Implementation of the Uncertainty Calculation for the Detection of Negative Effect of Smoking on the Bone Density of Paranasal Sinuses

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Abstract

The aim was to implement uncertainty calculation for detecting the negative effects of smoking on the bone density of the paranasal sinus. Materials and Methods: A total of 100 male participants aged 20 to 44 were included in the study and divided into two groups. The first group comprised individuals with minimal harmful habits, while the second group consisted of individuals who had been smoking for at least 10 years, consuming 1 to 2 packs of cigarettes per day. Results Bone density has a negative impact on the bone tissue of the upper wall of the maxillary sinus. The findings suggest that individuals with a pronounced decrease in minimum density, as well as those with a marked difference between minimum and maximum density values, may require heightened medical attention due to potential associations with undiagnosed diseases or specific structural characteristics in the skull. Conclusions. The uncertainty calculation was implemented for the detection of negative effect of smoking on the bone density of paranasal sinuses. The calculated difference between maximum and minimum density during the research suggests significant medical implications, especially considering the heterogeneity of the trabecular bone structure in the skull. Individuals with a marked difference may require heightened medical attention, potentially associated with undiagnosed diseases or specific structural characteristics in the skull.

Keywords [1]

Bone density, multispiral computer tomography, uncertainty, paranasal sinuses, smoking

1. Introduction

Calculating uncertainty is an important method for determining investigated parameters, successfully applied in various scientific and technical fields [1]. This method has found application in medical practice, primarily in laboratory diagnostics [2]. Although uncertainty calculation can also be successfully applied to calculate other indicators, it is particularly interesting when standard statistical data processing is not feasible for various reasons. The results of uncertainty calculation in physiological conditions and under pathological conditions are particularly intriguing. One area of interest is the impact of harmful habits on the human body [3].

Habits have become ingrained in human life, rooted in biological processes, and formed based on close neural interactions [4]. Once formed, habits can accompany a person throughout

ProfIT AI 2023: 3rd International Workshop of IT-professionals on Artificial Intelligence (ProfIT AI 2023), November 20–22, 2023, Waterloo, Canada
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their entire life, exerting both positive and negative effects on the human body [5]. A striking example of the negative impact of harmful habits on the human body is smoking, which adversely affects almost all organs and tissues, including bone tissue [6]. Men are the undisputed leaders in tobacco consumption among the population [7].

Recently, osteoporosis was predominantly considered a female disease [8, 9]. However, recent data from the International Osteoporosis Foundation show that men are also quite often affected by this condition. According to the statistics of the International Osteoporosis Foundation, for instance, one in five men will experience a spine fracture by the age of 50 due to osteoporosis [10]. While the relationship between osteoporosis and the bones of the spine and hip is well-researched, less explored but equally important is the topic of skull bone density and its changes under the influence of negative factors.

Changes in skull bone density, intensified by smoking, can act as a trigger for the development of pathological inflammatory processes [11]. Moreover, it can become a factor contributing to the spread of inflammatory processes in the cranial cavity and/or eye sockets, thus leading to complications.

Considering all the aforementioned, **the aim** of our study was to implement uncertainty calculation for detecting the negative effects of smoking on the bone density of the paranasal sinus.

2. Material and Methods

A total of 100 male participants aged 20 to 44 were included in the study and divided into two groups. The first group comprised individuals with minimal harmful habits, while the second group consisted of individuals who had been smoking for at least 10 years, consuming 1 to 2 packs of cigarettes per day. To eliminate the influence of other harmful habits (e.g., alcohol or drug addiction), all participants were advised to fill out a questionnaire anonymously. The questionnaire included inquiries about demographic data (age), the presence of concomitant diseases, particularly endocrine disorders that could disturb electrolyte balance, such as diabetes, thyroid diseases, and parathyroid diseases. Questions about other harmful habits (alcohol and drug addiction) were also included.

All participants provided informed consent to participate in the experiment, and the study was approved by the bioethics committee of Kharkiv National Medical University (protocol 1 dated 08.11.2018).

Computed tomography (CT) scans were conducted on all patients at the Kharkiv Clinical Institute of Emergency Surgery using a Toshiba Aquilion CT scanner (Japan) [12]. During the research, preference was given to the results obtained specifically through multi-slice spiral computed tomography (MSCT), considering its undeniable advantages compared to cone-beam computed tomography (CBCT), primarily due to the presence of a densitometric scale. The CT results were analyzed using RadiAnt DICOM Viewer [13]. Attention was focused on the upper wall of the maxillary sinus, considering its higher susceptibility to pathological processes compared to other areas. The more frequent inflammation of this sinus could be explained by its structural features, such as its higher position compared to the natural ostium. The proximity to tooth locations was also considered, which might create conditions for odontogenic spread of the pathological process [14]. Additionally, this sinus is the largest in size, potentially leading to the development of extensive purulent inflammatory processes capable of spreading to adjacent organs and tissues, resulting in complications.

