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Presence of Rib Notching as an Indicator of Hypertension and its Sequelae in Cardiovascular Diseases in an Historic African American Skeletal Population

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Abstract

Background: Cardiovascular disease (CVD) is the leading cause of death in the United States and around the world. A plethora of scientific findings identify African Americans as having the highest rates of CVD in comparison to other racial/ethnic groups in the United Sates. Associated with a wide range of congenital and chronic cardiac disorders, rib notching is a pathognomonic diagnostic marker used in today's medical practice. Unfortunately, rib notching has not been studied in human skeletal collections, particularly in a collection of historic African Americans.

Objective: This study presents a unique opportunity to evaluate rib notching in the Cobb Collection, a well-known collection of 987 de-fleshed human cadavers donated for research purposes between 1932 and 1969 to Howard University.

The historical context of this collection combined with our preliminary analysis of the clinical and demographic records on these individuals indicates a stress-intensive lifestyle for many that imposed significant CVD risk factors.

Methods: A sample of 219 CC individuals (CCIs) were selected from our digitized records and examined for evidence of notching of their ribs. Due to incomplete and broken ribs in the collection, ribs were assembled according to size with the smallest ribs in an individual given a designation of '1'. Those individuals who clearly had rib notching were photographed and examined to determine the number of rib notches, if the notches were bilateral or unilateral, as well as the location of the rib notches. Careful attention was made to ensure that man-made notches were not included in the data.

Results: From the 53 individuals that were identified as having rib notching, 44 of them were due to cardiovascular ailments while the others were due to pathologies that could potentially lead to hypertension if left untreated. Males were more likely to have rib notching when compared to their female counterparts.

Conclusion: From the results of this study, a strong link is observed between CVD and rib notching. This makes rib notching assessment a useful diagnostic tool for historical skeletal samples or for confirming previous diagnoses of CVD. This study also provides a major improvement to our understanding of CVD in historical African American populations. The historical context of diseases now rampant in the African American community can inform clinicians in their efforts to develop precision interventions designed to treat CVD in this vulnerable population.

Keywords

Cobb Collection; Historic health disparities; Minority health; Hypertension; Cardiovascular disease; Washington D.C.; Skeletal collection

Abbreviations

CVD= Cardiovascular disease; CVDs= Cardiovascular diseases; CC= Cobb Collection; CCIs= Cobb Collection individuals; CRL= Cobb Research Laboratory; TOF= Tetralogy of Fallot; SVC= Superior vena cava obstruction; CITI= Collaborative Institutional Training Initiative; ICD= International Classification of Diseases

Introduction

CVD and health disparities in African Americans

Cardiovascular diseases encompass pathologies of the heart and blood vessels. CVD accounts for 50% of non-communicable disease deaths in the world and causes more deaths than cancer and lung diseases combined in the United States. (WHO, 2017) Many CVDs are related to atherosclerosis, the buildup of plaque on arterial walls, which can lead to myocardial ischemia which reduces blood and oxygen supply to the myocardium resulting in cerebrovascular accident [1]. Left unchecked, myocardial ischemia can lead to myocardial infarction (myocardial tissue necrosis) and congestive heart failure which are associated with significant morbidity and mortality. Data from the National Vital Statistics System (CDC, 2017) shows that the avoidable death rate is nearly twice that in African Americans compared to European Americans [1]. A major health disparity and leading cause of CVDs in African Americans is low cardiorespiratory fitness, which has been linked to a sedentary lifestyle by the American Heart

Association [2]. Dating back to the early 1900s, cardiovascular diseases such as myocardial infarctions were hard to diagnose. It was not until the 1920s and 1930s that physicians began to acquire the tools necessary to study these disease *in vivo* in patients with heart ailments. In the 1920s a set of three techniques emerged as the primary tool for diagnosis. The "Master Two Step" involved monitoring patients' hearts as they performed various exercises. The anoxemic test required the patient to inhale oxygen-depleted air until he/she developed cardiac ischemia while the electrostatic ballistogram recorded the body's motions produced by heartbeats [3]. These indirect methods were used to detect cardiac occlusion up until the 1950s [4].

