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PREVENTIVE DENTAL CARE UTILIZATION AND INFECTIVE ENDOCARDITIS AMONG MEDICAID BENEFICIARIES WITH CONGENITAL HEART DEFECTS IN GEORGIA, 2008-2019

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Abstract

PREVENTIVE DENTAL CARE UTILIZATION AND INFECTIVE ENDOCARDITIS AMONG MEDICAID BENEFICIARIES WITH CONGENITAL HEART DEFECTS IN GEORGIA, 2008-2019

By Ketki Vinayak Joshi

Background: Congenital heart defects (CHD) are common birth defects affecting ~1% of U.S. live births annually. Children with CHD are recommended to receive preventive dental care due to their susceptibility to infective endocarditis (IE). Understanding the association of preventive dental care utilization and IE is crucial for informing targeted interventions that could improve oral health outcomes and mitigate IE burden for children with CHD. It is hypothesized that children with CHD, enrolled in Georgia Medicaid between 2008-2019, with at least one annual preventive dental care visit, will be at lower risk of IE compared to those without any preventive dental care visits.

Methods: This retrospective cohort study assessed the association between preventive dental care utilization and IE among 61,024 children with CHD, aged 1 to 18 years, enrolled in Georgia Medicaid between 2008-2019. Logistic regression models estimated crude and adjusted risk ratios (RRs) and 95% confidence intervals (CIs) for IE risk, controlling for CHD anatomic severity, sex, race and ethnicity, birth year cohort, Social Deprivation Index (SDI), and rurality. Effect modification was explored, with the CHD anatomic group identified as a significant modifier, leading to subgroup analyses.

Results: Among all CHD patients, 181 IE (0.30%) cases were identified, and 65.64% had at least one annual preventative dental visit. For subgroups with valve lesions or shunt lesions, having at least one annual preventive dental care visit showed a significantly lower risk of IE (aRR=0.32, 95% CI: 0.18-0.56, and aRR=0.17, 95% CI: 0.07-0.38, respectively).

Conclusions: At least one annual preventive dental care visit reduced the risk of IE among children with CHD. Despite Medicaid dental coverage, a large proportion of children with CHD did not receive annual preventive dental care visits. Future research should focus on developing and evaluating interventions to increase dental care access and improve utilization among this vulnerable population.

Word count: 300

Key words: Congenital Heart Defects, Infective Endocarditis, Preventive Dental Care, Pediatric Medicaid Beneficiaries

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Contents

List of Abbreviations

ACA	Affordable Care Act
AHA	American Heart Association
ASD	Atrial Septal Defect
CDT	Current Dental Terminology
CHD	Congenital Heart Defects
CHIP	Medicaid's Children's Health Insurance Program
ED	Emergency Department
FIPS	Federal Information Processing Standards
GA	Georgia
IE	Infective Endocarditis
PFO	Patent Foramen Ovale
SDI	Social Deprivation Index
TOF	Tetralogy of Fallot

CHAPTER 1: BACKGROUND

Congenital Heart Defects

Congenital heart defects (CHD) are the most common birth defect affecting nearly 1% of all live births per year in the United States (U.S.).[1] CHD is a structural and functional defect of the heart and blood vessels that arise during cardiac embryogenesis.[2] These defects obstruct blood flow in the great vessels and change the normal blood flow pattern causing a range of symptoms.[3] CHD causes a range of symptoms based on the anatomic defect and severity, ranging from no symptoms to death shortly after birth. More severe CHD may present with heart failure, feeding difficulty, breathlessness, and cyanosis. While severe CHD typically emerges shortly after birth and requires surgical intervention, symptoms related to less severe CHD may or may not appear until later in life. Complications in adulthood are lesion dependent and can include endocarditis, respiratory infections, pulmonary hypertension, high blood pressure, and heart failure.[4] Individuals born with heart defects may also have genetic or health issues that increase the risk of long-term disability. About 20% of cases of CHD can be linked to genetic syndromes or teratogens, but the origins of the majority of cases (around 80%) remain largely unknown.[5] Possible factors that have been reported to increase the risk of CHD include maternal health status, exposure to therapeutic and nontherapeutic drugs, environmental exposures, etc.[6]

CHD was once considered primarily a pediatric condition, as patients with severe defects rarely survived into adulthood.[7] During the 1950s, the survival rate for children with CHD was 15%.[8] However, significant medical and surgical advancements have greatly improved the diagnosis and treatment of the disease with the current survival rate into adulthood exceeding 90%.[8] It is also observed that the prevalence of CHD has increased.[9] For example, in metropolitan Atlanta, the overall CHD prevalence was 81.4 infants per 10,000 births between 1998-2005.[10] Another study conducted in Canada which investigated

temporal trends for all-cause mortality from CHD between 1987 to 2005 showed an overall reduction in mortality by 31%.[11] The age distribution at death also has transitioned to align more closely with the general population revealing a shift towards lower mortality in severe forms of CHD, primarily in children, indicating an improvement in survival trends.[11] A study conducted to examine the mortality attributable to CHD across the lifespan from 1999 through 2017 in the U.S. showed a decline in mortality associated with CHD among children aged 1 to 17 years; specifically, among those aged 1 to 4 years, the mortality rate decreased from 1.43 to 0.95 per 100,000. Among children aged 5 to 17 years, rates decreased from 0.46 to 0.28 per 100,000.[12]

Prevalence of CHDs in the U.S.

CHD is the most common birth defect affecting nearly 1% of all live births per year in the U.S.[1] In 2010, the U.S. prevalence of CHD was estimated at around 2.4 million individuals affected across various age groups, consisting of approximately 1.4 million adults and 1 million children. Among these children, about 12% were identified as having a severe CHD. Among adolescents aged 13-17-years-old, prevalence of CHD was 13 per 1000, with 1.87 per 1000 having severe lesions.[13]

CHD Severity

Long-term cardiology care is needed for all individuals with CHD, regardless of defect severity, to monitor and manage their condition effectively. Depending on the anatomic groupings, CHD anatomy can be categorized based on the severity as severe defects, shunt defects, valve defects, and other vascular defects[14] (Appendix A). Severe defects such as Tetralogy of Fallot (TOF) and Tricuspid atresia requires surgery in the first year of life. Approximately 1 in every 4 babies born with a heart defect has critical CHD.[15] Valve defects range from mild defects that require intervention late in adulthood to severe stenotic valve lesions requiring intervention in the neonatal period. Shunt defects have

anomalous routes of blood flow within the heart, typically arising from developmental abnormalities during gestation. They are classified as either cyanotic or acyanotic, with cyanotic shunts resulting in impaired blood oxygenation and subsequent cyanosis, while acyanotic shunts maintain normal oxygenation levels.[16]

CHD Treatment, Costs, and Healthcare Utilization

Patients with CHD often require ongoing medical care that can include multiple procedures, surgeries and treatments. In the U.S., inpatient costs of a child with CHD increase by 1.6% annually until they reach 10 years of age; for a single birth year cohort (~50,000 births per year), inpatient costs are estimated to be one billion dollars until 10 years of age.[17] A population-based surveillance of CHD at five U.S. sites (Colorado, Georgia, New York, North Carolina, and Utah) identified adolescents, aged 11 to 18 years, by CHD-related ICD-9-CM codes from various site-specific administrative and clinical data sources.[18] Of these cases, 26% had severe CHD. Adolescents with severe CHDs demonstrated higher rates of inpatient and emergency department (ED) visits and were more likely to be covered by public health insurance compared to their non-severe counterparts (inpatient visit: 29% versus 18%, $p<0.0001$; ED visit: 28% versus 24%, $p<0.0001$). Across all sites, the Georgia site had the (GA) highest percentage of adolescents with ≥1 documented outpatient cardiology visits (78%), while Utah had the lowest (16%).[18] From 2011 to 2013, adolescents with severe CHDs consistently had higher rates of inpatient and ED visits compared to those with non-severe CHDs, and these adolescents living with CHD surpassed the general U.S. adolescent population in healthcare usage. In a retrospective cross-sectional study[19] examining healthcare spending for pediatric patients (0 to 19 years) in an Ohio Managed Care Plan, the total Medicaid spending over the 18month study period (7/19 to 12/20) was around $370 million, averaging $178 per patient per month. In this sample, 115,345 were pediatric patients, with 0.7% having a CHD, and a total spending of

about $39.3 million ($2,730 per CHD patient per month), representing 10.6% of Medicaid's total spending. The top 3% of high-spend patients with CHD (n=24) contributed 43.3% of the total CHD spending, like the cost of depression (n=2,797; ~$34M) and asthma (n=5,818; ~$32M) spending.[19] Individuals with CHD face a lifelong risk of cardiovascular complications, potentially necessitating further surgical or catheter-based therapies, leading to increased healthcare utilization. Therefore, there is often a significant financial burden for families of patients with CHD to navigate additional medical expenses in addition to special education services, regular healthcare and pharmaceutical costs, and lost earnings for caregivers.

CHD and Health Issues

The likelihood and severity of developmental disabilities or delays increase proportionally with the severity of the heart defect. Over 80% of individuals with CHD do not experience any developmental disabilities.[20] A study conducted at the Children's Hospital of Wisconsin showed a notable prevalence of developmental delay in children with CHD assessed during the first three years of life.[21] Additionally, those with CHD may experience further health complications associated with their specific heart defect, and the severity of the condition over time. This includes increased risk of pneumonia[22], arrythmia[23], pulmonary hypertension[24], and infectious endocarditis (IE).[25]

CHD and Infectious Endocarditis (IE)

IE is an infection of the endocardium of the heart, particularly affecting the heart valves.[26] It is caused by a variety of bacteria and fungi that enter the bloodstream and settle in the lining of the heart, valves, and/or blood vessels, and as such, is also called bacterial endocarditis.[27] Patients with prosthetic material in the heart, such as artificial valves, or patches with a residual shunt, are at particular risk of developing endocarditis. IE is a life-threatening infection with high morbidity and mortality.[28] There are two broad types of IE,

acute and chronic. The acute type usually develops suddenly with high fever, fatigue, chills, cough, increased heart rate, muscle and joint pain, swelling in the abdomen/legs, and is often life-threatening, whereas subacute IE develops over a period with mild fever, fatigue, weight loss and anemia.[27] The pathogenesis of IE is linked to the complex interaction between bloodstream pathogens and damaged endocardial cells. In patients with CHD, turbulent blood flow damages the endothelial cells resulting in the formation of nonbacterial thrombotic endocarditis. If a pathogenic microbial species colonizes this site by invading the bloodstream, it can lead to IE.[28]

