HHS Public Access

Author manuscript

Am J Med Genet A. Author manuscript; available in PMC 2025 June 01.

Published in final edited form as:

Am J Med Genet A. 2024 June ; 194(6): e63549. doi:10.1002/ajmg.a.63549.

Prevalence and Descriptive Epidemiology of Choanal Atresia and Stenosis in Texas, 1999–2018

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Abstract

Background: Choanal atresia and stenosis are common causes of congenital nasal obstruction, but their epidemiology is poorly understood. Compared to bilateral choanal atresia/stenosis, unilateral choanal atresia/stenosis is generally diagnosed later and might be under-ascertained in birth defect registries.

Methods: Data from the population-based Texas Birth Defects Registry and Texas vital records, 1999–2018, were used to assess the prevalence of choanal atresia/stenosis. Poisson regression models were used to evaluate associations with infant and maternal characteristics in two analytic groups: isolated choanal atresia/stenosis (n=286) and isolated, bilateral choanal atresia/stenosis (n=105).

Results: The overall prevalence of choanal atresia/stenosis was 0.92/10,000, and the prevalence of isolated choanal atresia/stenosis was 0.37/10,000 livebirths. Variables associated with choanal atresia/stenosis in one or both analytic groups included infant sex, pregnancy plurality, maternal race/ethnicity, maternal age, and maternal residence on the Texas-Mexico border. In general, adjusted prevalence ratios estimated from the two analytic groups were in the same direction but tended to be stronger in the analyses restricted to isolated, bilateral defects.

Conclusion: Epidemiologic studies of isolated choanal atresia/stenosis should consider focusing on cases with bilateral defects, and prioritizing analyses of environmental, social, and structural factors that could account for the association with maternal residence on the Texas-Mexico border.

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Author Contributions

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Conflict of interest

The authors have no conflicts of interest to disclose.

Keywords

choanal atresia; choanal stenosis; congenital; epidemiology; prevalence; registries

INTRODUCTION

Embryonic development of the nasal cavities to form a complete airway from the nostrils to the nasopharynx is a complex process. In humans, this process begins between the third and fourth weeks of gestation. By week seven, the connection between the nasal cavities and pharynx via the posterior choanae is established (Som & Naidich, 2013). Obstruction of the posterior choanae results in choanal atresia (complete obstruction) or stenosis (partial obstruction or narrowing). While choanal atresia/stenosis is a common cause of pediatric nasal obstruction (Smith & Ishman, 2018), it is a relatively rare condition with prevalence estimates on the order of 0.8–0.9/10,000 births (Case & Mitchell, 2011; Harris, Robert, & Kallen, 1997). The pathogenesis of choanal atresia/stenosis is not known (Galluzzi, Garavello, Dalfino, Castelnuovo, & Turri-Zanoni, 2021; Kurosaka, 2019).

Choanal atresia/stenosis can occur unilaterally or bilaterally. Common presenting symptoms include respiratory distress, feeding difficulties, and rhinorrhea, although the frequency of these symptoms varies by laterality (Paradis et al., 2021a). Cases with bilateral choanal atresia present with respiratory distress soon after delivery because neonates breathe primarily through the nose. Cases with unilateral defects or only stenosis are often identified later in infancy or early childhood. Based on a multicenter study of 215 cases in Canada, 1980–2010, the mean age at presentation was less than one month for cases with bilateral defects. In contrast, the mean age at presentation for cases with unilateral defects was over 1.5 years (Paradis et al., 2021a). Choanal atresia/stenosis is treated surgically, but restenosis, requiring revision surgeries, is common (Paradis et al., 2021b).

Some cases with choanal atresia/stenosis occur in association with chromosomal or other malformation syndromes and sequences (reviewed in (Kurosaka, 2019)). CHARGE syndrome (CHARGE is an acronym based on the common features of this syndrome: *C*oloboma, *H*eart defects, *A*tresia of the choanae, *R*enal (genitourinary) abnormalities and *E*ar anomalies/deafness (Pagon, Graham, Zonana, & Yong, 1981)) is the most frequent syndromic diagnosis associated with choanal atresia/stenosis, and occurs in 10%−16% of individuals with choanal atresia/stenosis (Case & Mitchell, 2011; Paradis et al., 2021a). Most instances of CHARGE syndrome are due to pathogenic genetic variants in chromodomain helicase DNA binding domain 7 (*CHD7*, OMIM *608892) (Legendre et al., 2017; Vissers et al., 2004).