Post-World War II, there was a boom in medical research in the United States due to increased government funding. Before this time, the methods for diagnosing and treating heart diseases were limited to assessing patient medical histories, chest x-rays, electrocardiograms, and minor surgeries to mediate aliments related to cardiac pathology. Although limited, these methods, especially assessing patient histories, provided important information with regard to clinical findings. With the use of through patient examinations and medical histories, physicians were able to identify other factors, such as hypertension, that were linked to CVDs. Furthermore, patient care was centered on a deep understanding of the patient's background and persisting habits over extended periods of time [5]. With the advent of the Framingham Heart Study, a cohort of medical histories collected from a population of about 4,000 men and women, it was confirmed that hypertension, hypercholesterolemia, and tobacco use were important contributing factors to CVDs. The Framingham Heart Study allowed physicians to better identify patients who could benefit from preventative measures to combat CVD [6].

The Cobb Collection

The Cobb Collection (CC), a major skeletal and dental collection of the Cobb Research Laboratory (CRL), contains 19th and 20th century human anatomical materials, clinical, and demographic records. This collection was started by and named after Dr. William Montague Cobb, professor and chair of anatomy at Howard University and the first African American to earn a Ph.D. in biological anthropology. The Cobb Collection database contains autopsy reports completed by Dr. Cobb, death certificates, and other revealing demographic information about the patients. Unlike many other forensic laboratories, the research conducted on the Cobb Collection individuals emphasizes gaining more insights into the lives of African Americans and looking into the impact of race/ethnicity has had on the health of an individual. The research on the Cobb Collection has contributed to dispelling preconceived biases about African Americans as being physically and/or mentally inferior in comparison to other groups and has allowed for the emergence of an authentic, comprehensive consideration of the historical context of African American health [7].

Rib notching

Rib notching refers to the deformation of the superior or inferior surface of the rib. Vascular structures undergo alterations to compensate for certain changes in the body such as extreme blood pressure levels, blockage of blood flow. And even imbalanced hormone levels. This vasculature may lengthen or thicken in response to high pressure, which may apply enough pressure and force to change the structures around them. Rib notching; therefore, can either be caused by vascular or nonvascular

alterations. Vascular rib notching is due to enlarged intercostal vasculature which puts greater pressure onto the neighboring ribs and, consequently, leads to bony erosion. Non-vascular rib notching is caused by neurogenic conditions such as neuromas and neurofibromatosis or irregular cortical thickening due to diseases such as hyperparathyroidism [8]. Rib notching can also be classified based on location. Inferior rib notching can have etiologies ranging from arterial, venous, neurogenic, and osseous causes. Superior rib notching, similarly, has osseous, autoimmune, and genetic etiologies [9].

Rib notching is usually discovered via chest x-ray *in vivo* and was originally used only in the diagnosis of pathognomonic of coarctation of the aorta or constriction of the aortic arch. It wasn't until 33 years after the discovery of x-rays, in 1928, that rib notching began to be associated with multiple vascular conditions and not just aortic coarctation. The proposed classifications for the causes of rib notching include arterial, venous, arteriovenous, and neural (associated with neurofibromatosis).

Various diseases that cause rib notching

The rib cage encloses various vital organs that encompass the respiratory system. Rib notching may be caused by disruption to blood flow within any of these organs resulting in the offset in pressures within these systems [10].

Pulmonic stenosis occurs when there is a malfunction near or on the pulmonary valve, which leads to the obstruction and slowing of blood flow from the right ventricle to the pulmonary arteries that feed the lungs. This obstruction causes the pulmonary valve leaflets to thicken and fuse together, forcing the right ventricle to work harder to compensate for the loss of efficiency. This thickening of the valves is what leads to rib notching [11].

Coarctation of the aorta is the narrowing of the aorta, most commonly distal to the left subclavian artery, increasing upper body arterial pressure and thus causing upper extremity hypertension [12]. Chronic increases in upper extremity blood pressure results in the enlargement of the anastomosing costal arteries and thus notching of the inferior border of the ribs. Diagnosis of coarctation of the aorta can be made by a plain chest x-ray [13,14].