Given the challenges in anatomical point selection for obtaining representative bone density data, uncertainty calculation was employed to determine the range of minimum and maximum values that would be reliable for the calculated parameter. The uncertainty calculation followed a widely accepted algorithm described in our previous works [15, 16].

3. Results

As a result of our conducted research, it can be hypothesized that density has a negative impact on the bone tissue of the skull, particularly on the upper wall of the maxillary sinus. Table 1 presents the results of a study on bone density in the maxillary sinus measured in Hounsfield Units (HU) for two groups: the 1st Group (smokers) and the 2nd Group (control).

Table 1
The results of the study of bone density (HU - Hounsfield Units) in the maxillary sinus (1st(smokers) and 2nd (control) Groups)

Indicator	1st Group Max	1st Group min	2nd Group Max	2nd Group Min
$U_A(H_{Hi})$	79.74	24.9	28.18	19.94
$U_B(H_{Hi})$	0,00044	-0,000009	0.0007	-0.0000017
U_c	79.74	24.9	28.18	19.94
U	159.48	49.80	56.38	39.87

The calculated parameters $U_B(H_{Hi})$ and U show some variations and might represent specific characteristics or derived measures related to bone density.

In the figure 1 the results of determining the density count in each of the groups (experimental and control) are presented.

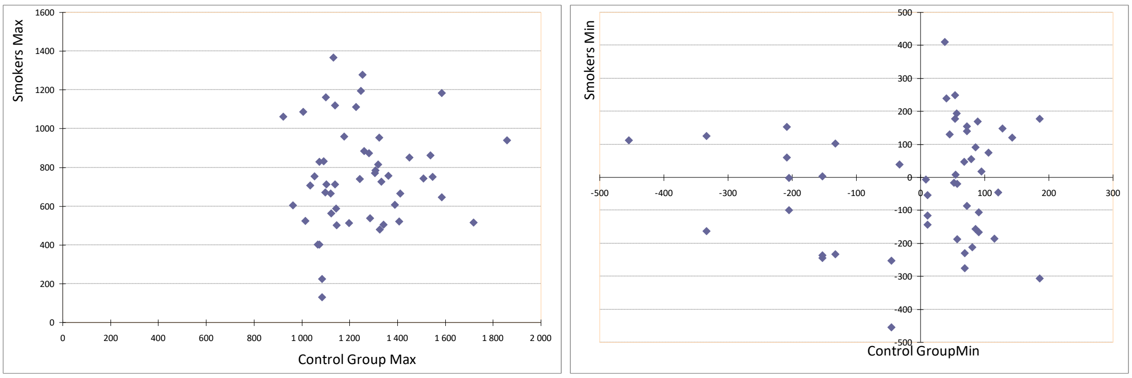
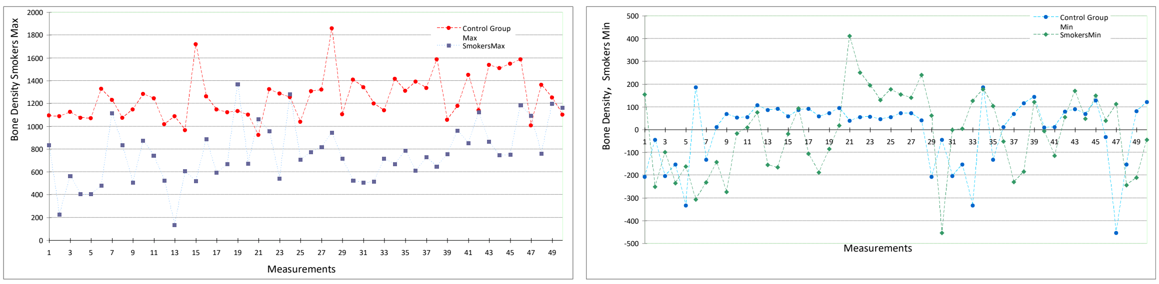


Figure 1: Maximum (a) and minimum (b) bone tissue density values in the study and control groups

In analyzing the obtained results, we believe particular attention should be given to the differences in density values between the experimental and control groups to determine the negative impact of nicotine on the human body. Fig. 2 illustrates the variations in minimum and maximum density within the two groups of individuals included in the study.

