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Cost-Effectiveness of Routine Screening for Critical Congenital Heart Disease in US Newborns

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Abstract

OBJECTIVES—Clinical evidence indicates newborn critical congenital heart disease (CCHD) screening through pulse oximetry is lifesaving. In 2011, CCHD was added to the US Recommended Uniform Screening Panel for newborns. Several states have implemented or are considering screening mandates. This study aimed to estimate the cost-effectiveness of routine screening among US newborns unsuspected of having CCHD.

METHODS—We developed a cohort model with a time horizon of infancy to estimate the inpatient medical costs and health benefits of CCHD screening. Model inputs were derived from new estimates of hospital screening costs and inpatient care for infants with late-detected CCHD, defined as no diagnosis at the birth hospital. We estimated the number of newborns with CCHD detected at birth hospitals and life-years saved with routine screening compared with no screening.

RESULTS—Screening was estimated to incur an additional cost of $6.28 per newborn, with incremental costs of $20 862 per newborn with CCHD detected at birth hospitals and $40 385 per life-year gained (2011 US dollars). We estimated 1189 more newborns with CCHD would be identified at birth hospitals and 20 infant deaths averted annually with screening. Another 1975 false-positive results not associated with CCHD were estimated to occur, although these results had a minimal impact on total estimated costs.

CONCLUSIONS—This study provides the first US cost-effectiveness analysis of CCHD screening in the United States could be reasonably cost-effective. We anticipate data from states that have recently approved or initiated CCHD screening will become available over the next few years to refine these projections.

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Dr Peterson led the study design, data analysis, and interpretation of findings; and drafted the initial manuscript. Dr Grosse assisted with the study design, data analysis, and interpretation of findings; and edited the manuscript. Drs Oster and Olney provided clinical oversight, assisted with the interpretation of findings, and edited the manuscript. Dr Cassell assisted with the study design and interpretation of findings, and edited the manuscript. All authors approved the final manuscript as submitted.

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Keywords

Congenital heart defects; neonatal screening; costs and cost analysis

Critical congenital heart disease (CCHD) was added to the US Recommended Uniform Screening Panel for newborns in 2011.[1] Many states before and since have proposed or approved legislation or regulations requiring CCHD screening at birth hospitals.

CCHD is typically diagnosed prenatally or during postnatal clinical examination. However, newborns with CCHD might not present with signs or symptoms of their condition at birth hospitals. If these newborns leave the birth hospital without a diagnosis, they are at risk for cardiovascular collapse or death.[2] Population-based data from California from 1998 to 2004 suggested at least 0.9 infant deaths per 100 000 live births occurred in the United States due to missed CCHD (calculated from unpublished data obtained from study authors),[3,4] although authors suggested the number of infants affected by missed CCHD could be much greater. That estimate is equivalent to 36 infant deaths annually in the current US birth cohort.[5] A retrospective analysis of Florida Birth Defects Registry data from 1998 to 2007 estimated 23% (n = 825 in 3603) of infants with CCHD did not receive a diagnosis during their birth hospitalization, of whom 1.8% died before readmission or upon emergency hospital readmission.[6]

Recent studies in the United States and Europe indicate CCHD screening through pulse oximetry (a test that measures levels of blood oxygen saturation) can detect CCHD in newborns whose condition is otherwise not apparent at the birth hospital.[7] At present, there is no published economic evaluation of costs and outcomes of newborn CCHD screening in the United States.[8] This study aimed to estimate the cost-effectiveness of screening all US newborns unsuspected of having CCHD.

METHODS

Model

We developed a cohort state transition model using TreeAge Pro 2011 (Williamstown, MA) and Excel software based on available estimates from recent US and European studies (Fig 1). The model assessed the number of additional newborns with CCHD detected at birth hospitals, number of lives saved, and number of life-years gained from screening. We did not assess quality-adjusted life-years because of a lack of relevant data. We assessed inpatient medical costs from the perspective of the US health care sector. The model's time horizon was infancy (<1 year of age); therefore, costs were not discounted. All costs are presented as 2011 US dollars. Where necessary, costs were inflated by using annual estimates from the US Producer Price Index for Hospitals.[9] Estimates of life expectancy for the current US birth cohort were discounted at 3%.[10] Model inputs included results from analyses of hospital screening costs in New Jersey in 2012[11] and inpatient costs for infants with CCHD born in Florida from 1998 to 2007,[6] which were undertaken in part to provide information for this analysis (Table 1).