Primary aortic thrombosis is a rare lesion consisting of the thrombosis of an artery without an apparent underlying cause. This pathology has been sighted in arteries of upper and lower extremities, but there are few reported cases that indicate involvement of the aorta [15].

Pulmonary-oligemia/AV malformation is a rare and mostly congenital cardiovascular pathology that is commonly associated with hereditary hemorrhagic telangiectasia. It can be seen as a filling defect in the lungs where vasculature is significantly diminished due to a collapsed vessel [16].

Teralogy of Fallot (TOF) is a congenital cardiac malformation that consists of overriding aorta, ventricular septal defect, right ventricular hypertrophy, and pulmonary stenosis. It causes cyanosis in newborns. TOF presents in 3 per 10,000 newborns with a 3% genetic recurrence rate. It is associated with trisomy disorders such as trisomy 13, 18, and 21. Patients may later develop chronic complications such as arrhythmias and pulmonary regurgitation [17]. Unilateral rib notching has been observed in TOF [18].

Absent pulmonary artery is a rare condition that occurs in one out of every 200,000 people and usually occurs with congenital cardiac malformations such as TOF or septal defects. The disease is commonly

diagnosed around 14 years of age, but asymptomatic cases are incidentally observed during adulthood by abnormal chest x-rays. Patients can present with nonspecific pulmonary symptoms such as dyspenea, chest pain, or recurrent infections [19].

Pulmonary stenosis is a malformation near or of the pulmonary valve, leading to right ventricular hypertrophy due to compensation. 95% of these cases are congenital and may be associated with congenital cardiac defects such as TOF and Marfan's syndrome [11].

Arteriovenous malformations on the chest wall are extremely rare abnormal connections of arteriovenous structures in the chest. They are usually asymptomatic, but can present with fatal hemorrhage and pain. Treatment varies depending upon location and symptoms [20]. Unilateral rib notching has been reported in spinal cord arteriovenous malformation [21].

Intercostal neuroma is a benign tumor of the nerve that supplies the ribs. This can be caused by surgeries around the chest, such as breast procedures and cholecystectomies [22].

Superior vena cava obstruction (SVC) is caused by the compression of the superior vena cava by a mass, commonly by neoplasms of the lung and mediastinum [23]. The obstruction of the SVC leads to dyspnea, dysphagia, feelings of fullness in the head, upper and lower extremity edema, and prominent venous pattern (Figure 1-4).

Figure 1: CC456 with Rib Notching present.

