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Original research

Prevalences of concha bullosa and nasal septum pneumatization and their relationship with nasal septum deviation in cone-beam computed tomography

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Purpose
This study was conducted to evaluate whether concha bullosa (CB) and nasal septum pneumatization (NSP) have an impact on nasal septum deviation (NSD) and to determine the prevalence of CB and NSP in a subgroup of the Turkish population in the Mediterranean region.

Materials and Methods
CBCT images of 230 patients were evaluated retrospectively for the presence of CB, NSP and NSD. CB was defined as the presence of any size of pneumatization within the superior, middle, or inferior turbinate. CB laterality, NSP, NSD, age and gender were also recorded. Data analysis was performed with SPSS. Statistical significance was considered to be $p < 0.05$.

Results
66.5 % of the patients had at least one CB, 59.1% of the patients had NSP and 50% of the patients had NSD. While there was no significant difference between the prevalence of concha bullosa and nasal septum pneumatization and gender, there was a significant difference between the prevalence of nasal septum pneumatization and age ($p = 0.026$). There was no relationship between NSD and CB and NSP.

Conclusion
Despite the hypothesis that CB and NSP impact NSD, this study indicates that there is no relationship between NSD and CB/NSP.

Keywords: *Pneumatization, concha bullosa, nasal septum, cone-beam computed tomography, nasal cavity*

Introduction

Numerous congenital anomalies and variations in paranasal sinus structures have been described (1). Many of these variations can vary depending on age, gender and region. One of these defined anatomical variations is a pneumatized turbinate known as concha bullosa (CB), which indicates the presence of air cells in the turbinates (2). Made up of bone and cartilage, the nasal septum divides the nasal cavity into two sides and is an important supporting structure. (3). Some degree of deviation is clinically acceptable, although a completely flat septum is extremely rare (4). However, deviation of the nasal septum (NSD), one of the more common anatomical variations of the nasal complex, is a strong risk factor for nasal cavity obstruction and sinusitis (4). Although the exact mechanism by which CB is formed is unknown, the airflow pattern of the nasal cavity is thought to play an important role. Since the convexity of the deviation significantly reduces the airflow in the nasal cavityincreases the risk

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of pneumatising the contralateral middle turbinate (5). Another anatomical variation of the nasal septum is its pneumatisation, which can block the osteomeatal complex and thus be a potential predisposing factor for various sinonasal mucosal diseases. (6). In cases where excessive pneumatization of the sphenoid sinus progresses forward, nasal septum extension occurs. Identifiable sphenoid sinus extension in the nasal septum is known as nasal septum pneumatization (NSP). While this pneumatization may occur only in the rostral septum, it may also spread to the middle or most of the septum (7). It is not usually clinically significant, but may contribute to narrowing of the sphenoethmoidal recess. (8).

Recent advances in diagnostic imaging methods enable variations in anatomical structures to be detected easily. The ability to visualise the osteomeatal complex using conventional radiographic techniques is limited. With the introduction of cone beam computed tomography (CBCT), it has become possible to improve the diagnosis of anatomic abnormalities and pathology in the structure of the nasal cavity and the surrounding paranasal sinuses. (9). CBCT is widely accepted by maxillofacial radiologists as one of the pioneering tools for sinus evaluation, although it is a relatively new technology in the field of oral and maxillofacial radiology (10). CBCT imaging of the nasal cavity and sinus offers several advantages over multi-slice CT, including easier image acquisition, greater image accuracy due to better bone delineation, multi-slice reformatting, reduced radiation dose, faster scan time and lower cost. (11).

The osteomeatal complex can be evaluated to help diagnose, treat, and reduce complications from maxillofacial pathology. However, there is little information on CB, NSP, and NSD in the Turkish population in the Mediterranean region. Therefore, this study aims to provide a reference for studies of paranasal region anatomy. The aim of this study was to determine the prevalence of CB and NSP and their relationship to NSD in a subset of the Mediterranean Turkish population using CBCT. The null hypothesis is that there is no significant relationship between the presence of concha bullosa (CB) or nasal septum pneumatization (NSP) and nasal septum deviation (NSD) in the Turkish population of the Mediterranean region.