Clinical Case Definition

CCHD has been defined as congenital heart defects that require surgery or catheter intervention within the first year of life.[2] A 2009 article endorsed by the American Heart Association and American Academy of Pediatrics identified a subset of CCHD conditions that present with hypoxemia among newborns as amenable to detection through screening with pulse oximetry at birth hospitals.[2] On the basis of available estimates from recent studies, clinical case criteria for this analysis included 12 screening-detectable CCHD conditions: aortic interruption atresia/hypoplasia, coarctation hypoplasia of the aortic arch, dexto-transposition of the great arteries, double-outlet right ventricle, Ebstein anomaly, hypoplastic left heart syndrome, pulmonary atresia (intact septum), single ventricle, tetralogy of Fallot, total anomalous pulmonary venous connection, tricuspid atresia, and truncus arteriosus. Although screening might also detect critical forms of aortic and pulmonary stenosis, we did not include those conditions because administrative diagnostic codes (*International Classification of Diseases, Ninth Revision, Clinical Modification*) from which we derived clinical information do not distinguish critical forms of those conditions. The 7 conditions identified as primary targets for CCHD screening in the United States are dexto-transposition of the great arteries, hypoplastic left heart syndrome, pulmonary atresia, tetralogy of Fallot, total anomalous pulmonary venous connection, tricuspid atresia, and truncus arteriosus, which mostly or always present with hypoxemia in the newborn period.[12]

Screening Cohort

Our model assessed a scenario in which all newborns unsuspected of having CCHD were screened at US birth hospitals. Nonhospital births were excluded, as were newborns diagnosed through existing pre- or postnatal procedures (referred to here as timely diagnosed) because we assumed they would not be subject to screening. We estimated the prevalence of newborns with late-detected CCHD in the current US hospital birth cohort (Table 2). We estimated an annual screening cohort of 3 952 138 newborns, of whom 1534 had CCHD not diagnosed through existing procedures.

Screening Cost

We estimated hospitals' screening cost was $13.50 per newborn based on a recent study in New Jersey, where a legislative mandate for CCHD screening offered an opportunity to collect cost information from a random sample of 7 hospitals.[11] This cost was based on a time and motion study and the US national average hourly wage for registered nurses plus a fringe benefit of 33.2%. Based on a national estimate that 6.7% of newborns are admitted to special/intensive care nurseries per year[13] the estimated screening time per newborn reported in that study, regardless of nursery care facility (eg, well-newborn or special/intensive care), was just over nine minutes. The associated labor and equipment costs per newborn screened were $6.68 and $6.82 (including amortization and maintenance of pulse oximeters and the cost of sensors), respectively, yielding a total estimate of $13.50 per newborn. Only 1 hospital among 7 in the New Jersey evaluation used fully reusable sensors to screen well newborns; therefore, the equipment cost estimate in our base case model primarily reflects the cost of fully or partially disposable screening sensors, which are more expensive than reusable sensors.

Screening Performance and Diagnostic Follow-up

Given the US recommendation to screen newborns after 24 hours of birth,[1] we used screening sensitivity (77.5%) and false-positive rate (0.05%) data from recent meta-analysis for our model based on the results of 7 screening studies (n = 132 361 newborns) conducted ≥24 hours of birth (Table 1).[7] CCHD detected among those newborns closely approximated the clinical conditions considered in this analysis, with the exception that some cases of aortic and pulmonary stenosis were detected in the screening performance studies but not included in our analysis due to available data.

We assumed that all newborns who screen positive for CCHD undergo a confirmatory echocardiography examination and that a proportion of those newborns require transportation to another facility for examination and/or follow-up treatment. The assumption that all newborns with questionable screening results undergo echocardiography may be conservative. It is recommended that newborns with low pulse oximetry readings undergo a full physical examination to rule out other causes of hypoxemia before undergoing an echocardiography;[12] we did not include the costs or outcomes of such testing in our model. A recent analysis of the Florida Birth Defects Registry reported that 43% (n = 1547/3603) of newborns with CCHD were transferred during their birth hospitalization.[6] We used this estimate to represent the number of newborns requiring transport to another facility after possible CCHD detection through screening.

Infants with true positive screening results were assigned the cost of an echocardiography with a positive result (eg, a CCHD diagnosis). Infants with false positive screening results were assigned the cost of an echocardiography with a negative result (i.e., no CCHD diagnosis). Infants with false negative screening results, excluding those that died in the community, were assigned the cost of a positive echocardiography (assumed to occur upon hospital re-admission). Infants with CCHD in the no screening scenario discharged without a diagnosis and subsequently re-admitted were also assigned the cost of a positive echocardiography. We used Current Procedural Terminology codes and a national private health insurance claims data set, the MarketScan 2009 Commercial Claims and Encounters Research Database,[14] to estimate the costs of inpatient infant echocardiography (including physician interpretation) and emergency ground transport by ambulance to another facility (Table 1). We assigned an aggregate hospital cost per day ($4294) to infants ultimately diagnosed with CCHD based on information from the online database of the Agency for Healthcare Research and Quality Health Care Utilization Project 2009 Kids' Inpatient Database (www.hcupnet.ahrq.gov).[15] This estimated cost represents the mean hospital cost per day for infant hospitalizations with a principal diagnosis for CCHD conditions considered in this analysis. We assumed infants who did not receive a CCHD diagnosis at the birth hospital would be readmitted to a facility capable of treating CCHD and would not require transfer to another hospital.

Hospitalizations and Mortality

We used available estimates from the published literature to make inferences about the likely experiences of infants detected through routine CCHD screening (Table 1). On the basis of the Florida Birth Defects Registry study, infants with late-detected CCHD (defined

as diagnosis after birth hospital discharge) spent an average of 18% more days in inpatient care compared with infants with timely detected CCHD during the first year of life (44.3 vs 37.5 days). This estimate was adjusted for sociodemographic (eg, race/ethnicity) and clinical factors (eg, CCHD type). We assumed that infants that died during the first year of life would experience half the number of hospitalized days surviving infants did. As noted earlier, an analysis of the Florida Birth Defects Registry reported 1.8% of deaths among infants with late-detected CCHD occurred either outside a hospital following birth hospital discharge or upon emergent hospital readmission after birth hospital discharge.[6] We assumed CCHD detection through screening would eliminate such deaths but not affect other deaths among infants with CCHD.