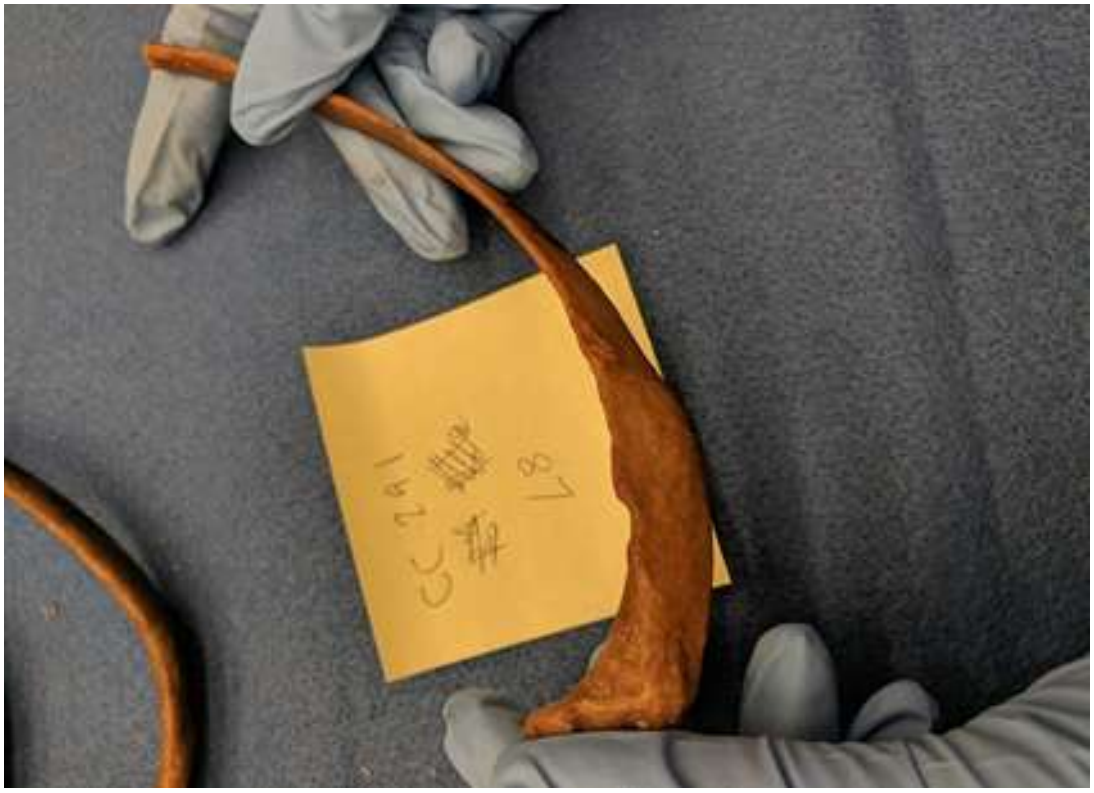

Figure 2: CC291 With Rib Notching present.

Figure 3: Control without Notching Present.

Figure 4: Example of CC239 ribs arranged by increasing size.

Research Hypothesis

Our working hypothesis is that rib notching can be used as a marker for the presence of circulatory diseases, specifically the sequelae of hypertension, in the examination of human skeletal remains. Therefore, the discovery of these cardiovascular pathologies can aid in the reconstruction of the historical records of CVD health and thus provide insights into the duration and intensity of this health disparity.

Materials and Methods

Equipped with Howard University Institutional Review Board exemption for studying historical skeletal and dental remains, CITI-certified researchers evaluated the 987 clinical records of the Cobb Collection to identify individuals who died from cardiovascular-involved diseases based on the ICD-10 classification of "Diseases of the Circulatory System." Archival records of the definitions and interpretations of the specific cardiovascular pathologies observed in the Cobb Collection at the time of diagnoses were also sought, having obtained the ICDs for the relevant periods (WHO, 1990). Both historical and

contemporary ICD codes were used in order to create a cohort of 219 CCIs.

For each individual studied, ribs were assembled according to size. Due to incomplete and broken rib collections of certain individuals, the exact anatomical locations of ribs were not analyzed. Instead, ribs were ranked from smallest to largest ribs within each individual, with the smallest rib given the designation of "1" and then subsequently numbered consecutively. Each individual was examined to determine whether the rib notches were unilateral or bilateral, the total number of notches, and the location of the notches. If an individual was reported to have signs of rib notching, ribs were arranged as a whole to be photographed, in addition to each individual rib. Ribs with clearly evident non-natural edges and/or man-made notches were not included in the sampling. Breaks, scrapes, shatters, and cuts to ribs were also noted.

Results and Discussion

Of the 219 individuals surveyed for evidence of rib notching, 53 of these individuals were identified to have bilateral or unilateral rib notching. The 53 rib-notched individuals were then studied further. It was recognized that there were a total of 38 men that presenting with rib notching and 15 women, suggesting that men tend to be more susceptible to developing rib notching than their female counterparts. The average age of the skeletal population that experienced rib notching was 65.06 years, while the average age of the 219 individuals' surveyed was 62.83 years. All of the men studied and many of the women had worked physically intensive labor demanding jobs prior to their deaths.

Along with these results, it was also observed that 44 of the rib notching cases were correlated with cardiovascular ailments, while the majority of the remaining cases were due to pathologies that could potentially lead to hypertension, if left untreated for a prolonged period of time (Table 1). There were two cases, carcinoma of the uterus in a 66 year old female and pulmonary tuberculosis in a 34 year old male who cases of death had no direct relationship with cardiovascular or other vascular diseases.