Certain conditions including poor dental hygiene, major dental procedures, skin infections, intravenous drug use, and other infectious diseases are risk factors for acquiring IE.[26,27] It is estimated that children with CHD are at risk of developing IE almost 15 to 140 times higher than the general population;[29] incidence of IE is 1.1 per 1,000 patient-years among adults with CHD[30] compared to 1.7 to 6.2 per 100,000 patient-years in the general population.[31] In a population-based analysis to determine the cumulative incidence and predictors of IE in children, 0 to 18 years, using 1988-2010 data from the Quebec CHD database, results revealed a risk of 6.1/1000 children up to 18 years of age (95% CI: 5.0-7.5).[32] Furthermore, a nested case-control analysis showed that individuals with specific CHD lesions including cyanotic CHD, endocardial cushion defects, and left-sided lesions exhibited a higher risk of IE compared to those with atrial septal defects (ASD).[32]

CHD and Dental Infections

Dental health among individuals with CHD is known to be poor[33] compared to the general population.[33-35] In a large international study examining dental health behavior among adults with CHD,[36] those who were older, female with higher education, who had employment, and were diagnosed with less severe CHD defects had better optimal dental health behavior.[37] It is interesting to note however, that 73% of participants in this study

were from the U.S., and they reported going for annual dental visits.[36] The American Dental Association and the American Academy of Pediatric Dentistry both recommend dental check-ups every six months, and more frequently if there is a risk of caries, often experienced by those with CHD.[38-40]

While research suggests no significant oral health differences between patients with and without CHD,[41,42] when dental hygiene is poorly maintained, children with CHD commonly do experience dental caries.[33,43] Several studies show that patients with CHD are affected by oral health conditions compared to those without CHD, such as excessive plaque, gingivitis, and caries.[7,44-46] In a study assessing oral health status and dental anomalies among children with CHD, 2-10 years of age, data showed a significantly higher prevalence of caries in children above 5 years of age compared to children aged 5 years or younger ($p=0.005$), indicating an increase in caries prevalence with increasing age among CHD patients.[47] In a study conducted to determine dental caries prevalence among children with CHD, 147 children, aged 3-17 years, found that 38.8% exhibited at least one untreated carious lesion.[43] Additionally, 37.4% had a dmft/DMFT (dmft represents decayed, missing, and filled primary teeth and DMFT represents decayed, missing, and filled permanent teeth) with score ≥ 2, indicating an elevated caries risk. Children and adolescents with CHD displayed higher DMFT scores compared to their same aged counterparts without CHD, with statistically significant results among those children who were older compared to those who were younger.[43] A cross-sectional study conducted among 111 Sudanese children with CHD (mean age 7.2 ± 3.0 years) and 182 controls (mean age 7.2 ± 2.8 years) demonstrated that those with CHD had a statistically significant higher mean number of sites with plaque and gingivitis compared to those without CHD.[45] To lower the risk of IE following dental procedures, it has been suggested that maintaining optimal oral health is more effective at reducing the incidence of bacteremia compared to relying on prophylactic antibiotics.[28]

IE and Dental Infections

The human oral cavity is believed to host more than 500 bacterial species, comprising aerobic and anaerobic gram-positive and gram-negative microorganisms.[48] Individuals with CHD have been reported to have an increased risk of IE due to oral bacteremia[49] and approximately 5% of IE cases are thought to be caused by oral bacteria following dental treatment.[50,51] In a study of 205 children and adolescents (mean age 10.8 years), baseline blood samples were taken before dental procedures, with a second blood sample collected 30 seconds after a single conservative dental procedure. Results showed that the prevalence of bacteremia significantly increased following rubber dam placement ($p=0.01$) and matrix band/wedge placement ($p=0.001$) compared to baseline; aerobic bacterial isolation showed a significant rise after these procedures compared to baseline.[52] Maintaining optimal oral hygiene and gingival health is linked to a decreased likelihood of developing bacteremia, potentially leading to a lower risk of developing IE.[28,53,54]

Study Rationale

Research on preventive dental care utilization and factors associated with it among individuals with CHD is sparse in the U.S. Challenges exist in dental care access and delivery in the general population, with cost being the top reason individuals do not seek dental care.[55] Low dental care utilization is also reported among individuals with birth defects; however, this understanding is limited to pediatric populations.[56] A nation-wide U.S. study examining preventive dental care utilization among of children, aged 1 to 17 years, with and without heart conditions showed that about 83% of CHD patients received preventive dental care.[57] In GA, dental care coverage for children and adolescents with CHD shifted to Medicaid with the inception of the PeachCare for Kids program in 1998: this program offers comprehensive dental care to all income eligible children through Medicaid's Children's Health Insurance Program (CHIP). Medicaid-enrolled children overall are

reported to be more likely to receive dental care compared to privately insured children; however, it is not clear whether these services are adequate or aimed at preventive care services.[58]

It is necessary to understand the association between preventive dental care utilization and its association with IE among children with CHD who are enrolled in Medicaid. Knowledge of the role of preventive dental care utilization associated with IE risk in children with CHD will likely help programs improve preventive dental care utilization and prevent adverse health outcomes associated with poor oral health, including IE. The current study proposes to assess the association in a pediatric cohort with CHD, aged 1-18 years, who were enrolled in GA Medicaid between 2008-2019. It is hypothesized that children with CHD, enrolled in GA Medicaid between 2008-2019, who had at least one annual preventive dental care visit will be at lower risk of developing IE compared to those without any dental care visits.

CHAPTER II: METHODS

Study Design

The current study used a retrospective cohort study design using administrative data from a CHD data repository that included a GA Medicaid claims data. Patient consent was waived by the Emory University IRB and confidentiality was maintained as this research was assessed via a secondary data analysis approach.

Data Source and Storage

The principal data source utilized was GA Medicaid claims data. Medicaid, a federal initiative that is state administered and funded through state and federal taxes, is a healthcare coverage program for those facing financial challenges in accessing medical services by covering partial or total medical, dental and vision expenses. Data were extracted from Emory's population-based, CHD surveillance data repository, which includes GA Medicaid administrative claims spanning from January 1, 1999, through December 31, 2019, for individuals with a CHD diagnosis. For the current study, outpatient claims covering a 12-year period from 2008-2019 were used to construct a de-identified, de-duplicated analytic dataset. These GA Medicaid claims data were obtained from the Centers for Medicare and Medicaid Services (CMS) via the Research Data Assistance Center (ResDAC), a CMS contractor that assists academic, government, non-profits, and for-profits organizations in acquiring Medicaid and/or Medicare datasets [ResDAC. (n.d.). Retrieved February 16, 2024, from http://www.resdac.org/].

All data for the current study were stored and examined on a secure, private, Federal Information Security Management Act (FISMA)-compliant network storage drive at Emory University, Rollins School of Public Health, Information Technology Department server system. To ensure data confidentiality, the secure data storage drive is maintained by authorized Rollins School of Public Health Information Technology office personnel and is

only accessible to study researchers; all protected health information (PHI) was excluded from the analytic dataset.

Study Population

The initial GA Medicaid dataset consisted of 100,463 unique beneficiaries. CHD patients having an IE diagnosis before at least one preventive dental care visit (exposure) during the study period were excluded (n=112). Other exclusions included beneficiaries born before 1/1/2001 or after 12/31/2018 (n=10,294), beneficiaries with an 'other CHD' and 'other Vascular' classification (Appendix A) (n=463) and those with diagnostic codes 745.5 or Q21.1 ASD or PFO in isolation or in combination with "other" CHD codes due to lack of specificity of these codes (n=28,568) (Rodriguez et al 2018). Two individuals with unknown sex were also excluded. The final analytic sample consisted of 61,024 children with CHD, aged 1 to 18 years (born between 01/01/2001 - 12/31/2018), who were enrolled in GA Medicaid sometime between 2008-2019; all beneficiaries were diagnosed with CHD as defined by having at least one CHD-associated ICD-9-CM (38 codes) and/or ICD-10-CM (49 codes) code (Appendix A), with at least one GA Medicaid healthcare encounter during 2008-2019 (Figure 1).

Exposure Variable

Beneficiaries were classified as either having at least one annual preventive dental care visit or having no annual preventive dental care encounters during the study period. Preventive dental care encounters were operationalised based on CDT codes, updated by the American Dental Association,[59] and included CDT codes D1000-D1999 (Appendix C). Annual rate of preventive dental care visits during the 2008-2019 study period served as the primary exposure variable. First, the year of first preventive dental care visit was captured for each patient and stored in a new variable. Another variable was created to capture the total number of preventive dental care visits for each observation until the outcome first

occurred between 2008 to 2019, else it was calculated till the end of the study period. The annual average number of preventive dental care visits per year for each observation was calculated by dividing the total number of preventive dental care visits by the total years of preventive dental care utilization; this was further classified into two categories: 'No visits', and 'At least one visit' to create the exposure variable of annual average preventive dental care visit.

Outcome Variable

IE was the outcome variable of interest in the analysis. IE was dichotomously categorized as either 'having an IE diagnosis' or 'not having an IE diagnosis' ('Yes'=1/ 'No'=0) sometime in their medical Medicaid claims history between 2008-2019. Only cases occurring after at least one preventive dental care visit were included in the study; IE cases occurring before any preventive dental care visit were excluded from analysis (Figure 1). An occurrence of IE was operationalized based on six ICD-9-CM codes and five ICD-10-CM codes listed in Appendix B.

Covariables

CHD Anatomic Severity

CHD anatomic severity has a five-level classification scheme (Appendix A). The classification scheme includes: (1) severe; (2) shunt; (3) valve; (4) shunt and valve; and (5) other CHD anomalies. Those in the severe group typically require surgery in the first year of life. For this study, CHD anatomic severity groups were collapsed and categorized into 3 groups: Severe, Valve, and Shunt; the Valve group includes those with valve and shunt lesions. The other CHD anomalies group was omitted from analysis.

Birth Year Cohort

Patients were between ages 1 and 18 years on the date of their first dental encounter which occurred between 2008-2019. A three-category birth year cohort variable was created

to represent patient age: 2001-2006, 2007-2012, and 2013-2018 for patients born between 01/01/2001 - 12/31/2018.

Sex

Sex was coded as '0' for males and '1' for females.

Race and Ethnicity

Race and ethnicity were classified into a combined variable with the following 5 categories: '1' for Non-Hispanic White (nHW), '2' for Non-Hispanic Black (nHB), '3' for Hispanic, '4' for other race (which included Asian, American Indian/Native American, Native Hawaiian/Pacific Islander, and multi-racial), and '9' for Unknown. Unknowns were omitted from analysis.

Social Deprivation Index (SDI)

Beneficiaries were classified by a Social Deprivation Index (SDI), a composite social determinants of health measure, developed by the Robert Graham Center, Policy Studies in Family Medicine & Primary Care, to estimate the social deprivation of one's residential area such as county, census tract, or ZCTA.[60-62] It assesses seven salient social determinants of health measures or demographic characteristics collected by the American Community Survey, which are considered to represent the socio-economic variation in health outcomes. The seven demographic characteristics of the residential area that make up the index include: percent living in poverty, percent with less than 12 years of education, percent single-parent households, the percentage living in rented housing units, the percentage living in the overcrowded housing unit, percent of households without a car, and percentage unemployed adults under 65 years of age.[60-62] During creation of the SDI, these factors were converted into centiles to create a common scale, and then, were analyzed through factor analysis, and subsequently, weighted using the calculated factor loadings.[62] Correlation analysis between the calculated deprivation index, measures of health care outcomes

(mortality, infant mortality, low birth weight, diabetes), and measures of primary health care access (avoidable hospitalizations, availability of health care providers, uninsured and rurality) found that SDI was positively associated with mortality, low birth weight, infant mortality, diabetes prevalence, and ambulatory care sensitive hospitalizations.[62] In the current analyses, SDI scores were categorized into quartiles ranging from least to most deprived SDI scores: 1-42 (least deprived quartile), 42-65, 66-85, and 86-100 (most deprived quartile).