Sensitivity Analyses

A dearth of previous research on this topic limited our options for sensitivity analysis of the model's base case assumptions. For this reason, we varied base case estimates by 50% in both directions for most model inputs. In addition, we examined 2 alternate scenarios. In one, we assumed hospitals exclusively used reusable screening sensors for well newborns at a cost of $7.74 per newborn (inclusive of labor and equipment), based on the recent New Jersey study of hospital screening costs.[11] This value already fell within the range of our primary sensitivity analysis, although we included this separate test to directly investigate the potential cost impact of reusable screening sensors. In the second alternate analysis, we tested a scenario in which all deaths among infants with late-detected CCHD were avoided as a result of timely detection. Such a mortality improvement is not likely, but this scenario seemed worth testing given the data challenges that hinder robust estimates of avoidable mortality among infants with late-detected CCHD.

We first assessed model inputs in isolation through 1-way sensitivity analyses. We then used a probabilistic sensitivity analysis of 1000 simulations in which all model inputs were simultaneously varied within their specified range using triangular probability distributions. We examined probability estimates that screening would be cost-effective at monetary values per life-year that decision makers might consider; specifically, $50 000 and $100 000 per life-year gained.[16]

RESULTS

Base Case

In a hypothetical scenario of routine CCHD screening for US newborns unsuspected of having CCHD, we estimated 1189 more newborns with CCHD would be identified at birth hospitals annually, 20 infant deaths would be averted, and 614 life-years would be gained (Table 3). We estimated 345 newborns with CCHD would still be discharged from birth hospitals annually without CCHD detection (because screening is not 100% sensitive to detect CCHD), and routine screening would yield 1975 false-positive results.

Without routine screening, the total estimated inpatient cost for CCHD during all of infancy averaged over the entire cohort was $70.32 per infant (Table 3). With screening, the total estimated average cost for inpatient care, plus screening and associated costs, was $76.59

per infant; hence, an incremental cost of $6.28 per newborn screened. This additional cost consists of screening and confirmatory testing, slightly offset by anticipated savings in inpatient costs during infancy. The estimated cost of false-positive screening results (confirmatory echocardiography and transportation when necessary) constituted a modest 3% ($0.20 per infant screened) of the estimated incremental screening cost per newborn (data not shown).

We estimated an incremental cost of $20 862 per additional newborn with CCHD detected at birth hospitals and $40 385 per life-year gained (Table 3). Taking into account only the additional cost of screening (without respect to any reduction in hospital treatment costs during infancy as a result of timely detection) the estimated cost per additional newborn with CCHD detected at the birth hospital was $45 724 (data not shown).

Sensitivity Analyses

We tested the influence of each model input in isolation through a series of 1-way sensitivity analyses (Table 4). On the basis of the primary sensitivity analysis range of ±50%, we specified that for each model input (Table 1), the parameters that had the greatest relative influence on the results were as follows: the number of hospitalized days for infants with late-detected CCHD surviving infancy (range for the incremental cost per life-year gained: −$134 614 [cost-saving] to $215 383), the proportion of late detected CCHD among infants with CCHD (range: $11 004 to $108 528), and the hospital cost to screen each newborn (range: −$3052 [cost-saving] to $83 821). The parameters that had the least relative influence on the model results were the cost of echocardiography, cost and probability of transport for echocardiography and/or treatment, the mortality rate among infants with screening-detected CCHD, and the false-positive rate.

The alternate 1-way sensitivity analyses indicated reusable sensors and greater mortality improvements could have a substantial impact on the model results. If all hospitals used fully reusable sensors to screen well newborns, we estimated screening would incur just an additional $0.52 per newborn and $3319 per life-year gained (Table 4). If all deaths among infants with late-detected CCHD were avoided by virtue of screening detection, our model estimated 94 lives would be saved annually (data not shown), at an incremental cost per life-year gained of $10 817 (Table 4).

The probabilistic sensitivity analysis indicated a 33% chance the incremental cost of screening for CCHD compared with existing clinical practice would be cost-saving; that is, the net cost would be negative. The analysis indicated a 52% chance the incremental cost of screening would be <$50 000 per life-year gained and a 73% chance the incremental cost of screening would be <$100 000 per life-year gained (Fig 2).

DISCUSSION

We estimated routine screening of US newborns would identify an additional 1189 infants with CCHD at birth hospitals that would otherwise be discharged without a diagnosis. We estimated screening would save 20 infant lives annually at a cost of $40 385 per life-year gained under base case assumptions. Sensitivity analyses suggested screening is likely to be

cost-effective under a range of plausible circumstances. Notably, screening was estimated to incur an additional cost of approximately just $0.50 per newborn if all hospitals used reusable sensors to screen well-newborns, which is a conceivable scenario. The average private insurance reimbursement for inpatient infant echocardiography in our analysis was approximately $200, which is low relative to hospital charges. That cost had little influence on the total estimated cost of screening due to the small number of infants referred for echocardiography. A sensitivity analysis tested the echocardiography cost at approximately $1000 for each infant. That analysis indicated the total cost per newborn screened would increase by less than $0.40 per newborn compared to the base case analysis (from $6.28 to $6.66) and the cost-effectiveness ratio per life year gained would rise only modestly (from $40 385 to $42 874).