Materials and Methods

Ethical statement

This retrospective study was conducted according to the tenets of the Declaration of Helsinki, and ethical approval was obtained from the Akdeniz University Faculty of Medicine Ethics Committee before starting the study (the ethics approval number was KAEK-230).

Data collection

CBCT images of patients who attended the University Faculty of Dentistry, Department of Oral and Maxillofacial Radiology for any reason between February 2020 and January 2021 were investigated retrospectively for the presence of CB, NSP and NSD. CBCT images in which the entire osteomeatal complex entered the imaging field were included in the study, and the following exclusion criteria were applied to select the final study group: (1) images of individuals with any congenital or developmental anomaly affecting the craniofacial region, (2) images suggestive of trauma, (3) images with pathologies such as cysts or tumors, and (4) images with poor image quality. The Metasoft Dentasist programme was used to record the patients' medical history (version 3.0.448, Turkey).

Acquisition and interpretation of images

CBCT images were acquired with a Veraview X800 CBCT unit (J. Morita Mfg. Corp., Kyoto, Tokyo) in accordance with the manufacturer's instructions (field of view: 15x 15x 7.5; 320 µm; 4.8 mA; 99 kvP and 35.8 s and imaging area: 15x 15x 13.9; 320 µm; 4.8 mA; 99 kvP and 35.8 sec) and the scans were analysed using i-Dixel software (v. 2.3.6.1 J Morita Mfg. Corp., Kyoto, Japan). All CBCT images were evaluated independently by two researchers with expertise in dental radiology. The images were viewed on the same LED monitor at a distance of approximately 40-50 cm from the monitor, in a dimly lit room, and with appropriate tonal adjustments. To avoid investigator fatigue, investigators evaluated up to ten CBCT images per day.

In the present study, the classification of variation in paranasal sinus anatomy proposed by Dawood (12) was adopted. The presence of pneumatization in either the turbinates or the nasal septum was recorded, and the frequency of pneumatization in the osteomeatal complex was determined (Figure 1, Figure 2 and Figure 3). The frequency of CB and NSP was also recorded. All turbinates were evaluated separately and CB was defined as the presence of any size of pneumatization in the superior, middle or inferior turbinate, while the presence of any size of pneumatized area in

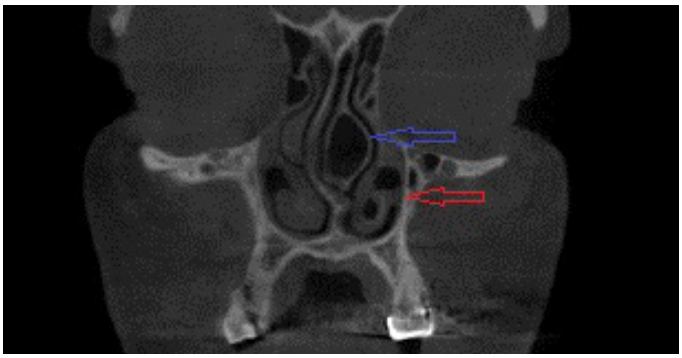

Figure 1. *Middle (blue arrow) and inferior (red arrow) concha bullosa in the coronal section.*