Rurality

Rurality was categorized as those residing in non-metropolitan or rural counties compared to those who resided in metropolitan or urban counties. Initially, county and state FIPS, or the full FIPS variable was used to identify county of residence. County of residence was then classified by 6 levels plus unknown if the county of residence was missing. This scheme is based on the 2013 NCHS Urban-Rural Classification Scheme for Counties.[63] The 6 levels of classification include: 1. four metropolitan or urban classes - large central metro (‘1’), large fringe metro (‘2’), medium metro (‘3’) and small metro (‘4’); and 2. two non-metropolitan or rural classes - micropolitan (‘5’) and noncore (‘6’). This six-level variable was further collapsed into a dichotomous variable for rural residence, Y/N; the four metropolitan categories were coded as urban (‘0’ = No) and the two non-metropolitan categories were coded as rural residence (‘1’=Yes). Missing data received a code of ‘9’ for Unknown. Unknown rurality was omitted from analysis.

Statistical Analysis

All statistical analyses were conducted using R (Appendix D) in a dedicated Thesis project subdirectory using R studio. The ‘dplyr’ and ‘gtsummary’ packages was used to conduct descriptive statistics. Demographic characteristics of the analytic sample included frequencies and percentages for all the categorical variables. Chi-square p-values (alpha

level: $p<0.05$) determined any statistical differences in demographic characteristics by IE. Unknowns for any variables were not considered in the analysis. All covariates were selected based on previous literature and availability in the Medicaid dataset.

Logistic regression, using the 'glm' function, was used to estimate crude and adjusted risk ratios, cRR and aRR, respectively, and 95% confidence intervals (CIs). Effect modification was examined for selected covariables, including CHD anatomic group, birth year cohort, race and ethnicity, and SDI. CHD anatomic group was identified as a significant effect-modifier based on the test of homogeneity ($p<0.05$). Three subsets were created for CHD group categories - Severe, Valve, and Shunt, and crude and adjusted logistic regression analyses were conducted by CHD group category. Co-variables were included in the model based on *a priori* criterion.

IRB and Ethnical Considerations:

Emory IRB approval (STUDY00006154) was received on July 10, 2023.

CHAPTER III: RESULTS

A total of 61,024 patients were included in the analytic sample. Table 1 presents the demographic and clinical characteristics of CHD patients, by total and stratified by the presence or absence of IE. A total of 20,966 (34.36%) had no dental visit between 2008 and 2019 and 40,058 (65.64%) had at least one preventive dental care visit. Among the 20,966 individuals who did not have any visits, 100 (0.48%) were diagnosed with IE, compared to just 81 (0.20%) among the 40,058 (65.64%) individuals who had at least one visit. Those with at least one preventive dental care visit had 0.42 (cRR) times less risk of having an IE diagnosis compared to those with no preventive dental care visits. Overall, the median for annual preventive dental care visits was 1 (0-1.5), for those with at least one annual preventive dental care visit.

There were 181 (0.30%) cases of IE among those with at least one annual preventive dental care visit. Overall, more than half of the children with CHD had a shunt defect (58.74%), followed by those with valve lesions (31.98%) or a severe defect (9.28%). However, among those with an IE diagnosis, this distribution reversed with about half having a severe CHD (49.72%), followed by those with a valve lesion (29.83%) or a shunt defect (20.44%) (data not shown). nHB children with CHD were the most prevalent, 40.79%, with another 38.74% who were nHW. An additional 4.04% of the study cohort were Hispanic with the remaining 16.43% from other racial groups including Asian, American Indian/Native American, Native Hawaiian/Pacific Islander, and multi-racial; among children with CHD who had an IE diagnosis, 35.36% were nHW, 27.62% were nHB, a small proportion were Hispanic and 33.15% were from the ‘other’ racially diverse group (33.15%) (data not shown). Overall, most children with CHD were from urban areas (79.46%), while only 20.54% resided in rural regions. Over 25% of those with an IE diagnosis resided in the most socially deprived areas (SDI score between 86-100) (data not shown). Significant associations were revealed between

IE and annual preventive dental care visits ($p< 0.001$), CHD anatomic severity ($p < 0.001$), and race and ethnicity ($p < 0.001$). No significant associations were found between IE diagnosis and birth year cohort, sex, SDI or rurality (Table 1). A significant interaction was observed between annual preventive dental care visits and CHD anatomic group severity by IE status ($p=0.014$).

Table 2a presents the association between annual preventive dental care visits and IE among individuals with severe CHD, and the select covariates of birth year cohort, sex, race and ethnicity, SDI, and rurality. Among 5,663 CHD patients with severe anatomic lesions, 58% had at least one preventive dental care visit (data not shown). In the unadjusted model, the risk of having an IE diagnosis for patients with at least one annual preventive dental care visit was lowered by almost 2/3rd [crude relative risk (cRR)=0.65, 95% CI: 0.43-0.98] compared to those who reported having no preventive dental care visits. After adjusting for all covariates in the full model, the risk of having an IE diagnosis for patients with at least one annual preventive care dental visits remained and was reduced to 80% [adjusted risk ratio (aRR)=0.80, 95% CI: 0.51-1.26]. The aRR remained consistent after controlling for birth year cohort, race and ethnicity and SDI categories in the reduced model suggesting that the association was not statistically significant after accounting for the effects of covariates.

The association between annual preventive dental care visits and IE among individuals with valve-related CHD anatomic severity is presented in Table 2b. Among patients with valve lesions (N=19,517), those having at least one annual preventive dental care visit (73.76%) had a lower risk of IE compared to those reporting no preventive dental care visits (26.24%) [cRR= 0.41, 95% CI: 0.24-0.70]; risk of IE was reduced by 59% for those with at least one dental care visit compared to those with no preventive dental care visits, without accounting for other factors. After controlling for other factors in the full and reduced models, the association between annual preventive dental visits and IE remained significant [aRR=0.32,

95% CI: 0.18-0.56, p < 0.001] for both full and reduced models; those with at least one annual preventive dental care visit had a 68% lower risk of IE compared to those with no preventive dental care visits, after accounting for potential confounding variables. Among birth year cohorts, compared to the 2007-2012 cohort, the 2013-2018 cohort had a lower risk of IE [aRR=0.38, 95% CI: 0.18-0.75], whereas for the 2001-2006 cohort there was no association [aRR=0.99, 95% CI: 0.52-1.85]. The associations between other covariates compared to their referent groups were attenuated.

Table 2c presents the association between annual preventive dental care visits and IE among individuals with shunt lesions. Overall, those having at least one annual preventive dental care visit (62.38%) had a lower risk of IE compared to those who did not have any preventive dental care visits (37.62%) [aRR= 0.19, 95% CI: 0.09-0.41]. The full model adjusted for covariates showed that the association between annual preventive dental care visits and IE remained significant [aRR=0.17, 95% CI: 0.07-0.38, p< 0.001]. When a reduced model including only birth year cohort, race and ethnicity, and SDI was assessed using a priori selection method, the association remained consistent [aRR=0.17, 95% CI: 0.07-0.39].

Overall, results revealed a significant protective association between annual preventive dental care visits and IE across all CHD anatomic severity groups, after controlling for selected confounders; the association however, between annual preventive dental care visits and IE was not significant among individuals with a severe CHD.

CHAPTER IV: DISCUSSION

The study contributes to the existing literature by addressing a gap in knowledge and providing insights into the association between annual preventive dental care visits and IE risk among children with CHD. Our findings shed light on the relationship between annual preventive dental care visits and the occurrence of IE among patients with CHD, stratified by CHD anatomic severity groups. Notably, individuals with severe CHD anatomy exhibited the highest risk of IE, followed by those with valve-related and shunt-related defects, suggesting the importance of understanding the role of anatomic severity of CHD in assessing risk of IE. Results revealed significant protective associations for some types of CHDs and can guide clinical practice and future research.

About two-thirds (65.64%) of our study participants had at least one annual preventive dental care visit during the study period despite having preventive dental care coverage under GA's Medicaid "PeachCare for Kids" program. This is low compared to some other studies with this age group. For example, data from the National Survey of Children's Health (NSCH) between 2016–2019 showed that approximately 83% of children, aged 1-17 years, who had a heart condition received preventive dental care in the past 12 months; and children with heart conditions were more likely to have poor oral health compared to same-aged children without heart conditions (17.2% vs 13.7%; $p = 0.02$).[57] Another study that assessed parental knowledge regarding IE risk and oral health reported that only 4% of children with heart conditions had visited a dentist in the past 6 months, and that 98% of their parents were unaware of the relationship between oral hygiene and the risk of IE has in potentially worsening their child's heart condition.[64]

Our analysis revealed significant effect modification by CHD anatomic severity, suggesting that the relationship between at least one annual preventive dental care visit and IE varies by one's anatomic specificity of CHD; however, this association should be further

examined in large study samples. The most recent American Heart Association (AHA) endocarditis prophylaxis guidelines from the recommend antibiotic prophylaxis only for the highest risk patients – those who present with cyanosis, prosthetic valves or prosthetic material with a residual shunt.[28] As these conditions are most often seen in those with severe CHD conditions, this group is considered high risk for developing IE. In addition, common activities such as toothbrushing, flossing, and chewing can also lead to transient bacteremia, where bacteria from the mouth enters the bloodstream and travels to the heart damaging the heart tissue or valves, but data has suggested that preventive dental care can reduce the frequency and severity of bacteremia.[54] However, although preventive dental care plays a crucial role in reducing bacteremia and subsequent IE risk, it may not fully eliminate the risk, especially for those at the highest risk like those with severe CHD lesions. This type of effect modification has not been examined much in previous studies to our knowledge.