Cases with choanal atresia/stenosis that are not diagnosed with a syndrome or sequence may have only choanal atresia/stenosis, or they may have one or more additional major malformations. The latter subgroup may include cases with underlying syndromes or sequences that have not been diagnosed, as well as cases with patterns of malformations that are not yet recognized as syndromes or sequences. To reduce etiological heterogeneity, the subgroup of cases with additional major malformations is often excluded from epidemiological studies that aim to identify risk factors for non-syndromic choanal atresia/

stenosis. However, the epidemiology of choanal atresia/stenosis has not been extensively studied. Further, the studies that have been conducted were based on relatively small sample sizes, and varied with respect to case inclusion criteria (e.g. some studied included only choanal atresia where as other included both choanal atresia and stenosis). Consequently, the epidemiology of these conditions is poorly understood. To address this gap in understanding, we updated our prior study of choanal atresia/stenosis in Texas (Case & Mitchell, 2011) to include an additional 14 years of data.

MATERIALS AND METHODS

Editorial Policies and Ethical Considerations

The studies described in this manuscript were approved by the ethics committees of the University of Texas Health Science Center – Houston and the Texas Department of State Health Services.

Study Subjects

The data used for this study were obtained from the Texas Birth Defects Registry (TBBR). The TBDR is an active surveillance, population-based registry that was initiated in 1994 and has conducted surveillance statewide since 1999. The registry includes information on livebirths, stillbirths, fetal deaths, and terminations among Texas residents. To identify cases, registry staff visit or electronically query hospitals and birthing facilities to identify infants diagnosed with at least one of the monitored conditions before the age of one year. For each case, medical records from surveilled facilities are abstracted. Records from facilities not associated with a hospital or birth facility (e.g., private medical practices, independent genetic testing laboratories) are not reviewed (Miller, 2006; Texas Department of State Health Services, 2023a). Cases are also linked to their vital records, which contain demographic information.

In the TBDR, birth defects are classified using the Centers for Disease Control and Prevention modification of the British Pediatric Association Classification of Diseases (CDC/BPA) codes. The record for each coded birth defect also includes a brief description of the condition. Further, each birth defect is classified as either a possible or a definite diagnosis. A birth defect diagnosis is classified as possible when there is only a prenatal diagnosis (other than chromosome analyses) and no postnatal confirmation or when the postnatal description indicates that the diagnosis is not definitive (e.g., medical records include words or phrases such as “may have”, “probable,” or “appearance of”). Choanal atresia/stenosis is also classified by laterality (unilateral, bilateral, unspecified) and, for unilateral defects, by affected side (left, right, unspecified).

Cases for this study were ascertained by TBDR staff during the 20 years from 1999 through 2018. This study period was selected because 1999 was the first year that the TBDR ascertained cases statewide, and 2018 was the last birth year for which data collection was complete when this study was initiated. This study provides an update to an earlier TBDR-based study of choanal atresia/stenosis that was based on only six years (1999–2004) of data (Case & Mitchell, 2011).

Within the TBDR, cases with choanal atresia and cases with choanal stenosis are assigned the same CDC/BPA code (748.000). The CDC/BPA code of 748.000 is also assigned to atresia of the nares and piriform aperture atresia/stenosis. Consequently, for this study, cases were defined as any TBDR case delivered 1999–2018, with a CDC/BPA code of 748.000 and a written birth defect description consistent with choanal atresia/stenosis (Appendix, Table 1). Cases classified as possible choanal atresia/stenosis and cases with atresia/stenosis of structures other than the choanae (i.e., nares or piriform aperture) were excluded from this study. Because the CDC/BPA codes do not differentiate between choanal atresia and choanal stenosis, all analyses are based on data from cases with either choanal atresia or choanal stenosis.

For our analyses, phenotypic data for cases (e.g. additional birth defects) were obtained from medical records abstracted by the TBDR staff. Pregnancy outcome (livebirth, fetal death, induced termination) for cases was obtained from medical records, or when missing, from vital records. All other data for cases were obtained only from vital records, to allow for valid comparisons with birth certificate data from all livebirths.

Statistical Methods

Using data from all livebirths in Texas, 1999–2018 as the denominator, the birth prevalence of definite choanal atresia/stenosis and its 95% confidence interval (CI) were calculated. Birth prevalence and CIs were also estimated for four mutually exclusive subgroups of choanal atresia/stenosis: Chromosomal, choanal atresia/stenosis with a definite or possible chromosomal anomaly; Syndromic, choanal atresia/stenosis with a definite or possible non-chromosomal syndrome or sequence; Multiple, choanal atresia/stenosis with at least one additional major birth defect; and, Isolated, only choanal atresia/stenosis. Details related to the classification of the Chromosomal and Syndromic subgroups are provided in Benjamin et al. (Benjamin et al., 2023).