A recently published UK study assessed the cost-effectiveness of adding CCHD screening through pulse oximetry to standard newborn clinical examinations.[17] UK researchers estimated an additional 30 cases of clinically significant CCHD would be detected through screening per 100 000 live births, at an incremental cost per case detected of ~£24 000 in 2009 currency, equivalent to $37 400 (stats.oecd.org; £1 = $1.52 during 2009). This is somewhat lower than our finding of an additional $45 724 (2011 value) cost per CCHD case detected before accounting for reduced hospital costs attributable to timely diagnoses. However, the UK study used a different definition of CCHD than we used here, our study was based on a different clinical setting, and UK health care costs are generally lower than US costs.

A strength of the present analysis is its explicit calculation of an incremental cost per life-year gained. No previous cost studies have provided such estimates.[2,17,18] Another strength was that we initiated original analyses to generate empirical estimates of hospital costs and outcomes using representative data from individual US states. The estimates of screening costs were derived from an analysis of observed screening practices in a representative sample of birthing hospitals in New Jersey.[11] The estimates of costs attributable to preventable hospitalized days and preventable deaths were derived from an analysis of the statewide, population-based Florida Birth Defects Registry and that state's hospitalization data.[6,19–21] Estimates of screening performance were taken from a recent systematic review and meta-analysis.[7]

Our study had a number of limitations. Hospitals in other states might implement CCHD screening differently than New Jersey does and do so at a different average cost. However, given the widespread use of disposable screening sensors in most NJ hospitals, screening costs may be lower in other states if reusable sensors are widely adopted. Recent CCHD screening time estimates have been as little as 3.5 minutes per newborn.[19] However, our screening time estimate of nine minutes per newborn was based on a random sample of screenings observed by researchers and is consistent with a similar recent observational study that estimated 10 minutes per newborn.[20] The assumption in the New Jersey study that the cost of nursing time for CCHD screening is approximated by the value of average hourly compensation, although standard in economic evaluations, may be questioned by some observers. If nurses are able to fit this activity in their daily work schedule, as was the case in the New Jersey hospital sample, hospital personnel budgets may not increase if routine

screening is undertaken. However, this study did not account for start-up costs related to a new screening program, such as nurse training.

Florida has the fourth highest number of annual live births in the United States,[10] although experiences with CCHD among infants in that state may not be nationally representative. The Florida study was based on data from the state's birth defects registry, which identifies infants with CCHD based on *International Classification of Diseases, Ninth Revision, Clinical Modification* codes from primarily hospital discharge data but does not include clinically verified diagnoses.[21–24] The Florida Birth Defects Registry is reported to miss up to 15% of birth defects, depending on the defect.[24]

We used an overall estimate of 1.8% avoidable mortality among infants with late-detected CCHD based on an analysis of Florida infants,[6] which is equivalent to 28 avoidable deaths among the 1534 infants we estimated have late-detected CCHD in the current US birth cohort. This overall estimate, which does not take into account the fact that mortality among such infants is likely to vary substantially by CCHD type, may be conservative. As previously cited, a California study estimated a minimum of 36 deaths due to missed CCHD in the current birth cohort.[3] A study in Wisconsin from 2002 through 2006 assessed nonhospital and emergency department deaths within 2 weeks of birth among infants with all types of heart disease and reported a higher death rate, the equivalent of 103 deaths in the current US birth cohort.[25] However, that study did not report the total number of infants in the cohort with CCHD as required for our model.

Future analyses should go beyond our cost approach to include differences in noninpatient health care costs during and beyond infancy. Comparative data on health care resource utilization among children with CCHD who received timely diagnoses during their newborn period could facilitate a future cost-effectiveness analysis of CCHD screening with a longer time horizon. Such data could also provide additional estimates to refine the sensitivity analysis we presented in this preliminary economic evaluation of routine newborn CCHD screening. A future detailed analysis of mortality among infants with late-detected CCHD could also provide information to further refine model assumptions regarding deaths potentially avoidable through CCHD screening. Our analysis assumed full life expectancy for infants with CCHD who do not die due to late detection of their condition, although life expectancy varies substantially by CCHD type. An additional model extension could include the costs and health benefits of detecting non-CCHD conditions through CCHD screening. A prospective screening study from Sweden noted 45% of newborns with false-positive results from CCHD screening (ie, newborns with low pulse oximetry readings who did not ultimately receive CCHD diagnoses) had another significant heart malformation, lung problem, or infection.[18] Detecting such conditions through CCHD screening may have added health benefits, which could conceivably lower the overall incremental cost estimates reported here. Incorporating the costs and benefits of detecting non-CCHD conditions in a future cost-effectiveness analysis would, however, require robust, data on the outcomes of such conditions in the absence of CCHD screening.