The lack of a significant association found for those with severe CHD between preventive dental care visits and IE may be due to several reasons including that patients with severe lesions often present with more severe cardiac abnormalities and therefore, may have a higher baseline risk of IE compared to those with valve or shunt defects. In a single population-based study from a Quebec CHD database from 1988-2010 that assessed 47,518 children, aged 0 to 18 years, those with severe cyanotic lesions (including TOF and truncus arteriosus) had the highest risk of IE compared to those with ASD [aRR=6.44, 95% CI: 3.95–10.50], followed by those diagnosed with endocardial cushion defects [aRR=5.47, 95% CI: 2.89–10.36], and those with left-sided lesions [aRR=1.88, 95% CI: 1.01–3.49].[32] However, studies examining the association between preventive dental care and IE in pediatric CHD populations are limited, and those utilizing Medicaid beneficiaries are non-existent. A recent case-control study conducted by Lockhart et al.[65] examined oral hygiene status among hospitalized patients with IE (cases) and a group of outpatients with heart

valve disease without IE (controls). Oral hygiene status was measured by mean dental calculus and dental plaque indices. Results revealed that IE cases had a 53% higher mean dental calculus index (0.84 vs 0.55, 95% CI: 0.11 to 0.48) and a 26% higher dental plaque index (0.88 vs 0.70, 95% CI: 0.01 to 0.36) compared to controls. Additionally, IE cases reported fewer visits to dentists/dental hygienists compared to controls (p=0.013). Although the cohort utilized in the Lockhart et al. study was older than the cohort employed in our study, their findings on the association of oral hygiene and IE aligns with our study's findings.[65]

The current study has important implications for clinical practice, emphasizing the importance of regular preventive dental care in reducing the risk of IE among individuals with CHD. Clinicians should prioritize preventive dental care visits for patients with CHD to mitigate the risk of IE. Future research should further investigate the mechanisms underlying the observed associations and explore potential interventions to improve dental care access and utilization among children with CHD.

This study has some potential limitations. Errors or inconsistencies in the classification of study participants with respect to their dental care visit history and IE status could have led to misclassification bias. There was incomplete or sporadic utilization of preventive dental care among children during the study period from 2008 to 2019 and this may be due either to changes or inconsistencies in Medicaid eligibility over the study frame or inaccuracies in capturing preventive dental care visits within the dataset. To overcome this bias, exposure was represented as an average annual preventive dental care visit for each Medicaid beneficiary, and then this measure was categorized into two groups, at least one annual dental care visit or no dental care visits. Secondly, we may have missed some preventive dental care visits or IE diagnoses that were not recorded or captured, and therefore not submitted as a claim to GA Medicaid.

This study also has several potential strengths. GA Medicaid has extensive coverage for children with CHD. This coverage includes preventive dental care coverage for children and adolescents with CHD residing in the state of GA and is provided through the PeachCare for Kids program as part of Medicaid CHIP. In addition, this study used several inclusion and exclusion criteria to make the analytic sample homogenous. We had a relatively large sample of CHD cases and used a well-established classification scheme to identify CHD subtypes based on ICD-9-CM and ICD-10-CM CHD-related codes used in other CHD-related studies. All preventive dental care visits, CHD diagnoses, and a host of other data elements were recorded in the administrative Medicaid claims records from 2008-2019, reducing the potential for recall errors in exposure and outcome assessment. We also were able to examine other important demographic and social determinants, i.e., race and ethnicity, SDI, rurality, etc. and control for them analytically. In addition, the number of IE diagnoses for our overall cohort was low (0.30%). This study also did not account for factors such as skin infections/lacerations, immunodeficiency, and serious chronic conditions known to be predisposing factors for acquiring IE among children.[66] Although these conditions could have been identified via ICD-9-CM and ICD-10-CM codes available in our GA Medicaid data repository, the current investigation did not do so. As such, the current analysis may not fully capture the comprehensive range of risk factors that could have contributed to the development of IE in the study cohort. Future research could aim to address this limitation by incorporating more comprehensive data elements on additional risk factors for IE, thus providing a more nuanced understanding of IE risk which in turn could facilitate the development of more targeted preventive strategies.

Given that most CHD patients are not recommended to receive antibiotic prophylaxis according to current AHA guidelines, except in special cases such as those with prosthetic valves, shunts, patches, or repaired defects, maintaining good oral hygiene

becomes paramount. This emphasizes the critical role of regular preventive dental care visits and dental care practices to aid in reducing the risk of IE and other associated complications seen in CHD patients. By prioritizing oral hygiene, CHD patients can potentially mitigate the need for antibiotic prophylaxis and enhance overall cardiovascular health.

CHAPTER V: FUTURE DIRECTIONS AND PUBLIC HEALTH IMPLICATIONS

Moving forward, longitudinal studies tracking dental care visit patterns over time and research exploring the underlying pathways linking dental health to reduce IE in CHD patients are crucial. Integrating oral health assessments and preventive dental care into routine CHD management protocols is imperative, requiring collaborative efforts between dentists, cardiologists, and pediatricians. Additionally, further investigation into the socioeconomic determinants influencing dental care access and utilization among CHD patients is important. Public health implications entail health education campaigns to raise awareness, policy advocacy for improved dental care access and coverage, and interdisciplinary collaboration for coordinated care delivery to ensure equitable access to preventive dental care services for all CHD patients. Public health campaigns should not only emphasize the importance of regular dental visits, but also educate CHD patients and their families about proper oral hygiene practices and the link between oral health and overall cardiovascular well-being.

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TABLES

Table1. Descriptive characteristics of Georgia Medicaid beneficiaries with congenital heart defects by infectious endocarditis status, 2008-2019.

Characteristics	Total N = 61,024	Yes Infectious Endocarditis n = 181 (.30%)	No Infectious Endocarditis n = 60,843 (99.70%)	X^2 p value[1]
	N (%)	n (row %)	n (row %)	
Average Annual Preventive Dental Care Visits[2]				
No visits	20,966 (34.36)	100 (0.48)	20,866 (99.52)	<0.001
At least one visit	40,058 (65.64)	81 (0.20)	39,977 (99.80)	
CHD Anatomic Severity				
Severe	5,663 (9.28)	90 (1.59)	5,573 (98.41)	<0.001
Valve[3]	19,517 (31.98)	54 (0.28)	19,463 (99.72)	
Shunt	35,844 (58.74)	37 (0.10)	35,807 (99.90)	
Birth Year Cohort				
2001-2006	15,531 (25.45)	44 (0.28)	15,487 (99.72)	0.9
2007-2012	22,150 (36.30)	69 (0.31)	22,081 (99.69)	
2013-2018	23,343 (38.25)	68 (0.29)	23,275 (99.71)	
Sex				
Male	31,054 (50.89)	93 (0.30)	30,961 (99.70)	0.9
Female	29,970 (49.11)	88 (0.29)	29,882 (99.71)	
Race and Ethnicity				
Non-Hispanic, White	23,639 (38.74)	64 (0.27)	23,575 (99.73)	<0.001
Non-Hispanic, Black	24,891 (40.79)	50 (0.20)	24,841 (99.80)	
Hispanic	2,468 (4.04)	7 (0.28)	2,461 (99.72)	
Other[4]	10,026 (16.43)	60 (0.60)	9,966 (99.40)	
Social Deprivation Index Score (SDI)[5] (Quartiles)				
SDI (1-41)	16,378 (26.87)	42 (0.26)	16,336 (99.74)	0.3
SDI (42-65)	11,221 (18.41)	39 (0.35)	11,182 (99.65)	
SDI (66-85)	17,893 (29.35)	46 (0.26)	17,847 (99.74)	
SDI (86-100)	15,467 (25.37)	52 (0.34)	15,415 (99.66)	
Rurality				
Urban	48,441 (79.46)	146 (0.30)	48,295 (99.70)	0.5
Rural	12,518 (20.54)	33 (0.26)	12,485 (99.74)	

Acronyms: CHD = Congenital Heart Defects; SDI = Social Deprivation Index.

[1] Pearson's Chi-squared test.

[2] Annual preventive dental care visits before occurrence of IE.

[3] The valve group includes children with valve, shunt, and both value and shunt lesions.

[4] Other race and ethnicity includes Asian, American Indian/Native American, Native Hawaiian/Pacific Islander, and multi-racial.

[5] SDI score group 1-41 is least socially deprived, and SDI score group 86-100 is most socially deprived.

Notes. Cell size for unknown SDI and Rurality for IE group was too small to report and so, unknown for these two covariates were omitted from analyses.

Table 2a. Association between average annual preventive dental care visits and infectious endocarditis among children, 1-18 years old, with severe congenital heart defects, Georgia Medicaid, 2008-2019.

Characteristics	Severe CHD Group (N=5663)		
	Unadjusted cRR (95% CI)	Adjusted aRR (95% CI) (Full Model)	Adjusted aRR (95% CI) (*a priori* Model)
Average Annual Preventive Dental Care Visits			
No visits	ref	ref	ref
At least one visit	0.65 (0.43-0.98)	0.80 (0.51-1.26)	0.80 (0.51-1.26)
Birth Year Cohort			
2001-2006	-	0.76 (0.42-1.36)	0.76 (0.42-1.35)
2007-2012	-	ref	ref
2013-2018	-	1.14 (0.70-1.88)	1.13 (0.69-1.87)
Sex			
Male	-	ref	-
Female	-	0.88 (0.57- 1.34)	-
Race and Ethnicity			
Non-Hispanic White	-	ref	ref
Non-Hispanic Black	-	0.66 (0.35-1.22)	0.69 (0.37-1.26)
Hispanic	-	0.77 (0.18-2.19)	0.79 (0.19-2.24)
Other*	-	1.46 (0.89-2.41)	1.49 (0.91-2.45)
Social Deprivation Index Score (SDI) (Quartiles)**			
SDI (1-41)	-	ref	ref
SDI (42-65)	-	1.31 (0.71-2.43)	1.29 (0.69-2.38)
SDI (66-85)	-	1.18 (0.64-2.19)	1.13 (0.61-2.08)
SDI (86-100)	-	1.52 (0.83-2.82)	1.40 (0.78-2.52)
Rurality			
Urban	-	ref	-
Rural	-	0.76 (0.41-1.33)	-

Acronyms: CHD=Congenital Heart Defect; cRR= crude risk ratio; aRR=adjusted risk ratio; CI=Confidence Interval.

*Other race includes Asian, American Indian/Native American, Native Hawaiian/Pacific Islander, and multi-racial.

** SDI score group 1-41 is least socially deprived, and SDI score group 86-100 is most socially deprived.

Table 2b. Association between average annual preventive dental care visits and infectious endocarditis among children, 1-18 years old, with valve congenital heart defects, Georgia Medicaid, 2008-2019.

Characteristics	Valve CHD Anatomy Group (N=19,517)		
	Unadjusted cRR (95% CI)	Adjusted aRR (95% CI) (Full Model)	Adjusted aRR (95% CI) (*a priori* Model)
Average Annual Preventive Dental Care Visits			
No visits	ref	ref	ref
At least one visit	0.41 (0.24-0.70)	0.32 (0.18-0.57)	0.32 (0.18-0.56)
Birth Year Cohort			
2001-2006	-	0.99 (0.52-1.85)	0.98 (0.52-1.84)
2007-2012	-	ref	-
2013-2018	-	0.38 (0.18-0.75)	0.38 (0.18-0.76)
Sex			
Male	-	ref	-
Female	-	0.96 (0.56-1.65)	-
Race and Ethnicity			
Non-Hispanic White	-	ref	ref
Non-Hispanic Black	-	0.68 (0.36-1.27)	0.72 (0.39-1.32)
Hispanic	-	1.10 (0.18-3.73)	1.15 (0.18-3.86)
Other*	-	0.91 (0.38-1.96)	0.95 (0.40-2.03)
Socio Deprivation Index Score (SDI) (Quartiles)**			
SDI (1-41)	-	ref	ref
SDI (42-65)	-	1.19 (0.50-2.72)	1.14 (0.49-2.60)
SDI (66-85)	-	0.68 (0.32-1.47)	0.64 (0.30-1.38)
SDI (86-100)	-	1.31 (0.57-3.05)	1.10 (0.53-2.35)
Rurality			
Urban	-	ref	-
Rural	-	0.73 (0.35-1.49)	-

Acronyms: CHD=Congenital Heart Defect; cRR= crude risk ratio; aRR=adjusted risk ratio; CI=Confidence Interval.

