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Research article

Prevalence of chronic maxillary sinusitis in children from rural and urban skeletal populations in Poland

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ABSTRACT

Maxillary sinuses of 100 subadults from Cedynia, an early-urban site (stronghold), dated to the 10th-14th centuries AD, and of 28 subadults from Słaboszewo, a rural site, dated to the 14th-17th centuries AD, were examined for bone formation indicative of chronic sinusitis in order to explore the effect of urban and rural environments on the occurrence of upper respiratory tract infections in the past. We expected a higher prevalence of sinusitis in subadults from a stronghold than from a village, because of such factors as crowding, rapid spread of infections, and pollution from workshops located in the streets. We found a statistically non-significant tendency toward a higher prevalence of the condition in Cedynia compared to Słaboszewo (18.0% and 7.1%, respectively). The majority of maxillary lesions were classified as spicules. Changes to bone morphology suggestive of sinusitis of dental origin were not found. The development of observed osseous lesions may be attributed to culturally determined risk factors such as low quality of housing, air pollution caused by smoke from the household hearth and street workshops, poor levels of hygiene, and water contamination.

1. Introduction

Sinusitis is an inflammation of the mucosa of the paranasal sinuses, involving both infectious and noninfectious mechanisms (Chan et al., 2006; File, 2006; Benninger, 2010). The medical term is "rhinosinusitis", because the disease affects the mucous membranes lining both the nose and the sinuses. The paranasal sinuses are air-filled cavities in the bones of the face and skull, all of which communicate with the nasal cavity through narrow openings (ostia). The ostium of the maxillary sinus, the largest paranasal sinus, is situated in the superior aspect of the medial wall. This opening enables the sinus to be both drained and ventilated, though the location of the ostium makes these functions difficult in an upright position (Kariyawasam and Scadding, 2011). The mucosa of the sinuses is lined with a surface layer of cilia, which enables transport of mucus and particulate matter (viruses, bacteria, foreign animal and plant proteins, irritants) into the nasal cavity and then the nasopharynx, where it is swallowed. This process is known as mucociliary clearance. There are three conditions which are necessary for normal functioning of the sinuses: ostiomeatal patency, adequacy of mucociliary clearance, and normal quality and quantity of secretions. Disruption of any of these components may result in thickening of the mucosal layer, epithelial dysfunction, obstruction of the ostia, retention of secretions, and finally sinusitis. Impaired mucociliary mechanisms can result in mucous stasis within the sinuses that can lead to chronic dysfunction and infection (Hertler et al., 2006).

There are three categories of etiological factors leading to sinusitis: systemic (for example genetic), local host factors (anatomic abnormalities, local pathologies) and environmental factors (viral, bacterial and fungal infections, allergies, and pollutants, like dust, ozone, sulfur dioxide, smoke). Acute maxillary sinusitis is caused by blockage of the ostium through edema and inflammation of the nasal mucosa mainly resulting from viral infections (File, 2006). When the condition becomes chronic, a bacterial infection may develop, predominantly caused by *Streptococcus pneumoniae*, *Haemophilus influenzae*, and, most commonly in children, *Moraxella catarrhalis* (Leung and Katial, 2008; Romeo and Dykewicz, 2014). Chronic sinusitis relates to an infection with symptoms (nasal blockage/discharge, facial pain) lasting longer than 12 weeks. It is not a chronological extension of acute sinusitis, but a complex inflammatory process that can result from single or multiple inde-

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pendent (or interdependent) etiologies (Leung and Katial, 2008; Benninger, 2010). Today it is a common condition, accounting for a substantial morbidity rate, especially in areas with much atmospheric pollution (Hamilos, 2011). Of all the respiratory infections rhinosinusitis belongs to the most common illnesses affecting a high proportion of the population (File, 2006), including 18%-45% of children (Fokkens et al., 2012). The prevalence of rhinosinusitis in Europe is 10.9%, with marked geographical variation, and 14% in the USA (Fokkens et al., 2012). In Poland the prevalence of chronic rhinosinusitis is approximately 16% in adult population (Hastan et al., 2011; Khaitov et al., 2015). The main direct cause of chronic maxillary sinusitis, frequently associated with bacterial invasion, is obstruction of the ostium. In children, the most common predisposing factor is upper respiratory infection (File, 2006; Hertler et al., 2006; Benninger, 2010), which leads to narrowing of the ostia, smaller in children as compared to adults (Chan et al., 2006; Hertler et al., 2006). Immaturity of the immune system also contributes to pediatric sinusitis (Lusk, 2012). Each child has three to eight colds per year, up to 80% of which are associated with rhinosinusitis (File, 2006). Bacterial maxillary sinusitis complicates up to 2% of all upper respiratory infections (Clement, 2006).