CONCLUSIONS

Clinical evidence indicates newborn CCHD screening is a lifesaving program. Based on inputs from recent studies, CCHD screening appears cost-effective using conventional thresholds and may be cost-saving under some circumstances. We anticipate data from US states that have recently approved or initiated routine CCHD screening will become available over the next few years to refine these projections.

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ABBREVIATION

CCHD	critical congenital heart disease

References

1. Mahle WT, Martin GR, Beekman RH III, Morrow WR. Section on Cardiology and Cardiac Surgery Executive Committee. Endorsement of Health and Human Services recommendation for pulse oximetry screening for critical congenital heart disease. Pediatrics. 2012; 129(1):190–192. [PubMed: 22201143]
2. Mahle WT, Newburger JW, Matherne GP, et al. Role of pulse oximetry in examining newborns for congenital heart disease: a scientific statement from the American Heart Association and American Academy of Pediatrics. Pediatrics. 2009; 124(2):823–836. [PubMed: 19581259]
3. Chang RK, Gurvitz M, Rodriguez S. Missed diagnosis of critical congenital heart disease. Arch Pediatr Adolesc Med. 2008; 162 (10):969–974. [PubMed: 18838650]
4. State of California, Department of Public Health, Birth Records. [Accessed May 18, 2012] Birth Statistical Data Tables: Table 2-1: Number of live births by age of mother, California, 1960–2005 (by place of residence). Available at: www.cdph.ca.gov/data/statistics/Pages/StatewideBirth-StatisticalDataTables.aspx
5. Hamilton BE, Martin JA, Ventura SJ. Births: preliminary data for 2010. Natl Vital Stat Rep. 2011; 60(2):1–25. [PubMed: 22670489]
6. Peterson C, Dawson A, Grosse SD, et al. Hospitalizations, costs, and mortality among infants with critical congenital heart disease: how important is timely detection? Birth Def Res A. In press.
7. Thangaratinam S, Brown K, Zamora J, Khan KS, Ewer AK. Pulse oximetry screening for critical congenital heart disease in asymptomatic newborn babies: a systematic review. Lancet. 2012; 379(9835):2459–2464. [PubMed: 22554860]
8. Martin GR, Beekman RH III, Mikula EB, et al. Implementing Recommended screening for critical congenital heart disease. Pediatrics. 2013; 132(1):e185–e192. [PubMed: 23776113]
9. US Bureau of Labor Statistics. [Accessed May 18, 2012] Producer price index industry data: Hospitals (PCU622). 2011. Available at: www.bls.gov/data/#prices
10. National Center for Health Statistics. [Accessed December 1, 2011] United States life tables. 2011. Available at: www.cdc.gov/nchs/products/life_tables.htm
11. Peterson C, Grosse SD, Glidewell J, et al. A public health economic assessment of hospitals' cost to screen newborns for critical congenital heart disease. Public Health Reports. In press.
12. Kemper AR, Mahle WT, Martin GR, et al. Strategies for implementing screening for critical congenital heart disease. Pediatrics. 2011; 128(5) Available at: www.pediatrics.org/cgi/content/full/128/5/e1259.
13. Osterman MJ, Martin JA, Mathews TJ, Hamilton BE. Expanded data from the new birth certificate, 2008. Natl Vital Stat Rep. 2011; 59(7):1–28.

14. Hansen, LG.; Chang, S. [Accessed July 13, 2012] Health research data for the real world: the MarketScan databases. 2011. Available at: http://truvenhealth.com/assets/PH_11238_0612_TEMP_MarketScan_WP_FINAL.pdf
15. Agency for Healthcare Research and Quality. [Accessed May 25, 2012] Healthcare Cost and Utilization Project (HCUP). HCUP Kids' Inpatient Database (KID). 2009. Available at: www.hcup-us.ahrq.gov/kidoverview.jsp
16. Grosse SD. Assessing cost-effectiveness in healthcare: history of the $50,000 per QALY threshold. Expert Rev Pharmacoecon Outcomes Res. 2008; 8(2):165–178. [PubMed: 20528406]
17. Roberts TE, Barton PM, Auguste PE, Middleton LJ, Furmston AT, Ewer AK. Pulse oximetry as a screening test for congenital heart defects in newborn infants: a cost-effectiveness analysis. Arch Dis Child. 2012; 97(3):221–226. [PubMed: 22247242]
18. de-Wahl Granelli A, Wennergren M, Sandberg K, et al. Impact of pulse oximetry screening on the detection of duct dependent congenital heart disease: a Swedish prospective screening study in 39,821 newborns. BMJ. 2009; 338:a3037. [PubMed: 19131383]
19. Bradshaw EA, Cuzzi S, Kiernan SC, Nagel N, Becker JA, Martin GR. Feasibility of implementing pulse oximetry screening for congenital heart disease in a community hospital. J Perinatol. 2012; 32(9):710–715. [PubMed: 22282131]
20. Centers for Disease Control and Prevention. Assessment of current practices and feasibility of routine screening for critical congenital heart defects—Georgia, 2012. MMWR Morb Mortal Wkly Rep. 2013; 62(15):288–291. [PubMed: 23594685]
21. National Center for Health Statistics. [Accessed December 1, 2011] VitalStats - Births: Key birth statistics, 2009. 2009. Available at: www.cdc.gov/nchs/births.htm
22. National Birth Defects Prevention Network. State birth defects surveillance program directory. Birth Defects Res A Clin Mol Teratol. 2011; 91(12):1028–1149.
23. Salemi JL, Tanner JP, Block S, et al. The relative contribution of data sources to a birth defects registry utilizing passive multisource ascertainment methods: does a smaller birth defects case ascertainment net lead to overall or disproportionate loss? J Registry Manag. 2011; 38(1):30–38. [PubMed: 22097703]
24. Salemi JL, Tanner JP, Kennedy S, et al. A comparison of two surveillance strategies for selected birth defects in Florida. Public Health Rep. 2012; 127(4):391–400. [PubMed: 22753982]
25. Ng B, Hokanson J. Missed congenital heart disease in neonates. Congenit Heart Dis. 2010; 5(3): 292–296. [PubMed: 20576049]