*Other race includes Asian, American Indian/Native American, Native Hawaiian/Pacific Islander, and multi-racial.

**SDI score group 1-41 is least socially deprived, and SDI score group 86-100 is most socially deprived.

Table 2c. Association between average annual preventive dental care visits and infectious endocarditis among children, 1-18 years old, with shunt congenital heart defects, Georgia Medicaid, 2008-2019.

Characteristics	Shunt CHD Anatomy Group (N=35,844)		
	Unadjusted cRR (95% CI)	Adjusted aRR (95% CI) (Full Model)	Adjusted aRR (95% CI) (*a priori* Model)
Average Annual Preventive Dental Care Visits			
No visits	ref	ref	ref
At least one visit	0.19 (0.09-0.41)	0.17 (0.07-0.38)	0.17 (0.07-0.39)
Birth Year Cohort			
2001-2006	-	1.57 (0.57-3.94)	1.54 (0.56-3.87)
2007-2012	-	ref	ref
2013-2018	-	0.66 (0.31-1.40)	0.65 (0.31-1.39)
Sex			
Male	-	ref	-
Female	-	1.60 (0.83-3.20)	-
Race and Ethnicity			
Non-Hispanic White	-	ref	ref
Non-Hispanic Black	-	1.41 (0.60-3.46)	1.47 (0.63-3.58)
Hispanic	-	1.06 (0.06-5.72)	1.10 (0.06-5.92)
Other*	-	2.25 (0.93-5.64)	2.31 (0.96-5.76)
Social Deprivation Index Score (SDI) (Quartiles)**			
SDI (1-41)	-	ref	ref
SDI (42-65)	-	1.80 (0.67-5.06)	1.74 (0.65-4.89)
SDI (66-85)	-	1.50 (0.57-4.21)	1.43 (0.54-3.96)
SDI (86-100)	-	1.69 (0.61-4.84)	1.55 (0.58-4.32)
Rurality			
Urban	-	ref	-
Rural	-	0.75 (0.25-1.86)	-

Acronyms: CHD=Congenital Heart Defect; cRR= crude risk ratio; aRR=adjusted risk ratio; CI=Confidence Interval.

*Other race includes Asian, American Indian/Native American, Native Hawaiian/Pacific Islander, and multi-racial.

** SDI score group 1-41 is least socially deprived, and SDI score group 86-100 is most socially deprived.

FIGURES

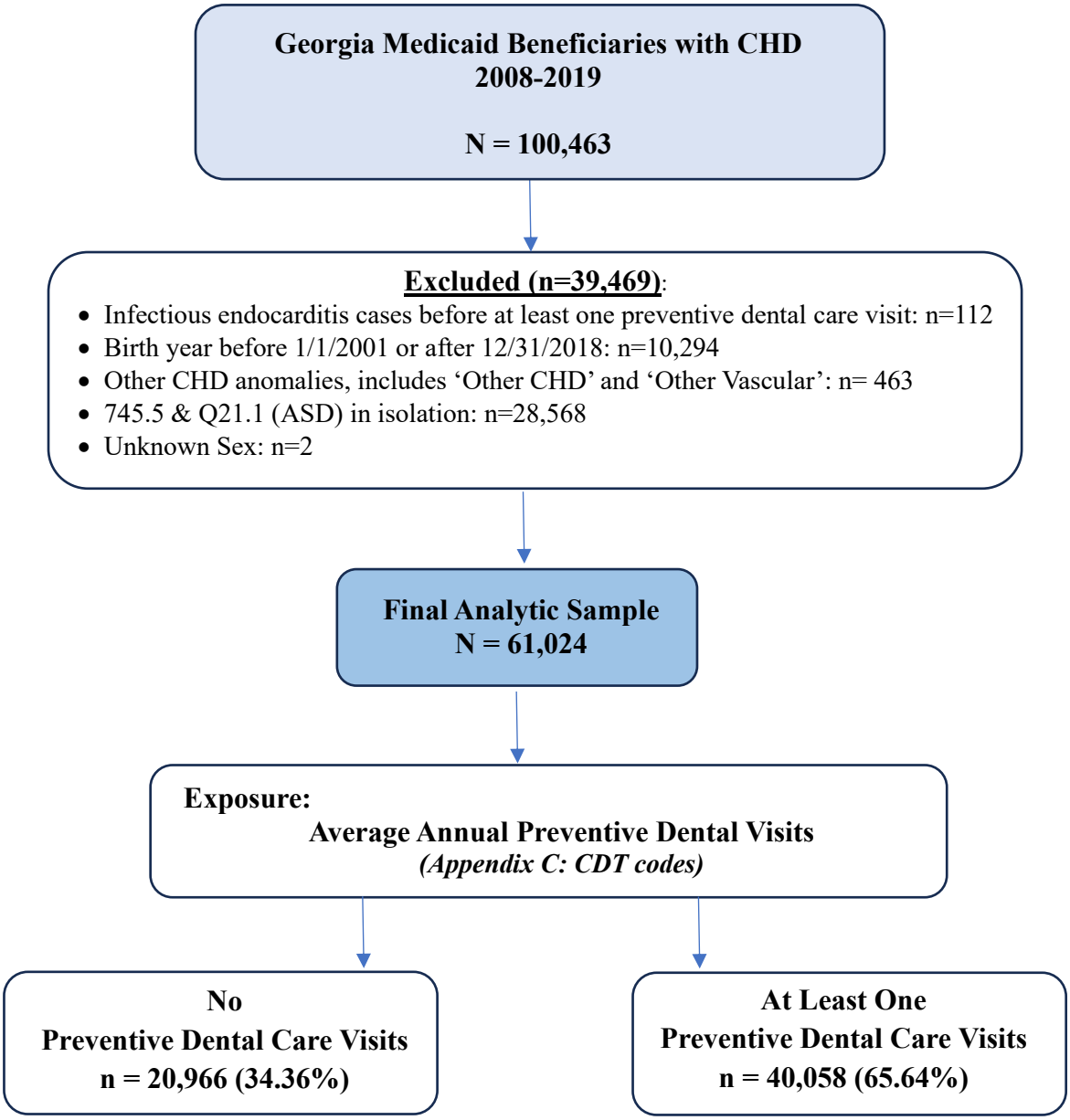

Figure 1. Cohort construction with inclusion and exclusion criteria.

APPENDICES

Appendix A. Congenital heart defect severity, ICD-9-CM and ICD-10-CM codes.

ICD Diagnosis Code Label	ICD-9-CM	ICD-10-CM
Severe *(15 ICD-9-CM codes and 14 ICD-10-CM codes)*		
Hypoplastic Left Heart Syndrome (HLHS)	746.7	Q23.4
Tricuspid Atresia, stenosis or absence	746.1	Q22.4
Hypoplastic right heart syndrome		Q22.6
Single ventricle, cor trioculare, double inlet left ventricle	745.3	Q20.4
Cor bioulare	745.7	
Pulmonary valve atresia or absence	746.01	Q22.0
Truncus Arteriosus, Common Truncus	745.0	Q20.0
Double outlet Right ventricle (DORV)	745.11	Q20.1
Double outlet Left ventricle (DOLV)		Q20.2
Tetralogy of Fallot	745.2	Q21.3
Transposition of the Great arteries (TGA), Complete TGA, dextro-TGA, TGA not otherwise specified, classical TGA[1]	745.1	Q20.3
	745.10	
	745.19	
Congenital Corrected transposition of great arteries (CCTGA), levo-TGA	745.12	Q20.5
Endocardial cushion defect; Atrioventricular septal defect; Complete atrioventricular canal defect (CAVCD) Endocardial cushion defect unspecified Endocardial cushion defect, other[1]	745.6	Q21.2
	745.60	
	745.69	
Interrupted aortic arch	747.11	Q25.21
Total anomalous pulmonary venous return (TAPVR)	747.41	Q26.2
SHUNT AND VALVE[2]		
SHUNT *(7 ICD-9-CM codes and 8 ICD-10-CM codes)*[3]		
Ventricular septal defect (VSD)	745.4	Q21.0
Secundum atrial septal defect (ASD)	745.5	Q21.1
Primum atrial septal defect	745.61	
Other specified defects of septal closure, sinus venosus ASD, inferior sinus venosus ASD, superior sinus venosus ASD	745.8	Q21.8
Congenital malformation of cardiac septum, unspecified		Q21.9
Unspecified defect of septal closure	745.9	
Patent ductus arteriosus (PDA)	747.0	Q25.0
Aortopulmonary septal defect (AP window)		Q21.4
Partial anomalous pulmonary venous return (PAPVR)	747.42	Q26.3
Anomalous pulmonary venous connection, unspecified		Q26.4
VALVE *(14 ICD-9-CM codes and 22 ICD-10-CM codes)*[4]		
Anomalies of the pulmonary valve; Pulmonary valve anomaly unspecified[1]	746.0	Q22.3
	746.00	
Pulmonary valve stenosis (PS)	746.02	Q22.1
Pulmonary valve anomaly, other, pulmonary valve regurgitation	746.09	Q22.2
Ebstein anomaly of the tricuspid valve	746.2	Q22.5

Congenital malformations of tricuspid valve		Q22.8
Congenital malformation of tricuspid valve, unspecified		Q22.9
Aortic valve stenosis (AS)	746.3	Q23.0
Aortic insufficiency or bicuspid or unicuspid aortic valve	746.4	Q23.1
Other congenital malformations of aortic and mitral valves		Q23.8
Congenital malformation of aortic and mitral valves, and specified		Q23.9
Mitral stenosis or mitral valve abnormalities	746.5	Q23.2
Mitral insufficiency, cleft mitral valve	746.6	Q23.3
Subaortic stenosis, subaortic membrane	746.81	Q24.4
Infundibular or subvalvular pulmonary stenosis	746.83	Q24.3
Coarctation of the aorta[1]	747.1	Q25.1
	747.10	
Supravalvular aortic stenosis		Q25.3
Hypoplasia of the aorta		Q25.42
Atresia or stenosis of aorta	747.22	Q25.29
Absence and aplasia of aorta		Q25.41
Atresia of pulmonary artery		Q25.5
Pulmonary artery atresia, coarctation, or hypoplasia of the branch pulmonary arteries	747.31	Q25.71
Anomalies of the pulmonary artery, other	747.39	Q25.79
OTHER CHD *(2 ICD-9-CM codes and 2 ICD-10-CM codes)*[5]		
Cor triatriatum	746.82	Q24.2
Coronary artery anomaly, anomalous coronary artery, anomalous left coronary artery off the pulmonary artery (ALCAPA), anomalous right coronary artery off the pulmonary artery (ARCAPA)	746.85	Q24.5
OTHER VASCULAR *(3 ICD-10-CM codes)*[6]		
Double aortic arch		Q25.45
Right aortic arch component of Vascular ring		Q25.47
Anomalous origin of the subclavian artery component of vascular ring		Q25.48

Acronyms: CHD = congenital heart defect; ICD-9-CM = International Classification of Diseases 9th revision, Clinical Modification; ICD-10-CM = International Classification of Diseases 10th revision, Clinical Modification.

