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Environmental Insults and Congenital Heart Defects

Abstract

Congenital heart defects are the leading cause of defect-associated infant mortality. They severely affect the structure and function of the heart, and complications can be lifelong. While it is known that the development of congenital heart defects is largely genetic, an epigenetic component is more prevalent in recent studies. Studies have shown that maternal exposure to environmental insults can influence congenital heart defect outcomes in infants, however, there is limited standardized data on these potential risk factors or triggers from the environment. Through thorough investigation of research papers and informative articles, this review reveals that maternal exposure to tobacco smoke, air pollution, and water contamination have the most direct links to the development of congenital heart defects. Each risk factor has a correlation with a specific type of congenital heart defect, all of which are expounded upon.

Introduction

Congenital heart defects are the most common birth defect, affecting 1% of births per year in the United States, or approximately 40,000 newborns (CDC 2020). Congenital heart defects (CHD) are the leading cause of defect-associated infant illness and death. 1 in 4 infants with CHD has a critical defect that requires surgery in their first year of life (CDC 2020). Maternal risk factors include genetics, maternal diabetes, rubella, certain medications (such as those with lithium or isotretinoin), and smoking. Complications associated with CHD include irregular heartbeat (called arrhythmia), heart infection (endocarditis), stroke, pulmonary hypertension, and heart failure (Mayo Clinic Staff 2021). Many of these can begin in childhood and pose a great risk if not treated properly. Although CHD are largely genetic and common in the United States among newborn infants, not much is known about potential risk factors or triggers from the environment. Therefore, this review will expound on maternal environmental risk factors for CHD.

Congenital Heart Defects

Congenital heart defects are birth defects that change the structure and functionality of an infant's heart. In a normal heart, blood is rotated throughout the body, heart, and lungs to

circulate oxygen. Chambers of the heart pump the blood, the valves allow blood through and prevent leakage, and the vessels provide the pathway. CHD can affect any one of these essential parts and disrupt the normal flow of blood to alter a person's cardiovascular anatomy. Some forms of CHD have little effect on infants while others are life-threatening.

The types of CHD range from mild to severe and are differentiated by the parts of the heart they affect. Defects can affect the valves, upper chambers of the heart (atria), lower chambers of the heart (ventricles), walls of the heart, or blood vessels. A common CHD is ventricular septal defect (VSD), which is defined by a hole in the interventricular septum, or the wall between the ventricles. This allows oxygenated blood to mix with deoxygenated blood. When this occurs, the heart inadvertently pumps mixed blood around the body (AHA Staff 2020). Deoxygenated blood is extremely detrimental because it causes hypoxia, which interferes with heart and brain function (AHA Staff 2020). Valve-related defects include pulmonary valve stenosis, in which the pulmonary valve does not open and close properly (AHA Staff 2020). This valve takes blood to the lungs to be oxygenated. Therefore, this CHD interferes with human function through preventing oxygen delivery. Another severe CHD is tetralogy of Fallot (TOF). It consists of four CHDs working in tandem: VSD, pulmonary valve stenosis, ventricular hypertrophy, and an aortic valve defect. Ventricular hypertrophy refers to the thickening of the wall of the right ventricle. The defect in the aortic valve manifests as swelling. The aortic valve ensures that blood flows in the correct direction (CDC 2020). TOF most often requires surgery shortly after birth, as it can result in infection, hypoxic seizures, and delayed development. Although there are numerous other types of CHDs, these are the most common.

Every patient with CHD has different effects, however, some long-term complications are more common than others. CHD patients can suffer from poor circulation and fatigue (Children's Health 2021). They are also more susceptible to respiratory diseases (such as pneumonia and COVID-19). Arrhythmias, or abnormal heart rhythms, can develop throughout one's lifetime and may require extra treatment. As previously stated, complications with CHD can expand well into adulthood. Thus, it is essential to have a greater understanding of potential environmental risk factors of CHDs during maternity to employ preventative measures.

Maternal Environmental Risk Factors and All Birth Defects

It is widely known that certain substances, like alcohol, should be avoided during pregnancy. Pregnancy is a critical time of development which causes a woman's body to be extremely sensitive to environmental insults. Every part of the infant forms at specific stages, thus exposure to harmful substances can affect proper development (MotherToBaby 2019).