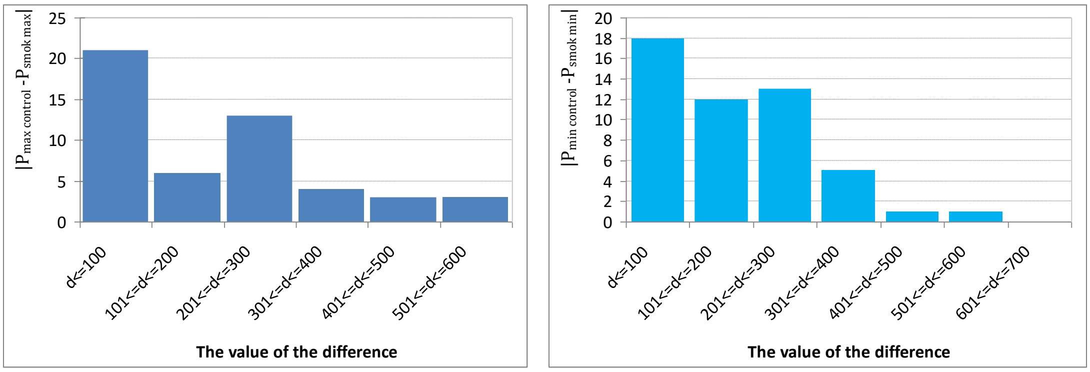


(a) (в)

Figure 2: Differences in maximum (a) and minimum (b) density between the experimental and control groups

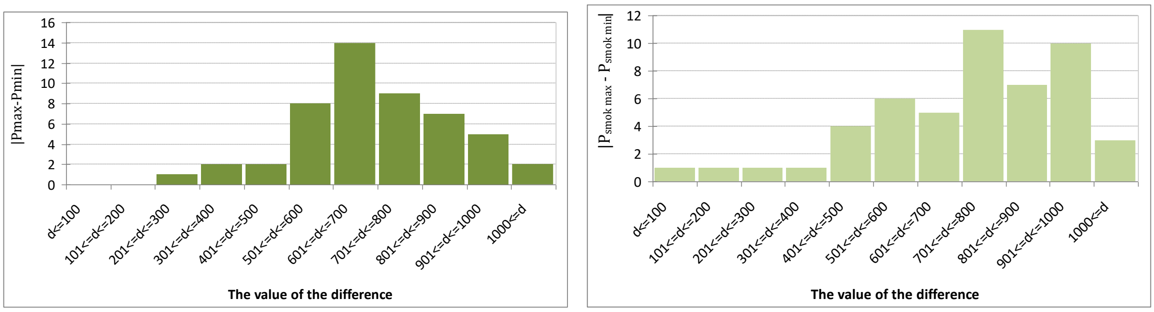
During our research, we obtained intriguing data regarding the heterogeneous decrease in density in each case. In light of this, it can be hypothesized that nicotine may exert varying degrees of negative influence on each individual. To assess the extent of this impact, we also calculated the difference in maximum and minimum density in each group. This approach allows us to identify a subgroup of individuals who are more susceptible to the adverse effects of smoking on bone tissue than others. Such individuals may subsequently represent a potential risk group for complications in inflammatory processes, especially if they occur in the paranasal sinuses.

Furthermore, these individuals also present scientific interest, as there is an opportunity to identify factors that could contribute to an increased sensitivity of organs and tissues to nicotine. This exploration could shed light on the underlying mechanisms that make certain individuals more vulnerable to the effects of smoking on bone density.



(a) (в)

Figure 3: The value of the difference of Maximum and Minimum bone density in 2 groups



(a) (в)

Figure 4: The value of the difference of Maximum and Minimum bone density in 2 groups

As seen in Fig. 3, in most cases, the difference between maximum and minimum values ranges from 0 to 100 Hounsfield Units (Hu). Groups of individuals with a difference of around 600 Hu deserve particular attention, suggesting that the bone tissue of such individuals may have a specific sensitivity to the detrimental effects of smoking, potentially leading to complications more frequently.

Individuals with a pronounced decrease in minimum density are even more concerning. Upon analyzing Fig. 3 (в), it is evident that in most cases, the difference between the minimum densities in the two groups ranges from 100 to 300 Hu. Although cases with a difference of 400 to 700 Hu are rare, these individuals may also cause concern among medical personnel regarding the potential development of complications in pathological processes.

During the research, the difference between maximum and minimum density was also calculated. In our opinion, this parameter can have significant medical implications, especially considering the heterogeneity of the trabecular bone structure in the skull. Therefore, individuals with a markedly pronounced difference between minimum and maximum density values may require heightened medical attention. This significant difference in their case may be associated with undiagnosed diseases or specific characteristics in the structure of the skull, such as the presence of diastemata.

4. Discussion

In recent years, the number of scientific studies indicating that smoking plays a significant role in reducing bone density, typical of osteoporosis, has increased [17]. At the same time, osteoporosis can significantly impact patients with chronic obstructive pulmonary disease (COPD), leading to reduced activity levels and diminished quality of life [18]. The combination of impaired lung function, decreased physical activity, and the presence of osteoporosis substantially increases susceptibility to falls and fractures. Therefore, it is essential to monitor bone mineral density in patients with a history of smoking and COPD to prevent complications associated with osteoporosis.