[1] Some ICD-9-CM codes were adjusted over time to include an additional decimal place, but are considered the same code

[2] Cases with no Severe codes and has both Shunt AND Valve codes.

[3] Cases with Shunt codes with or without any other group codes, but no Severe or Valve codes.

[4] Case with Valve codes with or without any other group codes, but no Severe or Shunt codes.

[5] Cases with only 'Other CHD' type group codes, AND no Severe, Shunt or Valve codes.

[6] Cases with 'Other Vascular' codes required either code Q25.45 or the combination of Q25.47 and Q25.48 to be included.

Notes. The **following 25 ICD-9-CM codes were excluded** from the case definition: 746.84 obstructive heart anomalies NEC, 746.86 congenital heart block, 746.87 malposition of heart, 746.89 congenital heart anomaly NEC, 746.9 congenital heart anomaly NOS, 747.20 congenital anomaly of aorta NOS, 747.21 anomalies of aortic arch, 747.29 congenital anomalies of aorta NEC, 747.3 pulmonary artery anomaly, 747.32 pulmonary AV malformation, 747.39 other anomalies of the pulmonary artery and circulation, 747.40 Great vein anomaly NOS, 747.49 great vein anomaly NEC, 747.5 and umbilical artery absence, 747.6 (end 1993) peripheral vascular anomaly NEC, 747.60 (begin 1993) unspecified peripheral vascular anomaly, 747.61 GI vessel anomaly, 747.62 renal vessel anomaly, 747.63 upper limb vessel anomaly, 747.64 lower limb vessel anomaly, 747.69 other specified peripheral vascular anomaly, 747.81 cerebrovascular anomaly, 747.82 spinal vessel anomaly, 747.83 persistent fetal circulation, 747.89 circulatory anomaly NEC, 747.9 circulatory anomaly NOS. **The following 24 ICD-10-CM codes** were excluded from the case definition: Q20.6 isomerism of atrial appendages, Q20.8 other congenitally malformations of cardiac chambers and connections, Q20.9 congenital malformation of cardiac chambers and connections unspecified, Q24.0 malposition of heart or Apex, dextrocardia, Q24.1 levocardia, Q24.8 other specified congenital malformations of the heart, Q24.9 unspecified defect of the heart, Q25.40 anomalies of aorta, unspecified, Q25.43 congenital aneurysm of aorta, Q25.4 for congenital dilation of aorta, Q25.46 torturous aortic arch, Q25.47 right aortic arch, Q25.49 other congenital malformations of

aorta, Q25.6 branch pulmonary artery stenosis, Q25.72 congenital pulmonary arteriovenous malformation, Q25.79 other congenital malformations of the pulmonary artery, Q25.8 other congenital malformations of other great arteries, Q25.9 congenital malformation of great arteries unspecified, Q26.0 congenital stenosis vena cava, Q26.1 left superior vena cava, Q26.5 anomalous portal venous connection, Q26.6 portal vein – hepatic artery fistula, Q26.8 other congenital malformations of great veins, Q26.9 anomalies of great veins unspecified.

Appendix B. Endocarditis ICD-9-CM and ICD-10 CM codes.

ICD-9-CM Code	ICD-9-CM Description
421.0	Acute and subacute bacterial endocarditis
421.1	Acute and subacute infective endocarditis classified elsewhere
421.9	Acute endocarditis, unspecified
424.9	Endocarditis, valve unspecified, unspecified cause
424.91	Endocarditis, classified elsewhere
424.99	Other endocarditis, valve unspecified
ICD-10-CM Code	**ICD-10-CM Description**
I33.0	Acute and subacute infective endocarditis
I33.9	Acute and subacute infective endocarditis, unspecified
I38.0	Endocarditis, valve specified
I39.0	Endocarditis and heart valve disorders classified elsewhere
I39.8	Endocarditis, valve unspecified, classified elsewhere

Appendix C. Dental CDT codes, American Dental Association.

CDT Code	CDT Code Description
D1110	Prophylaxis – adult age 14+
D1120	Prophylaxis – child through age 13 (up to 14th birthday)
D1206	Topical application of fluoride varnish
D1208	Topical application of fluoride – excluding varnish
D1310	Nutritional counselling for control of dental disease
D1320	Tobacco counselling for control and prevention of oral disease
D1321	Counselling for the control and prevention of adverse oral, behavioral, and systemic health effects associated with high-risk substance use
D1330	Oral hygiene instructions
D1351	Sealant – per tooth
D1352	Preventive resin restoration in a moderate to high caries risk patient; permanent tooth
D1353	Sealant repair-per tooth
D1354	Application of caries arresting medicament – per tooth
D1355	caries preventive medicament application – per tooth
D1510, D1515	Space maintainer – fixed, unilateral – per quadrant
D1516	Space maintainer – fixed – bilateral, maxillary
D1517	Space maintainer – fixed – bilateral, mandibular
D1520, D1525	Space maintainer – removable – bilateral
D1526	Space maintainer – removable – bilateral, maxillary
D1527	Space maintainer – removable – bilateral, mandibular
D1551	Re-cement or re-bond bilateral space maintainer – maxillary
D1552	Re-cement or re-bond bilateral space maintainer – mandibular
D1553	Re-cement or re-bond unilateral space maintainer – per quadrant
D1556	Removal of fixed unilateral space maintainer – per quadrant
D1557	Removal of fixed bilateral space maintainer – maxillary
D1558	Removal of fixed bilateral space maintainer – mandibular
D1575	Distal shoe space maintainer-fixed-unilateral
D1999	Unspecified preventative procedure, by report

Appendix D. R code.

```
#Loading the data and removing all exclusions
```{r, load_data}
library(labelled)
library(gtsummary)
library(dplyr)
library(lubridate)
library(multcomp)
Data_ORIGINAL <- read.csv("C:/Users/ketki/OneDrive - Emory
University/DENTAL_KETKI/DATA/Thesis_Ketki/cohort_final3_240222.csv", header = TRUE)
Rurality <- read.csv("C:/Users/ketki/OneDrive - Emory
University/DENTAL_KETKI/DATA/Thesis_Ketki/FIPS_FULL_Urban-Rural_added.csv", header =
TRUE)
#merging rurality data matched by FIPS code
Data_OG <- merge(Data_ORIGINAL, Rurality, by.x = "FIPS", by.y = "FULL_FIPS", all.x = TRUE)
#removing exclusions from GROUP variable
GROUP_variables <- c("5 - Other CHD", "6 - Other Vascular")
Data1 <- Data_OG[!(Data_OG$GROUP %in% GROUP_variables), ]
# Display the first few rows of the filtered data
table(Data1$GENDER)
#removing exclusions from GENDER variable- 1 observation
Data <- Data1[Data1$GENDER != "U", ]
table(Data$GENDER)
#Adding Other and Unknown from RACE2 variable
Data <- Data %>%
  mutate(RACE2 = ifelse(RACE2 %in% c("Other", "Unknown"), "Other", RACE2))
table (Data$flag_chd_asd_pfo_only)
#excluding 745.5 and Q21.1 ICD 9 and 10 codes from the data set
Data <- Data[Data$flag_chd_asd_pfo_only == 0, ]

#DESCRIPTIVE ANALYSIS
#BIRTH_YEAR VARIABLE
##Converting the DATA_BIRTH to a date object
Data$DATE_BIRTH <- as.Date(Data$DATE_BIRTH)
##Separating BIRTH DAY, MONTH and YEAR into three columns
Data$BIRTH_YEAR <- year(Data$DATE_BIRTH)
Data$BIRTH_MONTH <- month(Data$DATE_BIRTH)
Data$BIRTH_DAY <- day(Data$DATE_BIRTH)
#checking the range
min_BIRTH_YEAR = min(Data$BIRTH_YEAR, na.rm = TRUE)
print(min_BIRTH_YEAR)
max_BIRTH_YEAR = max(Data$BIRTH_YEAR, na.rm = TRUE)
print(max_BIRTH_YEAR)
#creating a subset- birth years 2001 to 2018
Data <- subset(Data, BIRTH_YEAR >= 2001 & BIRTH_YEAR <= 2018)
##creating cohorts for BIRTH_YEAR