Cause of Death	Frequency 1931-1969	Ages of Individuals	Male: Female	Years of Deaths	Race/Ethnicity of Individual
Carcinoma of uterus	1	66	0:1	1931	Not known
Pulmonary tuberculosis	1	34	1:0	1943	Not known
Hypertension	3	35, 70, 87	3:0	1935, 1946	African Americans
Cerebral hemorrhage	4	58, 70,73, 90	2:2	1947, 1948, 1949, 1950	African Americans
Congestive heart failure	11	38, 45, 48, 55, 67, 68, 74, 75, 77, 86, 95	9:2	1942, 1945, 1948, 1952, 1953, 1957, 1958	10 African Americans 1 European Americans
Chronic myocarditis	2	52, 87	2:0	1932, 1944	African Americans
CVA	5	52, 65, 70, 72,	4:1	1942, 1947,	African Americans

		83		1951, 1951, 1955	
Coronary failure	1	62	1:0	1952	African American
Arteriosclerosis	7	49, 70, 71, 76, 80, 82, 86	5:2	1933, 1934, 1945, 1953, 1954	African Americans
Cardiac hypertrophy	1	79	0:1	1933	African American
Hypertensive encephalopathy	1	77	1:0	1947	African American
Aortic aneurysm	1	45	1:0	1954	African American
Myocardial infarction	3	37, 62, 78	2:1	1934, 1956, 1958	2 African Americans 1 European American
Acute cardiac dilation	1	49	0:1	1933	African American
Cardiovascular disease	1	67	1:0	1957	African American
Chronic myocarditis	5	38, 40, 60, 65, 80	4:1	1942, 1944, 1945	4 African Americans 1 Not known
Coronary occlusion	3	45, 54, 63	1:2	1944, 1946, 1948	African Americans
Cerebral thrombosis	2	69, 73	1:1	1954, 1955	1 African American 1 European American

Table 1: Causes of death associated with rib notching in the Cobb Collection.

The cause of death with the highest frequency of rib notching was congestive heart failure which was reported as the clinical cause of death in 11 individuals from the Cobb Collection. These findings further support our hypothesis that rib notching can be used as a marker for the presence of CVDs within an individual.

In addition, racial/ethnic classifications of the individuals identified with rib notching included 19 “Colored”, 4 “White”, 27 “Negroes”, and 3 without race classification. For the purposes of this study, we have collapsed “Colored” and “Negro” into a single category designated African American and “White” is reclassified as European American.

This research offers a new perspective and expanded insights into the lives of African Americans living in Washington, DC between 1931 and 1969. There has been a paucity of historical data and prior scientific studies on African Americans in comparison to their European American counterparts. This report is the first to obtain and look at rib notching in an historical African American skeletal collection to

retrospectively reveal the magnitude of CVD in this vulnerable population. In conducting this research, we were able to initiate evidence-based conversations about the extent and persistence of CVD as a chronic disorder affecting early 20th century African Americans. This, in turn, gives us a window into the historical tenacity of this particular health disparity in the African American community.

Conclusions

Our research laboratory has been able to reconstruct the lives of individuals from over 400 years ago and draw conclusion on health disparities that greatly affected previous generations residing in Washington DC [24]. This allows us to create a more longitudinal perspective of African American biological history and health [24]. As a consequence, we are able to track the evolution of medical knowledge in diagnosis and treatment of CVDs and its application in African American communities. By seeking greater insights into disease susceptibility and diagnoses that occurred decades ago, we are able to relate these to current methodologies in order to construct the best healthcare solutions for future patients as well as understand the lifestyles of those who lived generations before us and the contributions of those lifestyles to pervasive CVD-health disparities [25,26].

Declaration of Interest

The authors have no declarations of any financial and personal relationships with other people or organizations that could inappropriately influence this work.

Funding Statement

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Ethics Statement

This study was exempted from Institutional Review Board review because it was based on skeletal materials from which informed consent was not possible. Nonetheless, the privacy rights of the (deceased) humans studied were observed and all authors involved in the research were CITI-certified.

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