Bone mineral density can be measured using various modern diagnostic methods, with dual-energy X-ray absorptiometry (DEXA) and quantitative computed tomography (QCT) being commonly used in clinical practice [19]. DXA is recommended by the World Health Organization as the gold standard for osteoporosis diagnosis. However, both DXA and QCT have limited availability, primarily in large tertiary hospitals or physical examination centers. Therefore, there is a need for a simple and accurate method to determine bone mineral density, allowing for timely prevention and treatment of osteoporosis and related complications.

The evaluation of Hounsfield units [20] (HU) is proposed as an important tool for screening changes in bone density. Determining HU in vertebral bodies is suggested as a quick and cost-effective method that provides additional information about bone health without additional radiation exposure. The optimal threshold for defining average bone mineral density associated with osteoporosis is proposed as 136.2 HU for men with a sensitivity of 95.0 and specificity of 77.6, and 137.9 HU for women with a sensitivity of 96.0 and specificity of 64.4.

Factors related to smoking that can influence bone density include the direct effects of nicotine and certain cigarette elements on osteoblast activity [21], inhibition by nicotine acid, increased estrogen metabolism with decreased estrogen levels, inhibition of ovarian function, and the long-term use of glucocorticoids leading to osteoblast proliferation inhibition.

Smoking is considered a significant risk factor for life-threatening diseases [22]. Prolonged smoking has been linked to a decrease in average life expectancy by 22 years and a threefold increase in mortality rates. Despite these risks, the number of smokers is expected to rise, leading to approximately 10 million deaths annually by 2030.

Smoking in childhood [23] and adolescence contributes to worsened general health, increased risk, and severity of respiratory diseases, impacting the development and functioning of the respiratory system. The statistics on smoking among children and adolescents are alarming, with a substantial number becoming regular smokers, leading to premature death. The exploration of smoking's impact on subgingival bacteria should consider eliminating other factors that may interfere and are related to gingivitis and periodontitis.

It is essential to recognize the adverse effects of smoking, particularly among the youth, as early smoking initiation often leads to nicotine addiction and complicates smoking cessation. The early development of generalized osteoporosis is an important consequence of smoking in those who start smoking at a young age, impacting the bones of the facial skeleton. The implications of these changes in the dental and periodontal tissues, affecting the early loss of teeth, should be given more attention by ear, nose, and throat specialists.

The impact of nicotine requires careful consideration, especially among the youth. An important adverse consequence of smoking in those who start at a young age is the early development of generalized osteoporosis. Despite this, the changes in the bones of the facial skeleton receive insufficient attention from ear, nose, and throat specialists compared to the attention given by dentists to changes in the dental and periodontal tissues. To assess the impact of smoking on subgingival bacteria, other factors that may interfere or are related to gingivitis and periodontitis should be eliminated.

In the context of examining the impact of smoking on bone density, our findings align with the broader scope of research in healthcare-related intelligent systems. Studies on an intelligent expert system for knowledge examination of medical staff regarding infections associated with the provision of medical care [23], as well as works in the areas of smart systems, data-driven services in healthcare, and the application of smart technologies for medical services, may contribute to the growing body of knowledge in the field of the detection of bone density [24].

The integration of smart systems and data-driven services in healthcare, as explored by some authors [25-27] emphasizes the importance of leveraging technology for improved medical outcomes. Our study, focusing on the influence of smoking on bone density, adds to this discourse by shedding light on a specific aspect of health that may be impacted by lifestyle choices such as smoking

In conclusion, smoking can be considered a fully-fledged risk factor for life-threatening diseases, affecting the respiratory system and bone density. Recognizing the impact of smoking on various aspects of health, including oral health, is crucial for providing comprehensive care and preventive measures. Continuous efforts are needed to raise awareness about the consequences of smoking, particularly among young individuals, and to promote strategies for smoking cessation.

5. Conclusion

The uncertainty calculation was implemented for the detection of negative effect of smoking on the bone density of paranasal sinuses. Our study suggests a potential negative impact of smoking on the skull bone tissue, specifically on the upper wall of the maxillary sinus.

Individuals with a pronounced decrease in minimum density, as well as those with a marked difference between minimum and maximum density values present scientific interest. Significant Medical Implications:

The calculated difference between maximum and minimum density during the research suggests significant medical implications, especially considering the heterogeneity of the trabecular bone structure in the skull. Individuals with a marked difference may require heightened medical attention, potentially associated with undiagnosed diseases or specific structural characteristics in the skull.

Our research contributes valuable insights into the complex relationship between bone density, smoking, and potential health complications, emphasizing the need for further research and clinical consideration of individuals with specific density patterns.

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