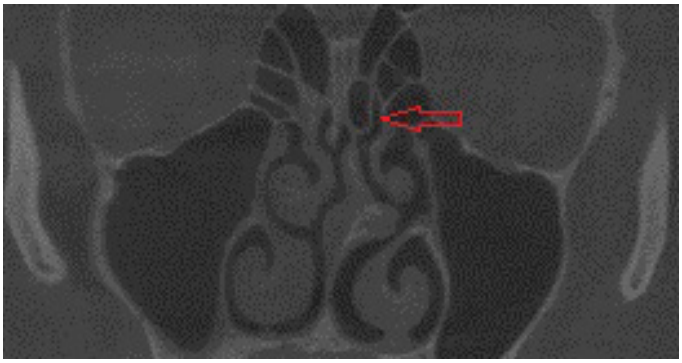

Figure 2. *Superior concha bullosa in the coronal section (red arrow).*

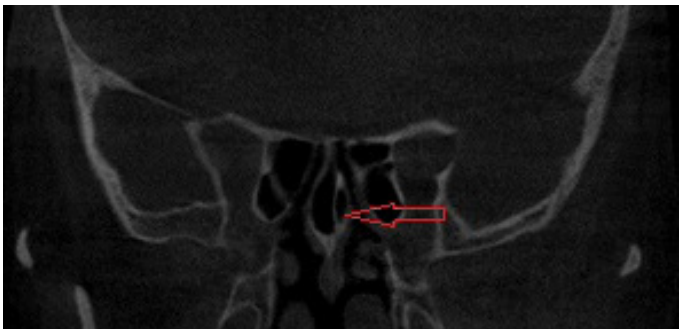

Figure 3. *Nasal septum pneumatization in the coronal section (red arrow).*

the nasal septum was considered as NSP. Site of the CB was evaluated separately for the superior, middle and inferior turbinates (right only, left only and bilateral). NSD as well as demographic data of the patients such as gender and age were recorded. Age was divided into three groups as follows: younger than 18 years; 18 to 65 years old; older than 65 years. Four weeks later, each observer selected 50 CBCT images randomly and re-evaluated them to determine the intraobserver agreement. In addition, the observers re-evaluated 50 CBCT images evaluated by the other observer in order to evaluate the interobserver agreement.

Statistical analysis

Data were statistically analysed using IBM SPSS Statistics (version 22.0. Armonk, NY: IBM Corp). Normality assumption of data was assessed by Shapiro-Wilk test. Descriptive analyses and frequencies were calculated for age, gender, presence of pneumatization, presence of CB, presence of NSP, CB laterality, and NSD. The Pearson chi-square test was used to analyse differences between categorical variables, and the Spearman correlation test was used to analyse associations. p values less than 0.05 was considered significant. The kappa coefficient was used to evaluate the intraobserver and interobserver agreement.

Results

The intraobserver and interobserver agreement coefficients were above 0.85 in all parameters. Of 230 patients in total, 117 (50.9%) were female and 113 (49.1%) were male, with a mean age of 39.41 ± 18.94 years. While 36 (15.7%) patients were younger than 18 years old, 172 (74.8%) patients were aged 18–65 years and 22 (9.6%) patients were older than 65 years. The prevalence of pneumatization in the osteomeatal complex was 82.6 % (n = 190), CB was detected in 66.5% (n = 153), NSP in 59.1% (n = 136), and NSD in 50% (n = 115). Table 1 shows the distribution of osteomeatal complex pneumatization, CB, NSP, and NSD according to gender and age groups. There was a significant difference between NSD and gender (p = 0.012), while NSP differed by age groups (p = 0.026).

CB was most common in the middle turbinate (n = 116, 50.4%), followed by the superior concha (n = 99, 43%) and inferior concha (n = 2, 0.9%). Table 2 shows the distribution of pneumatization in turbinate types according to gender, age and site. Table 3 shows the prevalence of anatomical variations in the sinonasal region in other studies.

While Spearman correlation analysis revealed no significant relationship between gender and CB and NSP presence (r=0,77, p=0,246 and r=0,32, p=0,628, respectively), a negative and significant relationship was found between gender and NSD presence (r=-0,165, p=0,012). In addition, a negative and significant association was found between age groups and the presence of NSP (r = -0.171 p = 0.009). The presence of CB and NSD showed no significant correlation with age groups (r = -0.31, p = 0.637 and r = -0.85, p =

Table 2. *Types of turbinate pneumatization stratified by gender, age and site variables.*

	Superior concha bullosa (Number/%)	Middle concha bullosa (Number/%)	Inferior concha bullosa (Number/%)
Female	52/52.5	62/53.4	1/50
Male	47/47.5	54/46.6	1/50
<18 age	12/12.1	20/17.2	0/0
18-65 age	77/77.8	84/72.4	2/100
≥65 age	10/10.1	12/10.4	0/0
Right	25/10.8	31/13.5	0/0
Left	23/10	36/15.5	1/0.45
Bilateral	51/22.2	49/21.3	1/0.45
Total	99/43	116/50.4	2/0.8

%: percent

Table 1. *Frequencies of the osteomeatal complex pneumatization (OMP), concha bullosa (CB), nasal septum pneumatization (NSP) and nasal septum deviation (NSD) stratified by gender and age variables.*

