Review, Statistics/ Data Report, Technical Report, Working Paper/ Pre-Print, English Language.
CINAHL		(MH "Social Class+") OR (MH "Socioeconomic Factors+") OR (MH "Health Status Disparities+") (MH "Income+") OR (MH "Poverty+") OR (MH "Poverty Areas+") OR socio-economic OR socioeconomic OR income OR sociodemographic OR inequalit* OR inequit* OR disparit* OR depriv*
	AND	(Congenital AND (heart OR cardiac OR cardiovascular)) OR (MH "Heart Defects, Congenital+")
	AND	(MH "Infant Mortality+") OR (MH "Child Mortality+") OR (MH "Hospital Mortality+") OR (MH "Mortality+") OR (MH "Survival+") OR (MH "Survival Analysis+") OR (MH "Survivors+") OR (MH "Death+") OR (MH "Perinatal Death+") OR (MH "Morbidity+") OR (MH "Treatment Complications, Delayed+") OR (MH "Postoperative Complications+") OR (MH "Intraoperative Complications+") OR (MH "Catheter-Related Complications+") OR (MH "Outcomes (Health Care)+") OR (survival or mortalit* OR death* OR complication* OR outcome*)