Data$BIRTH_YEAR_CAT <- cut(Data$BIRTH_YEAR,
                    breaks = c(2001, 2006, 2012, 2018),
                    labels = c ("2001-2006","2007-2012", "2013-2018"), include.lowest = TRUE)
## BIRTH_YEAR_CAT table
table(Data$BIRTH_YEAR_CAT, Data$BIRTH_YEAR)
```
```

```
#GROUP_CAT VARIABLE
Data$GROUP_CAT <- ifelse(Data$GROUP == "1 - Complex", "1 - Complex",
                  ifelse(Data$GROUP %in% c("2 - Shunt/Valve",   "4 - Valve"), "2 - Shunt/Valve",
                      ifelse(Data$GROUP == "3 - Shunt", "3 - Shunt", NA)))
table(Data$GROUP_CAT)
#SDI VARIABLE
##4 quartiles
Data$SDI_CAT_1 <- cut(Data$sdi_score,
                   breaks = c(1, 41, 65, 85, 100),
                   labels = c ("1-41","42-65","66-85","86-100"), include.lowest = TRUE)
table(Data$SDI_CAT_1)
#PREVDENT_ENDO_Annual_CAT- EXPOSURE VARIABLE
### DENTAL codes
# Create a vector to store the column names
col_names <- colnames(Data[, grep("^flag_dental_prev_", colnames(Data))])
# Find the index of the first non-NA value in each row
first_non_na_index <- max.col(!is.na(Data[, grep("^flag_dental_prev_", colnames(Data))]),
    ties.method = "first")
# Initialize a vector to store the year of first visit
year_of_first_visit <- character(nrow(Data))
# Assign the corresponding column names to the year_of_first_visit vector
year_of_first_visit[first_non_na_index > 0] <- col_names[first_non_na_index[first_non_na_index >
    0]]
year_of_first_visit[year_of_first_visit == ""] <- NA
# Add the new variable "year_of_first_visit" to the data frame
Data$year_of_first_visit <- year_of_first_visit
table(Data$year_of_first_visit )
# Check if flag_dental_prevent_08_19 is "2" and set year_of_first_visit to NA accordingly
Data$year_of_first_visit <- ifelse(Data$flag_dental_prevent_08_19 == "2", NA,
    Data$year_of_first_visit)
# Remove "flag_dental_prev_" from the values in Data$year_of_first_visit
Data$year_of_first_visit <- as.integer(sub("^flag_dental_prev_(\\d+)$", "\\1",
    Data$year_of_first_visit))
table(Data$year_of_first_visit)

###ENDO Codes
# Find the index of the first non-NA value in each row for endocarditis columns
first_non_na_index_endo <- max.col(!is.na(Data[, grep("^flag_endo_", colnames(Data))]),
    ties.method = "first")
# Initialize a vector to store the endocarditis year
endocarditis_year <- character(nrow(Data))
# Assign the corresponding column names to the endocarditis_year vector
endocarditis_year[first_non_na_index_endo > 0] <- colnames(Data[, grep("^flag_endo_",
    colnames(Data))])[first_non_na_index_endo[first_non_na_index_endo > 0]]
# Add the new variable "endocarditis_year" to the data frame
Data$endocarditis_year <- endocarditis_year
table(Data$endocarditis_year)
# Check if flag_dental_prevent_08_19 is "2" and set year_of_first_visit to NA accordingly
Data$endocarditis_year <- ifelse(Data$flag_endocarditis_08_19 == "0", NA, Data$endocarditis_year)
table(Data$endocarditis_year, Data$year_of_first_visit)
Data$endocarditis_year <- as.integer(sub("^flag_endo_(\\d+)$", "\\1", Data$endocarditis_year))
table(Data$endocarditis_year)
table(Data$year_of_first_visit)
# Create a new variable to store the difference
Data$diff <- Data$year_of_first_visit - Data$endocarditis_year
```

```
summary(Data$diff)
table(Data$diff)
# Subset the dataframe into two datasets based on the values of the diff variable where preventive
    dental visits happened before endocarditis occurence
Data <- Data[(Data$diff >= -11 & Data$diff <= -1) | is.na(Data$diff), ]
##final exposure variable- total number of prevdent visits for each observation before endocarditis:
dental_before_endo_total
###IMP:  exposure variable total number of prev visits before endocarditis
# Initialize the dental_before_endo_total variable
dental_before_endo_total <- numeric(nrow(Data))
# Get indices of endocarditis and dental visit variables
endo_vars <- grep("^flag_endo_", colnames(Data))
dental_vars <- grep("^flag_dental_prev_", colnames(Data))
# Loop through each row of the dataset
for (i in 1:nrow(Data)) {
  # Check if all endocarditis flags are NA (indicating no endocarditis information)
  if (all(is.na(Data[i, endo_vars]))) {
    # Sum all preventive dental visits
    dental_before_endo_total[i] <- sum(Data[i, dental_vars], na.rm = TRUE)
  } else {
    # Check if any endocarditis occurred in the row
    if (any(Data[i, endo_vars] > 0, na.rm = TRUE)) {
      # Find the first occurrence of endocarditis
      first_endo_index <- min(which(Data[i, endo_vars] > 0))
      # Check if any preventive dental visits exist before endocarditis
      if (first_endo_index > 1) {
        # Sum the number of preventive dental visits before endocarditis
        dental_before_endo_total[i] <- sum(Data[i, dental_vars[1:(first_endo_index - 1)]], na.rm =
      TRUE)
      }
    }
  }
}
# Add dental_before_endo_total as a new variable in the dataset
Data$dental_before_endo_total <- dental_before_endo_total
# Display the frequency table for dental_before_endo_total
table(Data$dental_before_endo_total)
##number of years: dental_before_endo_year
# Initialize the dental_before_endo_year variable
Data$dental_before_endo_year <- NA
# Loop through each row of the dataset
for (i in 1:nrow(Data)) {
  # Get the indices of endocarditis occurrences in the row
  endo_vars <- grep("^flag_endo_", colnames(Data))
  # Check if any endocarditis occurred in the row
  if (any(Data[i, endo_vars] > 0, na.rm = TRUE)) {
    # Find the first occurrence of endocarditis
    first_endo_index <- min(which(Data[i, endo_vars] > 0))
    # Get the indices of preventive dental visits from flag_dental_prev_08 to flag_dental_prev_19
    dental_vars <- grep("^flag_dental_prev_0[89]|flag_dental_prev_1[0-9]", colnames(Data))
    # Calculate the number of years before endocarditis happened
    Data$dental_before_endo_year[i] <- sum(!is.na(Data[i, dental_vars[1:(first_endo_index - 1)]]))
  } else {
    # If no endocarditis occurred, set dental_before_endo_year to 0
    Data$dental_before_endo_year[i] <- sum(!is.na(Data[i, dental_vars]))
```

```
  }
}
table(Data$dental_before_endo_year)
Data$PREVDENT_ENDO_CONT <- ifelse(Data$dental_before_endo_year == 0, 0,
     Data$dental_before_endo_total / Data$dental_before_endo_year)
summary(Data$PREVDENT_ENDO_CONT)
##creating Final categorical variable- PREVDENT_ENDO_Annual_CAT
Data$PREVDENT_ENDO_Annual_CAT <- cut (Data$PREVDENT_ENDO_CONT,
                    breaks = c(-1, 0, Inf),
                     labels = c( "No visits", "At least one visit"),
                     include.lowest = TRUE)
table(Data$PREVDENT_ENDO_Annual_CAT)
#checking for missing values
missing_values_all <- colSums(is.na(Data))
print(missing_values_all)
```
```{r}
#TABLE 1
install.packages("dplyr")
library(dplyr)
library(gtsummary)
Data |>
  select("PREVDENT_ENDO_Annual_CAT", "BIRTH_YEAR_CAT", "GENDER", "RACE2",
      "GROUP_CAT",  "SDI_CAT_1", "URBAN_DESC", "flag_endocarditis_08_19") |>
  tbl_summary(by = flag_endocarditis_08_19, missing = "no" ) |>
  modify_spanning_header(c("stat_1", "stat_2") ~ "**Endocarditis 0=No/1=Yes**") |>
  add_overall() |>
  add_p()
#2*2 table for exposure and outcome
table(Data$PREVDENT_ENDO_Annual_CAT, Data$flag_endocarditis_08_19, useNA = "always")
```
#SETTING A REFERENCE FOR EACH VARIABLE
```{r}
##flag_endocarditis_08_19: 1- yes, 0-no
Data$flag_endocarditis_08_19 <- as.factor(Data$flag_endocarditis_08_19)
Data$flag_endocarditis_08_19 <- relevel(Data$flag_endocarditis_08_19, ref = "0")
##flag_dental_prevent_08_19: 1-yes, 2-no
Data$flag_dental_prevent_08_19 <- as.factor(Data$flag_dental_prevent_08_19)
Data$flag_dental_prevent_08_19 <- relevel(Data$flag_dental_prevent_08_19, ref = "2")
##PREVDENT_ENDO_Annual_CAT: No visits
Data$PREVDENT_ENDO_Annual_CAT <- as.factor(Data$PREVDENT_ENDO_Annual_CAT)
Data$PREVDENT_ENDO_Annual_CAT <- relevel(Data$PREVDENT_ENDO_Annual_CAT, ref =
     "No visits")
##BIRTH_YEAR_CAT= "2007-2012"
Data$BIRTH_YEAR_CAT <- as.factor(Data$BIRTH_YEAR_CAT)
Data$BIRTH_YEAR_CAT <- relevel(Data$BIRTH_YEAR_CAT, ref = "2007-2012")
##RACE2= "Non-Hispanic, White"
Data$RACE2 <- as.factor(Data$RACE2)
Data$RACE2 <- relevel(Data$RACE2, ref = "Non-Hispanic, White")
##GENDER= "Male"
Data$GENDER <- as.factor(Data$GENDER)
Data$GENDER <- relevel(Data$GENDER, ref = "M")
##GROUP_CAT= "3 - Shunt"
Data$GROUP_CAT <- as.factor(Data$GROUP_CAT)
Data$GROUP_CAT <- relevel(Data$GROUP_CAT, ref = "3 - Shunt")
```

```
##SDI_CAT_1 = "1-41"
Data$SDI_CAT_1 <- as.factor(Data$SDI_CAT_1)
Data$SDI_CAT_1 <- relevel(Data$SDI_CAT_1, ref = "1-41")
##URBAN_DESC = "Urban"
Data$URBAN_DESC <- as.factor(Data$URBAN_DESC)
Data$URBAN_DESC <- relevel(Data$URBAN_DESC, ref = "Urban")
```
#INTERACTION
```{r}
#Interaction for PREVDENT_ENDO_Annual_CAT- significant for GROUP_CAT
##crude
model_INT <- glm(flag_endocarditis_08_19 ~ PREVDENT_ENDO_Annual_CAT, family = binomial
    (link = 'logit'), data= Data)
##fully adjusted model
model_INT <- glm(flag_endocarditis_08_19 ~ PREVDENT_ENDO_Annual_CAT +
    BIRTH_YEAR_CAT + RACE2 + GENDER + GROUP_CAT + SDI_CAT_1 + URBAN_DESC,
    family = binomial (link = 'logit'), data= Data)
##interaction for GROUP_CAT
model_INT <- glm(flag_endocarditis_08_19 ~ PREVDENT_ENDO_Annual_CAT + GROUP_CAT +