Most birth defects are thought to be caused by a combination of genetic and environmental factors. There are limited standardized data on birth defects, which has impeded progress towards understanding the cause of CHD (Weinhold 2009). However, as research has improved over the years, it is estimated that environmental contaminants cause about 10% of all birth defects (Landon 2020). For example, pregnant women are cautioned against eating fish because they contain mercury and polychlorinated biphenyl (PCBs), which are chemicals that Dengcan increase the likelihood of infants developing chronic brain damage, decreased cognitive abilities, and lower intelligence (Landon 2020). In addition, pesticide exposure disrupts the endocrine system—the messenger system which uses hormones to regulate organs—and increases the risk of birth defects. Carbon monoxide (found in cigarette smoke and automobile exhausts) and other air pollutants increase the risk of low birth weight and premature delivery. Furthermore, exposure to air pollution increases the likelihood of developing autism (Samuels 2021). Maternal alcohol use interferes with the infant's development of critical organs and systems. The most common consequences are brain damage and its lifelong effects on the infant (NIAAA 2021).

These various environmental risk factors during maternity are well characterized for inducing complications such as neurological damage, autism, premature delivery, and disruptions to the endocrine system. However, the interplay between environmental insults and CHD is not well understood. This review explores the link between air pollution, tobacco usage, water contamination, and alcohol consumption to CHD.

Maternal Environmental Risk Factors and Congenital Heart Defects

One environmental risk factor for CHD is air pollution. A study conducted in China found a link between air pollution and the risk of developing CHD. This study observed that maternal exposure to air pollutants posed the greatest risk during the first trimester of pregnancy (Yang et al. 2021). Certain air pollutants increased the risk of acquiring distinct types of CHD. For example, exposure to ozone increased the risk of developing ventricular septal defect (VSD)

and tetralogy of Fallot (TOF), with the risk increasing during each consecutive month in the first trimester (Zhang et al. 2016).

Maternal exposure to tobacco smoke has been highly correlated with the risk of developing CHD. It has been found that the periconceptional period is the time when the infant is most susceptible to developing CHD due to tobacco exposure (Forest and Priest 2016). The periconceptional period is defined as three months before pregnancy and the first trimester. Paternal smoking during this period also increases the risk of CHD due to proximity and the effect of secondhand smoke. Paternal smoking has been linked to conotruncal defects, septal defects, and ventricular outflow tract obstructions (Deng et al. 2013). Conotruncal cardiac defects are outflow defects that include TOF among others (GARD 2015). Maternal smoking during the periconceptional period often contributes to the development of nonsyndromic atrioventricular septal defect, or AVSD (Patel et al. 2012). This is a defect in which the valves between the right and left side of the heart are not formed correctly and cannot control the flow of blood (CDC 2020). This is a very serious defect which has been closely related to maternal smoking during the periconceptional period; 26% of mothers of AVSD cases report smoking (Patel et al. 2012).

Another environmental insult associated with CHD is water contamination. In 1973, a study found that one-third of patients with CHD had lived in an area of Tucson Valley that had groundwater contaminated with trichloroethylene (Goldberg et al. 1990). This is a chemical that contains chlorine and is dangerous to humans. This chemical was banned in the United States in 1977. Water contamination increased the chance of developing CHD by 17%, with 58% chance of ventricular septal defect (Nicoll 2018). Though research in this area is still developing, this association has been made and verified.

Finally, a small correlation has been found between maternal alcohol consumption and CHD. A 2019 study found that 1 in 9 pregnant women still consume alcohol (CDC 2021). Furthermore, about one third of pregnant women who drink alcohol participate in binge drinking, or having four or more drinks on one occasion (CDC 2021). A study conducted in mice in 1984 found a possible association between alcohol and CHD (Webster et al. 1984). Research since then has indicated that alcohol caused a small increase in risk for developing TOF during the periconceptional period, but no other CHD (Zhu et al. 2015).

Conclusion

In this review paper, I illustrate that CHD is a very common and often serious birth defect. 40,000 newborns are afflicted with CHD every year, and 25% have a critical defect that requires surgery. The complications are lifelong, yet not much is known about their environmental causes. Maternity is a sensitive time period in which environmental insults have a serious impact on the health of the infant. This review highlights the connections between numerous environmental insults during pregnancy and the risk of acquiring specific types of CHD. Air pollution is known to cause VSD and TOF. Tobacco smoke is associated with conotruncal cardiac defects and AVSD. The final two links I explored were water contamination to VSD and alcohol consumption to TOF.

This review underscores the correlation between environmental insults and CHD with the notion of providing a guide for common substances to avoid during pregnancy. Information about environmental causes of CHD is limited and outdated. Thus, with newer technologies, more research can be done to discover the causes of CHD, both environmental and genetic. The ultimate goal is to galvanize further discussion around this important issue and implement pertinent solutions.

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