To further characterize cases with choanal atresia/stenosis, the most frequent diagnoses in the Chromosomal and Syndromic subgroups were tabulated. In addition, cases in the Multiple subgroup were described, using counts and proportions, for the number and type of additional co-occurring CHARGE-related birth defects (e.g., coloboma). CHARGE-related birth defects were evaluated because CHARGE is the most common syndrome in cases with choanal atresia/stenosis (Case & Mitchell, 2011; Paradis et al., 2021a). Further, a diagnosis of CHARGE syndrome may be made after the TBDR ascertainment period of one year or may not be documented in the facilities reviewed by the TBDR staff (e.g., the TBDR does not review records from private medical practices). For this study, CHARGE-related birth defects were broadly defined (e.g., in addition to coloboma, “C” included anophthalmia and microphthalmia (Blake & Prasad, 2006)), and only birth defects categorized as definite were included. Further details of the criteria used to identify CHARGE-related birth defects are provided in Appendix Table 1.

Data for cases with isolated choanal atresia/stenosis were evaluated to assess potential trends in prevalence across the study period and to identify associated infant and maternal characteristics. All analyses used Texas livebirths in the dominator and the full Isolated subgroup in the numerator. To ensure comparability of the numerator and denominator data,

only data obtained from vital records were used in these analyses. Because bilateral choanal atresia/stenosis may be more completely ascertained than unilateral choanal atresia/stenosis, analyses were repeated using data only from cases with isolated, bilateral choanal atresia/stenosis in the numerator.

The Joinpoint Regression Program (v5.02) was used to estimate the annual percent change (APR) in the prevalence of isolated choanal atresia/stenosis per 10,000 livebirths during the study period. The 95% CI for the APR was also estimated. Models with 0, 1, 2, and 3 joinpoints (the default settings for these data) were compared using the weighted Bayesian information criterion. Results were interpreted using the criteria suggested in the Cancer Trends Progress Report, which include both the magnitude of change and statistical significance (National Cancer Institute, 2022). For example, an APC < −0.5 or APC > 0.5 that is not significantly different from zero is characterized as a non-significant change, whereas a statistically significant APC > 0 is characterized as increasing.

Characteristics of infants and their mothers were described, using counts and proportions, for all livebirths in Texas, as well as for the Isolated subgroup, and the subset of cases with isolated, bilateral choanal atresia/stenosis. Poisson regression was used to identify infant and maternal characteristics associated with isolated choanal atresia/stenosis. The regression analyses were restricted to include data from cases with mothers who were non-Hispanic White (NHW), non-Hispanic Black (NHB), or Hispanic because the number of cases with mothers from other races and ethnicities was small. Variables for which the 95% CI for the crude prevalence ratio (cPR) excluded one in the univariable analyses in either the full Isolated subgroup or the subset with isolated, bilateral defects were included in multivariable analyses for both groups. To protect subject confidentiality, variable categories with case counts <5 were either combined with another level (e.g., number of prior livebirths>1) or excluded from all analyses (e.g., underweight category of maternal body mass index). Descriptive statistics were generated and Poisson regression analyses were preformed using SAS (v9.4).

RESULTS

For the period 1999–2018, 706 cases with definite choanal atresia/stenosis were identified in the TBDR. All except five were liveborn. During the same period, there were 7,698,615 livebirths in Texas, yielding an overall prevalence of 0.92/10,000 livebirths (95% CI, 0.85, 0.99). Of the 706 cases, 85 (12%) were classified as Chromosomal, 174 (25%) as Syndromic, 161 (23%) as Multiple, and 286 (40%) as Isolated. The prevalence, per 10,000 livebirths, for each subgroup was: Chromosomal 0.11 (95% CI, 0.09, 0.14); Syndromic, 0.22 (95% CI, 0.19, 0.26); Multiple, 0.21 (95% CI, 0.18, 0.24); and, Isolated, 0.37 (95% CI, 0.33, 0.42).

The most common diagnoses in the Chromosomal subgroup were trisomy 21 (N=18), trisomy 18 (N=9), and trisomy 13 (N=6). In the Syndromic subgroup, the most common diagnoses were CHARGE (N=76) and acrocephalosyndactyly (N=20). In the Multiple subgroup (N=161), the majority of cases had at least one additional CHARGE-related birth defect: 82 (51%) of the cases in this subgroup had one, 32 (20%) had two, and 14 (7%)

had three or more CHARGE-related birth defects. The most frequent CHARGE-related birth defects were congenital heart defects (N=95, 59%), followed by ear anomalies/hearing loss (N=52, 32%), coloboma/other anomalies of the eye (N=24, 15%), and genital anomalies (N=13, 8%). The most frequent two-way combination of CHARGE-related birth defects was congenital heart defects with ear anomalies/hearing loss, which occurred in 34 (21%) cases in the Multiple subgroup.

Information on laterality and, for unilateral defects, the affected side was available for 565 (80%) of the cases of choanal atresia/stenosis (Table 1). Among all cases, there was a modest excess of bilateral defects (54%), and among cases with unilateral choanal atresia/stenosis, there was a modest excess of right-sided defects (54%). Across the subgroups, the proportion with bilateral defects ranged from 44% in the Isolated subgroup to 68% in the Syndromic subgroup. Among those with unilateral defects, the proportion with right-side choanal atresia/stenosis ranged from 48% in the Multiple subgroup to 65% in the Chromosomal subgroup.