WHAT'S KNOWN ON THIS SUBJECT

Critical congenital heart disease (CCHD) was recently added to the US Recommended Uniform Screening Panel for newborns.

WHAT THIS STUDY ADDS

Routine screening could cost an estimated additional $6.28 per newborn and $40 385 per life-year gained. The incremental cost of screening might be approximately $0.50 per newborn with reusable sensors. Future analysis of newborn screening programs may help refine these projections.

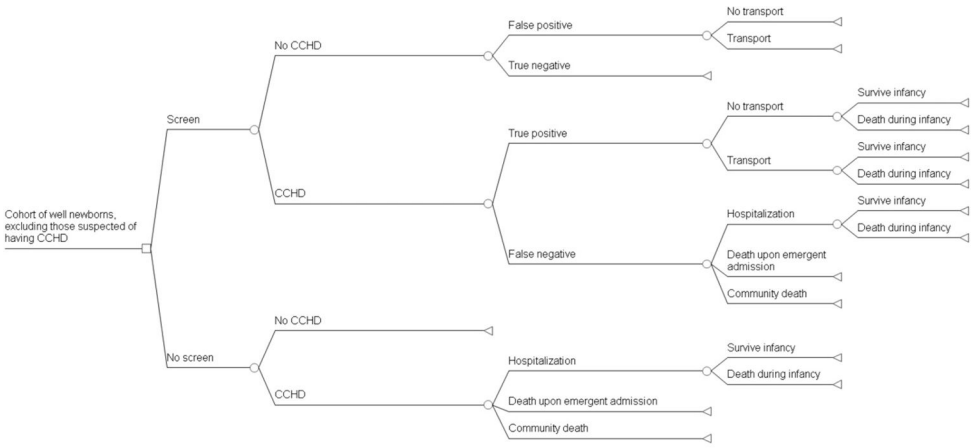

FIGURE 1.
Cohort state transition model of routine screening for CCHD in the United States.