    PREVDENT_ENDO_Annual_CAT*GROUP_CAT, family = binomial (link = 'logit'), data= Data)
cbind(exp(coef(model_INT)), exp(confint.default(model_INT)))
drop1(model_INT, test = 'Chisq')
##RR: when the outcome is rare (i.e., the prevalence is less than 10%)- using logistic regression
    coefficients to approximate risk ratios.
ratio <- exp(coef(model_INT))
CI <- exp(confint(model_INT))
## Combine into a data frame
result <- data.frame(RR = ratio,
                     lower = CI[,1],
                     upper = CI[,2])
## Print the results
print(result)
```
#STRATIFIED ANLYSIS BY GROUP_CAT FOR PREVDENT_ENDO_ANNUAL_CAT
```{r}
#Calculating RR and CI for SEVERE category
library(MASS)  # For stepAIC function
library(car)
# Stratified by SEVERE group category
subset_GROUP1 <- Data[Data$GROUP_CAT ==          "1 - Complex",]
table(subset_GROUP1$GROUP_CAT)
## Define reference levels for categorical variables
subset_GROUP1$flag_endocarditis_08_19 <- as.factor(subset_GROUP1$flag_endocarditis_08_19)
subset_GROUP1$flag_endocarditis_08_19 <- relevel(subset_GROUP1$flag_endocarditis_08_19, ref
    = "0")
subset_GROUP1$PREVDENT_ENDO_Annual_CAT <-
    as.factor(subset_GROUP1$PREVDENT_ENDO_Annual_CAT)
subset_GROUP1$PREVDENT_ENDO_Annual_CAT <-
    relevel(subset_GROUP1$PREVDENT_ENDO_Annual_CAT, ref = "No visits")
subset_GROUP1$BIRTH_YEAR_CAT <- as.factor(subset_GROUP1$BIRTH_YEAR_CAT)
subset_GROUP1$BIRTH_YEAR_CAT <- relevel(subset_GROUP1$BIRTH_YEAR_CAT, ref =
    "2007-2012")
subset_GROUP1$RACE2 <- as.factor(subset_GROUP1$RACE2)
subset_GROUP1$RACE2 <- relevel(subset_GROUP1$RACE2, ref = "Non-Hispanic, White")
subset_GROUP1$GENDER <- as.factor(subset_GROUP1$GENDER)
```

```
subset_GROUP1$GENDER <- relevel(subset_GROUP1$GENDER, ref = "M")
subset_GROUP1$SDI_CAT_1 <- as.factor(subset_GROUP1$SDI_CAT_1)
subset_GROUP1$SDI_CAT_1 <- relevel(subset_GROUP1$SDI_CAT_1, ref = "1-41")
subset_GROUP1$URBAN_DESC <- as.factor(subset_GROUP1$URBAN_DESC)
subset_GROUP1$URBAN_DESC <- relevel(subset_GROUP1$URBAN_DESC, ref = "Urban")
##crude model
model_GROUP1 <- glm(flag_endocarditis_08_19 ~ PREVDENT_ENDO_Annual_CAT, family =
    binomial (link = 'logit'), data= subset_GROUP1)
cbind(exp(coef(model_GROUP1)), exp(confint.default(model_GROUP1)))
model_summary <- summary(model_GROUP1)
# Extract risk ratios and confidence intervals
RR <- exp(model_summary$coefficients[, 1])
CI <- exp(confint.default(model_GROUP1))
# Combine RRs and CIs
results <- cbind(RR, CI)
# Round to two decimals
results_rounded <- round(results, 2)
# Print results
print(results_rounded)
## Model Specification- full model
model1 <- glm(flag_endocarditis_08_19 ~ PREVDENT_ENDO_Annual_CAT +
    BIRTH_YEAR_CAT + RACE2 + GENDER + SDI_CAT_1 + URBAN_DESC , family =
    binomial (link = 'logit'), data= subset_GROUP1)
cbind(exp(coef(model1)), exp(confint.default(model1)))
drop1(model1, test = 'Chisq')
## a priori selection
model1 <- glm(flag_endocarditis_08_19 ~ PREVDENT_ENDO_Annual_CAT +
    BIRTH_YEAR_CAT + RACE2 +SDI_CAT_1 , family = binomial (link = 'logit'), data=
    subset_GROUP1)
##calculate RRs
risk_ratios <- exp(coef(model1))
conf_intervals <- exp(confint(model1))
## Round to two decimal places
risk_ratios <- round(risk_ratios, 2)
conf_intervals <- round(conf_intervals, 2)
## Combine into a data frame
results <- data.frame(RR = risk_ratios,
                      CI_lower = conf_intervals[,1],
                      CI_upper = conf_intervals[,2])
## Print the results
print(results)
```
```{r}
# Stratified by VALVE group category
subset_GROUP2 <- Data[Data$GROUP_CAT ==
"2 - Shunt/Valve",]
table(subset_GROUP2$GROUP_CAT)
## Define reference levels for categorical variables
subset_GROUP2$flag_endocarditis_08_19 <- as.factor(subset_GROUP2$flag_endocarditis_08_19)
subset_GROUP2$flag_endocarditis_08_19 <- relevel(subset_GROUP2$flag_endocarditis_08_19, ref
    = "0")
subset_GROUP2$flag_dental_prevent_08_19 <-
    as.factor(subset_GROUP2$flag_dental_prevent_08_19)
subset_GROUP2$flag_dental_prevent_08_19 <-
    relevel(subset_GROUP2$flag_dental_prevent_08_19, ref = "2")
```

```
subset_GROUP2$PREVDENT_ENDO_Annual_CAT <-
    as.factor(subset_GROUP2$PREVDENT_ENDO_Annual_CAT)
subset_GROUP2$PREVDENT_ENDO_Annual_CAT <-
    relevel(subset_GROUP2$PREVDENT_ENDO_Annual_CAT, ref = "No visits")
subset_GROUP2$BIRTH_YEAR_CAT <- as.factor(subset_GROUP2$BIRTH_YEAR_CAT)
subset_GROUP2$BIRTH_YEAR_CAT <- relevel(subset_GROUP2$BIRTH_YEAR_CAT, ref =
    "2007-2012")
subset_GROUP2$RACE2 <- as.factor(subset_GROUP2$RACE2)
subset_GROUP2$RACE2 <- relevel(subset_GROUP2$RACE2, ref = "Non-Hispanic, White")
subset_GROUP2$GENDER <- as.factor(subset_GROUP2$GENDER)
subset_GROUP2$GENDER <- relevel(subset_GROUP2$GENDER, ref = "M")
subset_GROUP2$SDI_CAT_1 <- as.factor(subset_GROUP2$SDI_CAT_1)
subset_GROUP2$SDI_CAT_1 <- relevel(subset_GROUP2$SDI_CAT_1, ref = "1-41")
subset_GROUP2$URBAN_DESC <- as.factor(subset_GROUP2$URBAN_DESC)
subset_GROUP2$URBAN_DESC <- relevel(subset_GROUP2$URBAN_DESC, ref = "Urban")
##crude model
model_GROUP2 <- glm(flag_endocarditis_08_19 ~ PREVDENT_ENDO_Annual_CAT, family =
    binomial (link = 'logit'), data= subset_GROUP2)
cbind(exp(coef(model_GROUP2)), exp(confint.default(model_GROUP2)))
model_summary <- summary(model_GROUP2)
# Extract risk ratios and confidence intervals
RR <- exp(model_summary$coefficients[, 1])
CI <- exp(confint.default(model_GROUP2))
# Combine RRs and CIs
results <- cbind(RR, CI)
# Round to two decimal places
results_rounded <- round(results, 2)
# Print results
print(results_rounded)
## model specification- full model
model2 <- glm(flag_endocarditis_08_19 ~ PREVDENT_ENDO_Annual_CAT +
    BIRTH_YEAR_CAT + RACE2 + GENDER + SDI_CAT_1 + URBAN_DESC, family = binomial
    (link = 'logit'), data= subset_GROUP2)
cbind(exp(coef(model2)), exp(confint.default(model2)))
drop1(model2, test = 'Chisq')
## a priori selection
model2 <- glm(flag_endocarditis_08_19 ~ PREVDENT_ENDO_Annual_CAT +
    BIRTH_YEAR_CAT + RACE2 + SDI_CAT_1, family = binomial (link = 'logit'), data=
    subset_GROUP2)
#calculate RR and CI
risk_ratios2 <- exp(coef(model2))
conf_intervals2 <- exp(confint(model2))
## Round to two decimal places
risk_ratios2 <- round(risk_ratios2, 2)
conf_intervals2 <- round(conf_intervals2, 2)
## Combine risk ratios and confidence intervals into a data frame
results2 <- data.frame(RR = risk_ratios2,
                       CI_lower = conf_intervals2[,1],
                       CI_upper = conf_intervals2[,2])
## Print the results
print(results2)
```
```{r}
# Stratified by SHUNT group category
subset_GROUP3 <- Data[Data$GROUP_CAT ==
```

```
"3 - Shunt",]
table(subset_GROUP3$GROUP_CAT)
## Define reference levels for categorical variables
subset_GROUP3$flag_endocarditis_08_19 <- as.factor(subset_GROUP3$flag_endocarditis_08_19)
subset_GROUP3$flag_endocarditis_08_19 <- relevel(subset_GROUP3$flag_endocarditis_08_19, ref
    = "0")
subset_GROUP3$flag_dental_prevent_08_19 <-
    as.factor(subset_GROUP3$flag_dental_prevent_08_19)
subset_GROUP3$flag_dental_prevent_08_19 <-
    relevel(subset_GROUP3$flag_dental_prevent_08_19, ref = "2")
subset_GROUP3$PREVDENT_ENDO_Annual_CAT <-
    as.factor(subset_GROUP3$PREVDENT_ENDO_Annual_CAT)
subset_GROUP3$PREVDENT_ENDO_Annual_CAT <-
    relevel(subset_GROUP3$PREVDENT_ENDO_Annual_CAT, ref = "No visits")

subset_GROUP3$BIRTH_YEAR_CAT <- as.factor(subset_GROUP3$BIRTH_YEAR_CAT)
subset_GROUP3$BIRTH_YEAR_CAT <- relevel(subset_GROUP3$BIRTH_YEAR_CAT, ref =
    "2007-2012")
subset_GROUP3$RACE2 <- as.factor(subset_GROUP3$RACE2)
subset_GROUP3$RACE2 <- relevel(subset_GROUP3$RACE2, ref = "Non-Hispanic, White")
subset_GROUP3$GENDER <- as.factor(subset_GROUP3$GENDER)
subset_GROUP3$GENDER <- relevel(subset_GROUP3$GENDER, ref = "M")
subset_GROUP3$SDI_CAT_1 <- as.factor(subset_GROUP3$SDI_CAT_1)
subset_GROUP3$SDI_CAT_1 <- relevel(subset_GROUP3$SDI_CAT_1, ref = "1-41")
subset_GROUP3$URBAN_DESC <- as.factor(subset_GROUP3$URBAN_DESC)
subset_GROUP3$URBAN_DESC <- relevel(subset_GROUP3$URBAN_DESC, ref = "Urban")
##crude model
model_GROUP3 <- glm(flag_endocarditis_08_19 ~ PREVDENT_ENDO_Annual_CAT, family =
    binomial (link = 'logit'), data= subset_GROUP3)
cbind(exp(coef(model_GROUP3)), exp(confint.default(model_GROUP3)))
## model specification- full model
model3 <- glm(flag_endocarditis_08_19 ~ PREVDENT_ENDO_Annual_CAT +
    BIRTH_YEAR_CAT + RACE2 + GENDER + SDI_CAT_1 + URBAN_DESC, family = binomial
    (link = 'logit'), data= subset_GROUP3)
cbind(exp(coef(model3)), exp(confint.default(model3)))
drop1(model3, test = 'Chisq')
## a priori Selection
model3 <- glm(flag_endocarditis_08_19 ~ PREVDENT_ENDO_Annual_CAT +
    BIRTH_YEAR_CAT + RACE2 + SDI_CAT_1, family = binomial (link = 'logit'), data=
    subset_GROUP3)
#calculate RR and CI
risk_ratios3 <- exp(coef(model3))
conf_intervals3 <- exp(confint(model3))
## Round to two decimal places
risk_ratios3 <- round(risk_ratios3, 2)
conf_intervals3 <- round(conf_intervals3, 2)
## Combine risk ratios and confidence intervals into a data frame
results3 <- data.frame(RR = risk_ratios3,
                       CI_lower = conf_intervals3[,1],
                       CI_upper = conf_intervals3[,2])
## Print the results
print(results3)
```