Considering all 286 (285 livebirths, 1 fetal death) cases in the Isolated subgroup, the joinpoint model with zero joinpoints provided the best fit. Based on this model, there was a non-significant decrease in prevalence (APC=−1.2, 95% CI −4.0, 1.6) over the study period. Similar results were obtained when the analysis was repeated in the subset of cases with isolated, bilateral choanal atresia/stenosis (joinpoints=0, APC=−1.2, 95% CI −5.5, 3.3).

Infant and maternal characteristics for all livebirths in Texas, 1999–2018, as well as for all cases with isolated choanal atresia/stenosis and cases with isolated, bilateral choanal atresia/stenosis, are summarized in Table 2. In univariable Poisson regression analyses of data from the full Isolated subgroup, modest associations (crude prevalence ratios (cPR) ≥1.30 or cPR≤0.77) were observed for pregnancy plurality, maternal race/ethnicity, maternal age, and smoking during pregnancy (Table 3). However, only plurality and maternal race/ethnicity met the criterion for inclusion in the multivariable models: Choanal atresia/stenosis was more common in infants from multiple pregnancies than in singletons (cPR=2.26, 95% CI 1.42, 3.62), and less common in infants born to mothers who were Hispanic as compared to those born to mothers who were NHW (cPR=0.72, 95% CI 0.56, 0.93).

The variables that were modestly associated with choanal atresia/stenosis in the full Isolated subgroup were similarly associated in the subset of cases with bilateral choanal atresia/stenosis (Table 3). In this subset of cases, modest associations were also identified for infant sex, maternal education, maternal residence along the Texas-Mexico border, and maternal history of pregnancies not resulting in a livebirth. Infant sex, maternal race/ethnicity, maternal age, and maternal residence on the Texas-Mexico border met the criteria for inclusion in the multivariable models: Choanal atresia/stenosis was less common in infants of Hispanic as compared to NHW mothers (cPR=0.63, 95% CI 0.42, 0.94) and more common in female than male infants (cPR=1.63, 95% CI 1.10, 2.41), infants of mothers who were 25–29 years of age as compared to younger mothers (cPR=1.88, 95% CI 1.16, 3.06), and infants of mothers residing on the border as compared to those living in other regions of Texas (cPR=1.81, 95% CI 1.16, 3.06).

In general, adjusted prevalence ratios (aPR) from the multivariable models including plurality, infant sex, maternal race/ethnicity, maternal age, and maternal residence on the border, were similar to the estimates obtained in the univariable models (Table 3). Adjusted prevalence ratios from the analyses of isolated, bilateral choanal atresia tended to be higher than the corresponding estimates from the analyses of all cases with isolated choanal atresia (e.g., residence on border: isolated, bilateral aPR=2.67, all isolated aPR=1.50).

DISCUSSION

Over the 20 years from 1999–2018, the prevalence of choanal atresia/stenosis in Texas was 0.92/10,000 livebirths. This estimate is consistent with the prior estimate from the TBDR (0.91/10,000) (Case & Mitchell, 2011) and comparable to estimates from other population-based birth defects registries that ascertained cases up to one year of age (France: 0.78/10,000; California: 1.13/10,000) (Harris et al., 1997). However, this estimate is likely to underestimate the true prevalence of choanal atresia/stenosis because individuals with choanal atresia/stenosis who are diagnosed after one year of age would not have been ascertained by the TBDR.

Over a third of the cases with choanal atresia/stenosis in the TBDR were reported to have a chromosomal anomaly, syndrome, or sequence. An additional 22% of cases were reported to have co-occurring birth defects that might be due to undiagnosed syndromes. For example, 46 (29%) of the cases in the multiple subgroup had at least two additional features of CHARGE syndrome, which, under the clinical scoring system proposed by Verloes (Verloes, 2005), is consistent with a diagnosis of CHARGE (typical, partial or atypical CHARGE depending on the specific features). Despite differences in ascertainment methods, similar estimates were obtained for cases identified by pediatric otolaryngologists at tertiary care facilities (31% syndromic plus an additional 24% with associated defects) ((Paradis et al., 2021a), Table 2).

In this study, 40% of the cases with choanal atresia/stenosis had isolated defects. This estimate is relatively consistent with the proportion of isolated cases reported in smaller population-based birth cohorts (48%−52%) (Harris et al., 1997) and clinical series (53%) (Paradis et al., 2021a). The prevalence of isolated choanal atresia/stenosis in Texas during the study period was 0.37/10,000, which is similar to the previously reported estimate of 0.42/10,000 based on TBDR data from 1999 to 2004 (Case & Mitchell, 2011). The annual percent change (APR) in the prevalence of isolated choanal atresia/stenosis was negative but not significantly different from zero, suggesting either a minimal decrease or no change in the prevalence of isolated choanal atresia/stenosis over the study period.