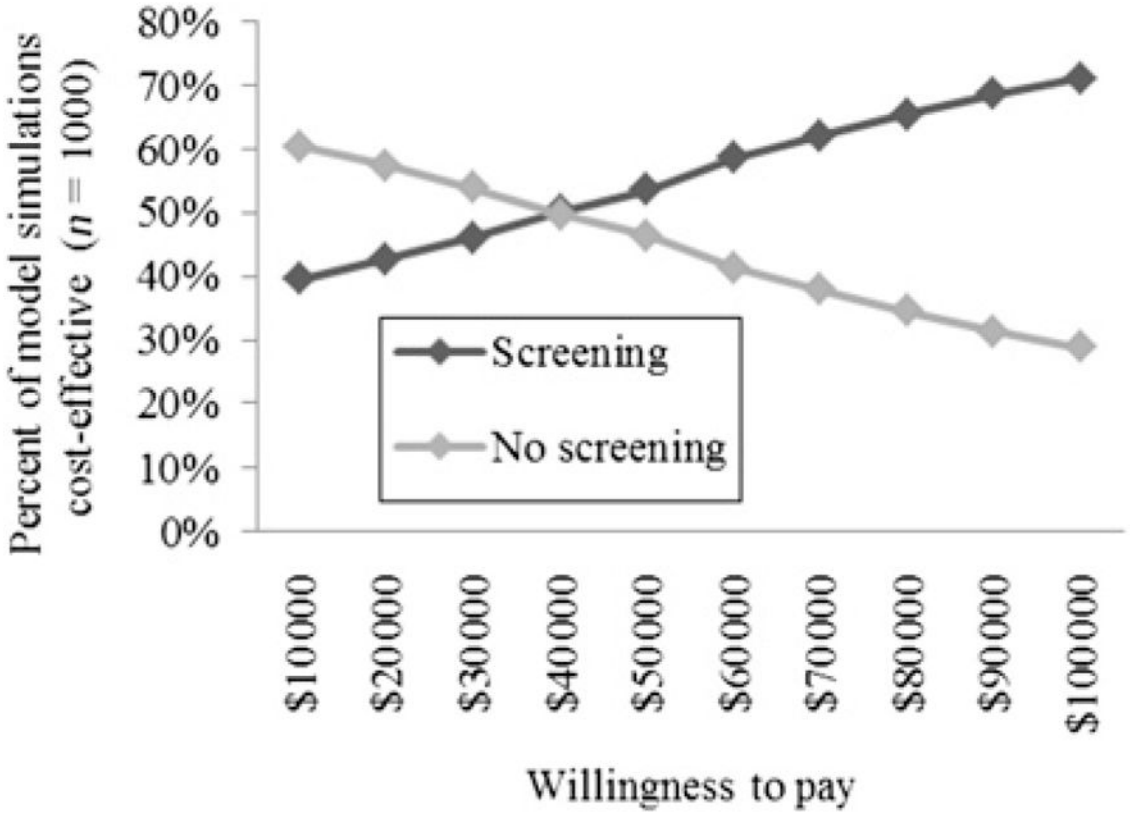

FIGURE 2.
Probabilistic sensitivity analysis of cost per life-year gained.

TABLE 1

Model Inputs for Routine Newborn Screening for CCHD in the United States

Parameter	Base Case	Source	SA[a]/Alternate 1-way SA
Costs[b]			
Cost per newborn screened for CCHD through pulse oximetry	$13.50	Peterson et al[11]	±50%/$7.74[c]
Cost of echocardiography (positive result; CCHD diagnosis)	$236	MarketScan,[d] CPT code: 93303+93320+93325	$83, $1084
Cost of echocardiography (negative result; no CCHD diagnosis)	$206	MarketScan,[d] CPT code: 93306	$65, $976
Cost of ambulance transport for offsite echocardiography or treatment	$439	MarketScan,[d] CPT code: 99466	$16, $1582
Cost of daily hospital treatment of infants with CCHD	$4294	Healthcare Cost Utilization Project Kids' Inpatient Database[e]	±50%
Hospitalized days during infancy			
Screening-detected CCHD: survive infancy	37.5	Peterson et al[6]	±50%
Screening-detected CCHD: death during infancy	18.8	Assumption: 50% of days for infants who survive	±50%
Late-detected[f] CCHD: survive infancy[g]	44.3	Peterson et al[6]	±50%
Late-detected CCHD: death during infancy	22.1	Assumption: 50% of days for infants who survive	±50%
Late-detected CCHD: death upon emergent hospital readmission	3.0	Peterson et al[6]	
Transition probabilities			
Late-detected CCHD	0.2290	Peterson et al[6]	±50%
Newborn transported to another hospital for echocardiography or treatment	0.4290		±50%
Death during infancy if CCHD is screening detected[h]	0.0618		±50%
Death if CCHD is late detected:			
Nonhospital death after birth hospital discharge	0.0085		±50%
Death upon emergent hospital readmission after birth discharge	0.0097		±50%
Other death during infancy	0.0618		±50%/0
Pulse oximetry test performance:			
Sensitivity	0.7750	Thangaratinam (2012)[5]	0.60, 1.00[i]
False-positive rate	0.0005		0, 0.002[i]
Health outcomes			
Life-years saved (discounted 3%)	30.28	US National Center on Health Statistics (2007)[9]	

SA, sensitivity analysis.

[a] The probabilistic SA used triangular distributions for all inputs.

[b] All costs presented as 2011 US dollars.[9]

[c] Assumed hospitals exclusively used reusable sensors for well newborns.

[d] MarketScan 2009 Commercial Database query: private insurance, fee for service (capitated plans excluded), inpatient services for patients' age <1 y. Model inputs are mean payments for Current Procedural Terminology codes after eliminating high and low outliers (top and bottom 1%). Sensitivity analysis used minimum and maximum values.

[e] 2009 Agency for Healthcare Research and Quality Healthcare Cost Utilization Project Kids' Inpatient Database database query: mean hospital cost per day among infants with CCHD (by *International Classification of Diseases, Ninth Revision, Clinical Modification* code: aortic interruption/atresia/hypoplasia: 747.11, 747.22); coarctation/hypoplasia of the aortic arch: 747.10; d-transposition of the great arteries: 745.10; double-outlet right ventricle: 745.11; Ebstein anomaly: 746.2; hypoplastic left heart syndrome: 746.7; pulmonary atresia: 746.01; single ventricle: 745.3; teratology of Fallot: 745.2; total anomalous pulmonary venous connection: 747.41; single ventricle: tricuspid atresia: 746.1; truncus arteriosus: 745.0) as the principal diagnosis (includes newborn costs).

[f] Late detected = no CCHD diagnosis before birth hospital discharge (refers to no screening scenario and infants with false-negative results in screening scenario).

[g] Twenty percent more days than infants with screening-detected CCHD, estimate inferred from the source study.

[h] Mortality estimate based death among infants with late detected CCHD who died after a postbirth hospital admission in the source study.

[i] Sensitivity analyses values are maximum and minimum values from screening studies performed ≥24 h.