The role of environmental pollution is increasingly recognized as a cause of rhinosinusitis in children (Hertler et al., 2006). Air pollutants act as irritants causing, among other things, dryness and local inflammation (Jackman and Kennedy, 2006; Benninger, 2010). There is consistent evidence that both ambient and household air pollution cause upper (laryngitis, sinusitis) and lower (bronchitis, asthma, chronic obstructive pulmonary disease) respiratory diseases and other conditions, which can even be fatal (WHO, 2014). Wood smoke contains irritants, systemic toxins and carcinogens, and has been proven to have considerable polluting effects (Ezzati and Kammen, 2001). Many studies have found a significant association between the occurrence of respiratory health problems and exposure to wood smoke (e.g. Larson and Koenig, 1994; Riojas-Rodríguez et al., 2001), and to particulate pollution from agriculture (McCurdy et al., 1996). Burning of wood for heating, cooking, and lighting results in exposure to such pollutants as fine particles and carbon monoxide (WHO, 2014; http://www.who.int/heli/risks/indoorair/indoorair/en/). It was also found that high amounts of polycyclic aromatic hydrocarbons present in wood smoke produce high levels of free radicals, DNA damage as well as inflammatory and oxidative stress response gene expression (Danielsen et al., 2011). As shown for India, all household members in poorly ventilated dwellings are exposed to the adverse effects of wood smoke, but the highest risks occur among women and their youngest children, who spend the most time near the domestic hearth (Smith, 2000; Balakrishnan et al., 2004; WHO, 2014). Studies comparing high and low woodsmoke areas found statistically significantly higher levels of congestion and wheezing in 1- to 5-year-olds, supporting the notion that young children are particularly susceptible to the adverse effects of wood smoke (Naeher et al., 2007).

Apart from reliance on biomass fuels, the main factors contributing to poor air quality also include poverty and low quality of housing (inadequate ventilation, crowding, unsanitary conditions). In poorly ventilated homes, the harmful health effects of indoor air pollution are exacerbated, because smoke can exceed acceptable levels for fine particles a hundredfold. In developing countries, indoor air pollution generated by inefficient and poorly ventilated stoves burning biomass fuels such as wood is responsible for the deaths of 1.6 million people annually, with predominant incidence among children under five years of age (WHO, 2014; http://www.who.int/heli/risks/indoorair/indoorair/en/). The use of open fires causes greater health risks than a stove with a chimney (Schei et al., 2004).

As a result of chronic or repeated inflammation, bone changes within the maxillary sinuses may develop. The sinuses may also become infected because of dental disease (e.g. caries and periapical lesions), such as an abscess that perforates the sinus (Roberts and Manchester, 2005, p 176). The maxillary sinuses exhibit a two-phased growth spurt, between birth and 3 years and again from 7 to 12 years of age, and reach their adult size by age 15 (Chan et al., 2006; Hertler et al., 2006; Lorkiewicz-Muszyńska et al., 2015). However, they are well-developed and extensively pneumatized already at birth, with mean width of 12 mm and mean height of 12.5 mm in the age category 0–12 months (Scheuer and Black, 2000, p. 135). Thus, already at birth they are clinically significant and radiologically visible (Chan et al., 2006; Krouse and Stachler, 2006). Pathological changes in the form of bone deposition and/or resorption are most commonly found on the floor of the sinus (Roberts and Manchester, 2005, p 174; Lewis, 2007, p 137; Roberts, 2007; Waldron, 2009; p 114). The use of periosteal new bone formation as an indicator of maxillary sinusitis in past populations was first presented by Wells (1964). Later studies showed rather low frequencies of this condition, less than 10%. Diagnostic criteria were provided by Boocock et al. (1995a) and this study was one of the first to have reported a relatively high prevalence of maxillary sinusitis, exceeding 50%. This result was likely due to a specific sample, deriving from a leprosy hospital cemetery. Clinical studies revealed a greater frequency of sinusitis in lepromatous individuals, caused by the involvement of the nasal mucosa in leprosy (Boocock et al., 1995a).

Environmental factors affecting the prevalence of maxillary sinusitis are the derivatives of climate, settlement pattern, and socio-economic system of a population. The extent to which those factors can be inferred for skeletal populations depends, among other factors, on the available contemporary archaeological and historical data and documentation. In past populations maxillary sinusitis has been found to be more prevalent in urban sites (Lewis et al., 1995; Roberts and Lewis, 2002; Roberts, 2007), although not universally (Panhuysen et al., 1997; Lewis, 2007; p 137). It has been suggested that the urban environment exposed people to pollutants in the atmosphere, both internally in poorly ventilated houses, and externally (Camuffo et al., 2000; Roberts and Manchester, 2005, p 174).

Children are among the most vulnerable members of a society, and their health parameters reflect the ability of the whole population to adapt to environmental conditions. We hypothesize that the development of urban centers in Medieval Poland, characterized by overcrowded and unsanitary conditions, resulted in higher rates of infectious diseases in urban children compared to their rural counterparts. This study aims to compare the prevalence of chronic rhinosinusitis in the skeletons of subadults excavated at two cemeteries associated with an urban and a rural community.

2. Materials and methods

2.1. Materials

We chose to examine non-adult individuals from an early-urban and a rural site to assess whether urbanization had a harmful effect on their health. The signs of maxillary sinusitis were recorded in subadults (<20 years) from two sites located on the territory of Poland, Cedynia (52°52′45.30″ N, 14°12′07.99″ E) dated to the 10th–14th centuries AD, and Słaboszewo (52°47′21.82″ N, 17°57′59.06″ E) dated to the 14th–17th centuries AD (Fig. 1). The distance between these two sites is about 280 km, and both are located in lowland lake areas. Although the sites are not contemporaneous, they both reflect the living conditions in Medieval Poland, because the settlement structure of the villages remained unchanged from early to Late Medieval and Early Modern times (Piontek, 1981; Chwalba, 2005). There were, in total, 257 indi-

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