Because cases with bilateral choanal atresia/stenosis are likely to be more completely ascertained by the TBDR than unilateral choanal atresia/stenosis, we assessed potential associations with maternal and infant characteristics in two analytic groups: (1) all cases in the Isolated subgroup, and (2) the subset of cases with isolated, bilateral, defects. In general, findings in the two groups were similar, although aPRs tended to be higher in the subset of cases with isolated, bilateral choanal atresia. For example, while cases were more likely to be female than male in both analytic groups, the association with sex was stronger in

the subset of cases with isolated, bilateral defects than in the full Isolated subgroup (aPRs 1.6 and 1.1, respectively). This pattern suggests that while the overall prevalence of isolated choanal atresia/stenosis may be similar in males and females, the phenotypic presentation may vary by sex, with affected females more likely than males to present with bilateral defects.

Results from prior studies have been mixed about sex differences in the prevalence of choanal atresia/stenosis (e.g. (Harris et al., 1997; Kancherla et al., 2014; Paradis et al., 2021a)). To some extent, this may reflect differences in study inclusion criteria (e.g., all cases versus non-syndromic cases). In the National Birth Defects Prevention Study (NBDPS), which excluded cases with choanal stenosis, 70% of cases with isolated choanal atresia were female (Kancherla et al., 2014), which is substantially higher than the proportion of females with either isolated choanal atresia or choanal stenosis (52%) in the TBDR. This could reflect sex-specific differences in phenotypic presentation (i.e., compared to affected males, females with choanal defects may be more likely to have choanal atresia). Thus, isolated choanal atresia/stenosis appears to be associated with infant sex. However, it is unclear whether females are more likely to be affected or whether affected females are more likely to have severe (e.g., bilateral versus unilateral, atresia versus stenosis) defects.

Although most aPRs were higher in the isolated, bilateral analytic group, the association with plurality was stronger in the full Isolated subgroup than in the subset of isolated cases with bilateral defects (aPRs 2.1 and 1.4, respectively) indicating that cases with unilateral defects largely drove the association observed in the full group. Although an association with plurality has not been formally assessed in other studies, in the NBDPS, the proportion of cases with isolated choanal atresia from multiple pregnancies was higher than the proportion of controls from multiple pregnancies (5% versus 3%) (Kancherla et al., 2014). In addition, considering all cases of choanal atresia/stenosis ascertained in three population-based registries, the twinning rate was slightly higher in cases (3%) than in the general population (2%) (Harris et al., 1997). There is no obvious biological explanation for why an association between plurality and choanal atresia/stenosis would be limited to, or markedly stronger for, unilateral than bilateral defects. However, a stronger association in cases with unilateral defects could be due to increased detection of mild defects in infants from multiple (as compared to singleton) pregnancies when at least one of the infants has a severe (i.e., ascertained) defect. We could not evaluate this possibility because our approved study protocol did not allow us to link records from twins or higher-order multiples.

In both analytic groups, there was some limited evidence for associations with maternal education, number of prior livebirths, number of prior non-livebirths, smoking during pregnancy, and maternal body mass index. Only smoking has previously been evaluated for association with isolated choanal atresia/stenosis. In the NBDPS, the association between isolated choanal atresia and smoke exposure (none versus active and/or passive, OR=1.4, 95% CI 0.8, 2.3) was similar to the associations observed in the TBDR. Given these findings and the known associations between smoking and other birth defects (Gould, Havard, Lim, The Psanz Smoking In Pregnancy Expert, & Kumar, 2020; Hackshaw, Rodeck, & Boniface, 2011), exposure to cigarette smoke should be considered a potential risk factor for isolated choanal atresia/stenosis.

Our study provides some evidence that isolated choanal atresia/stenosis may be associated with maternal age. The lowest prevalence was observed among infants of women under 25 years of age at delivery, but there was no clear pattern of increasing prevalence with increasing maternal age. While no obvious association with age was detected in other population-based cohorts (Harris et al., 1997), in the NBDPS, the proportion of mothers under the age of 25 years was lower for cases (20%) than controls (33%) (Kancherla et al., 2014). Collectively, these studies provide weak evidence that the prevalence of choanal atresia/stenosis is lower in the offspring of women under 25 years of age compared to older mothers.