TABLE 2

Estimated US Screening Cohort

Parameter	Prevalence per 100 000	Annual Hospital-based Birth Cohort	Estimate Details	Source
US Live births, in-hospital		3 957 304	98.9% of 4 000 279 live births	US Vital Statistics Reports (2011; based on 2010 data for total live births),[4] US National Center on Health Statistics (2011; based on 2009 data for proportion of hospital-based births)[7]
Condition prevalence				
CCHD screening targets[a]	169.3	6700	Based on a population study[b]	Peterson et al[6]
Timely detected CCHD[c]	130.5	5165		
Late-detected CCHD	38.8	1534		
Screening cohort	99 939.3	3 952 138	Excludes newborns with timely detected CCHD	Calculation

[a] Aortic interruption/atresia/hypoplasia, coarctation/hypoplasia of the aortic arch, dexto-transposition of the great arteries, double-outlet right ventricle, Ebstein anomaly, hypoplastic left heart syndrome, pulmonary atresia (intact septum), single ventricle, tetralogy of Fallot, total anomalous pulmonary venous connection, tricuspid atresia, and truncus arteriosus.

[b] Refers to late CCHD detection of 825 of 3603 (22.9%) infants live-born from 1997 to 2008, matched to hospital discharge records and with 1 of the CCHD conditions assessed in this analysis among a Florida hospital-based, live-birth cohort of 2 128 236 for that period.[25]

[c] Timely detection defined in source study as CCHD diagnosis before birth hospital discharge.

TABLE 3

Base Case Results for CCHD Screening in the United States

Result	Total		Incremental Cost-effectiveness Ratio
	Per Newborn	US Annual Screening Cohort[a]	
Screening performance			—
True positives (additional cases identified at birth hospitals)	0.000301	1189	—
False-positives	0.000500	1975	—
False-negatives	0.000087	345	—
Screening health benefits			—
Lives saved	0.000005	20	—
Life-years gained	0.000155	614	—
Screening cost			—
Average costs per newborn:			—
No screening	$70.32		—
Confirmatory echocardiography (% of total cost)	$ 0.09 (<1%)		
Hospitalizations during infancy (% total cost)	$ 70.23 (99%)		—
Screening	$76.59		—
Screening (% of total cost)	$13.50 (18%)		—
Confirmatory echocardiography (% total cost)	$ 0.19 (<1%)		—
Transportation to echocardiography or treatment (% of total cost)	$ 0.15 (<1%)		—
Hospitalizations during infancy (% total cost)	$62.72 (82%)		—
Total additional cost of screening compared with existing practice	$6.28	$24 802 782	—
Screening cost-effectiveness			
Per case identified	—	—	$20 862
Per life-year gained	—	—	$40 385

[a] Estimated annual cohort of hospital-born newborns unsuspected of having CCHD: 3 952 138 (see Table 2 for details).

TABLE 4

One-way Sensitivity Analyses

Parameter	Model Input	Incremental Cost of Screening per Newborn	Incremental Cost per Life-Year Gained From Screening
Costs			
Screening	High: $20.25	+$13.03	$83 821
	Low: $6.75	−$0.47	−$3052[a]
	Alternate: $7.74	+$0.52	$3319
Echocardiography (positive result [ie, CCHD diagnosis]/ negative result)	High: $1084/$976	+$6.66	$42 874
	Low: $83/$65	+$6.20	$39 928
Transport for echocardiography	High: $1852	+$6.67	$42 909
	Low: $16	+$6.13	$39 448
Daily cost of hospital treatment	High: $6442	+$2.55	$16 436
	Low: $2147	+$10.00	$64 333
Hospitalized days during infancy			
Infants with screening detected CCHD: survive infancy	High: 56.3	+$2.55	$16 436
	Low: 18.8	+$10.00	$64 33
Infants with screening detected CCHD: death during infancy	High: 28.1	+$7.02	$45 202
	Low: 9.4	+$5.53	$35 567
Infants with late-detected[b] CCHD: survive infancy	High: 66.4	−$20.92	−$134 614[a]
	Low: 22.1	+$33.47	$215 383
Infants with late-detected CCHD: death during infancy	High:33.2	+$5.41	$34 803
	Low: 11.1	+$7.14	$45 966
Transition probabilities			
Late detected CCHD	High: 0.3435	+$2.56	$11 004
	Low: 0.1145	+$9.99	$108 528
Transport for echocardiogram or treatment	High: 0.6435	+$6.35	$40 870
	Low: 0.2145	+$6.20	$39 899
Mortality among infants with late-detected CCHD			
Nonhospital death after birth hospital discharge	High: 0.1272	+$6.51	$33 972
	Low: 0.0042	+$6.04	$50 701
Death upon emergent hospital admission	High: 0.0145	+$6.53	$33 156
	Low: 0.0048	+$6.02	$52 870
Other death during infancy (also the mortality rate among infants with screening-detected CCHD in the model)	High: 0.0937	+$6.39	$42 550
	Low: 0.0309	+$6.16	$38 357
		+$7.77	$10 817
	Alternate: 0 for infants with screening-detected CCHD		
Pulse oximetry test performance: sensitivity	High: 1.00	+$4.12	$20 553
	Low: 0.60	+$7.95	$66 093
Pulse oximetry test performance: false-positive rate	High: 0.002	+$6.87	$44 195

Parameter	Model Input	Incremental Cost of Screening per Newborn	Incremental Cost per Life-Year Gained From Screening
	Low: 0	+$6.08	$39 115

[a] Cost-saving.

[b] Late detected is no CCHD diagnosis before birth hospital discharge (refers to no screening scenario and infants with false-negative results in screening scenario).