	OMP(Number/%)	CB(Number/%)	NSP(Number/%)	NSD(Number/%)
Female	102/53.7	82/53.6	71/52.2	49
Male	88/46.3	71/46.4	65/47.8	66
***p* value**	0, 092	0, 244	0, 626	0, 012*
Younger than 18 years old	30/15.8	25/16.3	26/19.1	19/16.5
18 to 65 years old	142/74.7	114/74.5	102/75	89/77.4
Older than 65 years old	18/9.5	14/9.2	8/6.9	7/6.1
***p* value**	0, 989	0, 894	0, 026*	0, 238

%: percent, *:p< 0.005

Table 3. *Previously published articles evaluating anatomical variations in the sinonasal region (CB: concha bullosa, NSP: nasal septum pneumatization, NDS: nasal septum deviation).*

First author, year, country	Anatomical variation Percentage (%)	Sample size
Stallman JS, 2004,USA	14–80 CB	1095
Mokhasanavisu VJP, 2019,India	60 CB	64
Tiwari R, 2015,India	76.4 CB; 50.4 medium CB	80
Borahan MO, 2019, Turkey	7.7 superior CB	300
Özdemir M, 2019,Turkey	29.3 superior CB 53.1 NSD	358
Yang B, 2008, China	0.03 inferior CB	18
Koo SK, 2017,South Korea	1 inferior CB	594
Dua K, 2005,India	2 NSP	40
Mladina R, 2017,Croatia	34.4 NSP 32 NSD	93
Dawood SN, 2020,İraq	61 CB, 71.7 NSD	300
Devaraja K, 2019, India	83 NSD	151
Smith KD, 2010,USA	80.5 NSD	883

0.2, respectively). One hundred and thirty six (59.1%) CBCT images had both CB and NSP, and there was a significant difference between the presence of CB and NSP ($p = 0.015$). In addition, a positive and significant relationship was found between the presence of CB and the presence of NSP ($r = 0.16$, $p = 0.015$).

While 153 (66.5 %) CBCT images had both NSD and CB, 136 (59.1%) CBCT images had both NSD and NSP. However, there was no difference between NSD and CB and NSP ($p = 0.675$ and $p = 0.788$, respectively). Spearman correlation analysis showed no significant relationship between the presence of NSD and CB ($r = 0.28$, $p = 0.677$) or between the presence of NSD and NSP ($r = 0.18$, $p = 0.79$).

Discussion

Computed tomography is considered the preferred method for evaluating nasal structures because it provides the best approximation of bone structure and includes soft tissue contrast for diagnostic imaging of the paranasal sinuses (13). The coronal approach is extremely important for accurately assessing the paranasal structures, with a particular focus on the osteomeatal complex. The use of CBCT for high-quality bone identification is considered an improvement over CT. By using very thin and multiplanar slices, it is possible to examine the maxillary structures, especially the paranasal sinuses, and determine their position, shape, and anatomical variations (14-16). Multiplane images obtained with CBCT provide precise three-dimensional visualization of the tooth and maxillofacial structures, offering advantages such as lower metallic artifacts, reduced cost, and lower radiation dose compared to multislice computed tomography (17, 18). Therefore, CBCT can be used by dentists and otolaryngologists to evaluate the paranasal sinuses. Given these advantages, we preferred CBCT to evaluate the nasal area.

Knowledge about pneumatization is not only relevant diagnostically but also reduces intra- and postoperative difficulties in endoscopic sinus surgery (19, 20). While pneumatization can vary depending on age, gender, geography, race, and ethnicity, some differences are not significant (18, 19).

CB is a common anatomical variation of the lateral nasal wall. Pneumatization of the superior and inferior turbinates is rare but possible, and the term concha bullosa is often used for pneumatization of the middle turbinate (16). To our knowledge, there are few comprehensive studies examining the anatomical variations of the superior, middle, and inferior turbinates and nasal septum in the same individuals (21, 22). The reported prevalence of CB is 14–80% (23). The prevalence of CB was 66.5% in the present study, which is consistent with the literature. The wide prevalence ranges of CB may reflect different definitions of CB (24). While CB is generally accepted as the pneumatization of the middle concha, it can also be seen in the superior and lower conchas. In the present study, CB was defined as the presence of any size of pneumatization in all turbinates, which may contribute to its relatively high prevalence.