In Texas, compared to the offspring of women who are NHW, isolated choanal atresia/stenosis was less common in the offspring of women who are NHB or Hispanic. Similar patterns were observed in the population-based birth cohort data from California (unadjusted ORs and 95% CI, NHB: 0.9, 0.5, 1.5; Hispanic: 0.9, 0.6, 1.2) (Harris et al., 1997) and in the NBDPS (compared to controls, cases were less likely to be NHB (12% versus 7%) or Hispanic (23% versus 10%) (Kancherla et al., 2014). Collectively, these studies support an association between choanal atresia/stenosis and maternal race and ethnicity.

Finally, our study provides evidence that the prevalence of isolated choanal atresia/stenosis varies by region, with higher prevalence in counties along the Texas-Mexico border compared to the non-border counties of Texas. This association was observed in adjusted analyses of both analytic groups and suggests that the risk of isolated choanal atresia/stenosis is influenced by factors, other than those included in our adjusted analyses, that differ between the border and non-border regions of Texas.

Factors that could contribute to the observed difference in prevalence of isolated choanal atresia/stenosis in the border and non-border regions of Texas include environmental exposures and individual-level risk factors, as well as social and structural determinants of health. Based on data from the TBDR, 1999–2008, county-level measures of maternal residential atrazine levels were associated with choanal atresia/stenosis (high versus low atrazine: adjusted OR=1.8, 95% CI 1.2, 2.7, trend p=0.002). However, since only 3 of the 32 border counties were in the high exposure category (see Figure in Agopian et al., 2013), atrazine exposure seems unlikely to explain the association with border region. As the prevalence of diabetes is higher on the border as compared to non-border regions of the United States (Diaz-Apodaca, Ebrahim, McCormack, de Cosio, & Ruiz-Holguin, 2010), maternal pre-gestational diabetes, which has been associated with choanal atresia (Tinker et al., 2020), might contribute to the differences across regions. Due to the small number of affected mothers of cases in our study population, we were unable to assess an association with diabetes in our study.

Data from the NBDPS also provide evidence that choanal atresia may be associated with characteristics of maternal diet (e.g., coffee consumption, specific nutrients) that might differ in the border and non-border regions of Texas. Other factors that might contribute to a higher prevalence of choanal atresia/stenosis in the border region include high rates of certain infectious diseases (e.g., tuberculosis, zika) as well as individual and ecological factors such

as poverty, lack of health insurance, and fewer years of formal education (Texas Department of State Health Services, 2023b).

Our results should be viewed in light of study limitations. In particular, some individuals with choanal atresia/stenosis will not be captured in the TBDR because they are diagnosed after one year of age or the condition is not documented in the records of the facilities that the TBDR surveils. Further, the likelihood that an individual with choanal atresia/stenosis is ascertained by TBDR staff may be related to severity, e.g., individuals with bilateral choanal atresia may be more likely to be included in the TBDR than individuals with unilateral choanal stenosis. Consequently, the observed associations may be impacted by selection bias that is differential with respect to defect severity. Because of this possibility, the analyses restricted to cases with isolated, bilateral choanal atresia/stenosis may more accurately portray (compared to analyses based on all cases with isolated defects) the epidemiology of this condition.

Our study also had several strengths. In particular, our analyses were based on a large population-based sample that, compared to prior studies, provided more precise estimates of prevalence and associations with infant and maternal characteristics. Considered in concert with results from other studies, our results indicate that isolated choanal/atresia is associated with infant sex and plurality, as well as with maternal smoking during pregnancy, age, race/ethnicity, and residence on the Texas-Mexico border. These findings provide direction for future studies. In particular, the observed association with maternal residence provides the rationale for studies focusing on potential environmental and social/structural risk factors that differ in prevalence in the border and non-border regions of Texas.

Funding information

This project was supported in part by funding from the Eunice Kennedy Shriver National Institute of Child Health and Human Development (1R01HD093660-01A1), the Centers for Disease Control and Prevention (CDC), as part of a birth defects surveillance cooperative agreement with the Texas Department of State Health Services (TX DSHS) (NU50DD000102) and by the Health Resources and Services Administration (HRSA). The contents are those of the authors and do not necessarily represent the official views of the CDC, TX DSHS, or HRSA.

Data availability statement

Due to data confidentiality governed by existing data use agreements, these data cannot be shared. Data from the Texas Birth Defects Registry may be requested by submitting a data use application to the Texas Department of State Health Services.

Appendix –

Table 1.

Criteria used to define CHARGE-related birth defects.

Category	BPA code†	Phenotypes	Description includes:‡
Coloboma and other ophthalmic features			
	743.0	Anophthalmos	-
	743.1	Microphthalmos	-

Category	BPA code†	Phenotypes	Description includes:‡
	743.340	Coloboma of lens	-
	743.430	Coloboma of iris	-
	743.490	Unspecified colobomas and anomalies of anterior eye segments; Coloboma not otherwise specified	'colobom' or 'colomb' or 'colbom' or 'microcolobom'
	743.520	Specified anomalies of optic disc; Hypoplastic optic nerve; Coloboma of optic disc; Optic nerve atrophy	'colobom' or 'colomb' or 'colbom' or 'microcolobom'
	743.535	Coloboma of choroid; Coloboma of retina	-
	743.480	Other specified colobomas and anomalies of anterior segments; Rieger's anomaly	'colobom' or 'colomb' or 'colbom' or 'microcolobom'
Heart			
	745 – 747.43	Any congenital heart defect within the specified BPA range	-
Atresia choanae and cleft lip/palate			
	748.0	Choanal atresia	'choan' or 'chaon' or 'chonal'
	749.0	Cleft palate alone	-
	749.1	Cleft lip alone	-
	749.2	Cleft lip with cleft palate	-
Genital			
Male	752.500	Undescended testicle, unilateral	-
	752.514	Undescended testicle, bilateral	-
	752.520	Undescended testicle, not otherwise specified	-
	752.685	Small penis, hypoplastic penis or micropenis	-
Female	752.440	Absence or other anomaly of vulva; Fusion of vulva, Hypoplastic labia majora; Large labia, Prominent labia, Absent external female genitalia	'hypopla' or 'small'
Ear and hearing			
	744.0	Anomalies of ear causing impairment of hearing	-
	744.2	Other specified anomalies of ear	-
	744.3	Unspecified anomalies of ear	-
Tracheo-esophageal			
	750.3	Tracheoesophageal fistula, esophageal atresia and stenosis	-
	750.4	Other specified anomalies of the esophagus	-

†The most specific BPA code category (i.e. 3-, 4-, 5- or 6-digit code) used to define a phenotype is provided: All sub-categories falling under that code are included.

‡In some instances, the most specific (i.e. 6-digit) BPA code includes more than one condition only some of which are features of CHARGE. For such codes, the 6-digit BPA and keywords or portions of keywords from the written birth defect description provided in the TBDR were used to define the CHARGE-related phenotype.

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Table 1.

Defect laterality and sidedness in cases with definite choanal atresia/stenosis, Texas, 1999–2018.

Laterality	n (%)				
	All cases	Chromosomal	Syndromic	Multiple	Isolated
Bilateral	304 (53.8)	40 (56.3)	89 (68.5)	70 (54.7)	105 (44.5)
Unilateral	261 (46.2)	31 (43.7)	41 (31.5)	58 (45.3)	131 (55.5)
Left	120 (46.0)	11 (35.5)	16 (39.0)	30 (51.7)	63 (48.1)
Right	141 (54.0)	20 (64.5)	25 (61.0)	28 (48.3)	68 (51.9)

Table 2:

Infant and maternal characteristics of livebirths and cases with definite, isolated choanal atresia/stenosis, Texas, 1999–2018.

Characteristic	Level	Livebirths n† (%)	All Isolated n† (%)	Bilateral n† (%)
Total		7,698,150	286‡	105
Infant sex	Male	39,343,52 (51.1)	136 (47.7)	41 (39.0)
	Female	37,642,63 (48.9)	149 (52.3)	64 (61.0)
Birth year	1999–2003	1,827,317 (23.7)	83 (29.0)	31 (29.5)
	2004–2008	1,978,982 (25.7)	65 (22.7)	19 (18.1)
	2009–2013	1,934,167 (25.1)	70 (24.5)	29 (27.6)
	2014–2018	1,958,149 (25.4)	68 (23.8)	26 (24.8)
Plurality	Singleton	7,462,975 (96.9)	264 (92.6)	100 (95.2)
	Multiple	235,343 (3.1)	21 (7.4)	5 (4.8)
Maternal race and ethnicity	NHW	2,709,495 (35.2)	119 (41.9)	50 (47.6)
	NHB	878,842 (11.4)	35 (12.3)	12 (11.4)
	Hispanic	3,711,074 (48.3)	118 (41.6)	43 (41.0)
	Other	390,102 (5.1)	12 (4.2)	0 (0.0)
Maternal age (years)	<25	2,945,182 (38.3)	94 (33.0)	29 (27.6)
	25–29	2,119,376 (27.5)	86 (30.2)	38 (36.2)
	30–34	1,685,026 (21.9)	66 (23.2)	22 (21.0)
	≥35	948,430 (12.3)	39 (13.7)	16 (15.2)
Maternal education	> High school	3,484, (45.5)	116 (43.3)	51 (49.0)
	High school	2,157,397 (28.2)	76 (28.4)	28 (26.9)
	< High school	2,011,663 (26.3)	76 (28.4)	25 (24.0)
Residence on border	No	6,756,102 (87.8)	243 (85.3)	83 (79.0)
	Yes	942,512 (12.2)	42 (14.7)	22 (21.0)
Prior livebirths	0	2,915,213 (38.3)	110 (39.2)	42 (40.4)
	≥ 1	4,689,755 (62.7)	171 (60.8)	62 (59.6)
Prior pregnancies not resulting in livebirths	0	6,050,457 (79.2)	220 (77.2)	76 (72.4)
	≥1	1,586,197 (20.8)	65 (22.8)	29(27.6)
Smoking during pregnancy	Yes	384,681 (5.0)	20 (7.0)	7 (6.7)
	No	7,294,324 (95.0)	265 (93.0)	98 (93.3)

Characteristic	Level	Livebirths n† (%)	All Isolated n† (%)	Bilateral n† (%)
Maternal body mass index§ (kg/m^2)	Normal (18.5–24.9)	2,547,332 (48.7)	88 (48.6)	32 (46.4)
	Overweight (25.0–29.9)	1,391,251 (26.6)	50 (27.6)	19 (27.5)
	Obese (≥ 30.0)	1,292,161 (24.7)	43 (23.8)	18 (26.1)

Abbreviations: NHW, non-Hispanic White; NHB, non-Hispanic Black

†Counts (n) may not sum to the total due to missing data.

‡285 liveborn, 1 fetal death

§Fields for maternal height and weight were added to the Texas birth certificates in 2005. Consequently, information on body mass index is only available for births from 2005–2018. The underweight category was omitted from the table due to small cell counts

Table 3.

Crude and adjusted prevalence ratios between select infant and maternal characteristics and isolated choanal atresia/stenosis, Texas, 1999–2018.

Characteristic	Level	Prevalence Ratios (95% confidence intervals)			
		All Isolated		Isolated, Bilateral	
		Crude	Adjusted[†]	Crude	Adjusted[†]
Infant sex	Male	Reference	Reference	Reference	Reference
	Female	1.11 (0.87, 1.41)	1.11 (0.90, 1.35)	1.63 (1.10, 2.41)	1.63 (1.14, 2.33)
Plurality	Singleton	Reference	Reference	Reference	Reference
	Multiple	2.26 (1.42, 3.64)	2.13 (1.42, 3.21)	1.59 (0.65, 3.91)	1.43 (0.63, 3.26)
Maternal race and ethnicity[‡]	NHW	Reference	Reference	Reference	Reference
	NHB	0.91 (0.62, 1.32)	0.93 (0.68, 1.29)	0.74 (0.39, 1.39)	0.80 (0.45, 1.42)
	Hispanic	0.72 (0.56, 0.93)	0.68 (0.54, 0.86)	0.63 (0.42, 0.94)	0.49 (0.32, 0.75)
Maternal age (years)	<25	Reference	Reference	Reference	Reference
	25, 29	1.33 (0.99, 1.78)	1.28 (1.00, 1.65)	1.88 (1.16, 3.06)	1.80 (1.16, 2.81)
	30, 34	1.20 (0.86, 1.66)	1.13 (0.85, 1.49)	1.42 (0.81, 2.47)	1.32 (0.79, 2.20)
	≥35	1.30 (0.89, 1.92)	1.22 (0.87, 1.69)	1.84 (1.00, 3.39)	1.72 (0.98, 3.01)
Maternal education	> High school	Reference		Reference	
	High school	1.06 (0.79, 1.42)		0.89 (0.56, 1.41)	
	< High school	1.00 (0.75, 1.34)		0.75 (0.46, 1.21)	
Residence on border	No	Reference	Reference	Reference	Reference
	Yes	1.21 (0.87, 1.69)	1.50 (1.10, 2.04)	1.81 (1.13, 2.89)	2.67 (1.63, 4.36)
Prior livebirths	0	Reference		Reference	
	≥1	0.96 (0.75, 1.23)		0.90 (0.61, 1.34)	
Prior pregnancies not resulting in livebirths	0	Reference		Reference	
	≥1	1.12 (0.84, 1.49)		1.45 (0.94, 2.22)	
Smoking during pregnancy	No	Reference		Reference	
	Yes	1.37 (0.86, 2.19)		1.31 (0.61, 2.81)	
Maternal body mass index[§] (kg/m^2)	Normal (18.5, 24.9)	Reference		Reference	
	Overweight (25.0, 29.9)	1.05 (0.74, 1.50)		1.06 (0.60, 1.86)	
	Obese (≥ 30.0)	0.97 (0.67, 1.41)		1.05 (0.59, 1.88)	

Abbreviations: NHW, non-Hispanic White; NHB, non-Hispanic Black

† Adjusted for infant sex, plurality, maternal race and ethnicity, maternal age and maternal residence on Texas-Mexico border

‡ The "other" category of maternal race/ethnicity was omitted from these analyses due to small cell counts.

§ Fields for maternal height and weight were added to the Texas birth certificates in 2005. Consequently, information on body mass index is only available for births from 2005–2018. The underweight category of body mass index was omitted from these analyses due to small cell counts.