CB is most commonly found in the middle concha, followed by the superior concha and the inferior concha (25). Similar to our study, Mokhasanavisu *et al.* (26) reported a frequency of CB at 60%, while Tiwari *et al.* (27) reported a rate of 76.4%. The prevalence of middle CB was 50.04% in the current study. While it is reported in the literature that superior CB is less common (25, 28), its prevalence was quite high in our sample (43%). Borahan *et al.* (25) reported a prevalence of 7.7%, and Özdemir and Kavak (29) reported a prevalence of 29.3%. A study reviewing CT scans found 16 cases of inferior CB (0.03%) (2), which was lower than in the current study (0.9%).

Some studies have reported that there was no significant difference between gender and the prevalence of CB (25, 29, 30), which aligns with our findings. Alnatheer *et al.* (31) performed a literature search identifying 26 case reports of inferior turbinate pneumatization published between 1999 and 2021, determining that the prevalence of inferior CB was higher in females (31). The number of inferior CB cases was the same in females and males (n = 1) in the current study. According to Borahan *et al.* (25), there was no significant difference between age groups and the prevalence of CB. Similarly, no significant difference in the prevalence of middle and superior concha bullosa according to age was reported by Koo *et al.* (28), which is consistent with our findings. On the other hand, Özdemir and Kavak (29) found a significant difference according to age and speculated that the prevalence of CB may diminish with age. Although there was no significant difference in the present study, the prevalence of CB was lower in individuals aged 65 or older, supporting the findings of Özdemir and Kavak (29). However, these authors considered the mean and median ages of patients with and without CB, while age was divided into three groups in the current study.

When the site of superior and middle CB is considered, the current study's results are similar to those of Borahan *et al.* (25), as both indicated a higher incidence of bilateral CB than unilateral CB. On the other hand, Özdemir and Kavak (29) found a higher incidence of unilateral CB than bilateral CB. This discrepancy can be attributed to different site definitions. While Özdemir and Kavak (29) classified sites as unilateral or bilateral, the current study and Borahan *et al.* (25) classified them as right side, left side, and bilateral. In the case of middle turbinate concha bullosa, Koo *et al.* (28) reported an incidence of 17.3% for unilateral and 36.4% for bilateral. The incidence of unilateral type was 11.3% and bilateral type was 27.4% for superior turbinate concha bullosa. The incidence of concha bullosa of the inferior turbinate was 1.0% (28). In Alnatheer *et al.*'s (31) study, the number of bilateral and left inferior CB cases was similar, which is consistent with our findings.

The nasal septum comprises the perpendicular plate of the ethmoid bone and the vomer. The perpendicular plate of the ethmoid bone extends to the frontal bone and sphenoidal rostrum and continues above the cribriform plate (32). Mladina *et al.* (33) called pneumatization of the perpendicular plate of the ethmoid bone "sinus septi nasi" and hypothesized that sinus septi nasi originates from the frontal sinus, the sphenoidal sinus, or the vomeronasal organ. The prevalence of NSP was 59.1% in the current study. While this was higher than reported by Dua *et al.* (34) (2%), Dawood (12) (16.7%), Devajara *et al.* (18) (27.1%), and Mladina *et al.* (33) (34.4%), it was lower than reported by Mureşan *et al.* (32). The cause of these different results may be ethnic differences or the origin of the NSP (from the frontal sinus, sphenoidal sinus, or vomeronasal organ). The origin of the NSP was considered in the present study. All pneumatized areas in the nasal septum were considered as NSP, regardless of their location, which may be a limitation of this study. While there was no significant difference between gender and NSP prevalence, there was a significant difference and correlation between age groups ($p = 0.026$ and $p = 0.009$, respectively) in the current study. Most pneumatized patients were between 18 and 65 years old. Similar to the current study, Dawood's study (12) found that the frequency of anatomic variants did not differ significantly with respect to gender. Nasal septal deviation was present at the rate of 73.4% in females and 70.2% in males. Meanwhile, NSP was found in 18% of females and 15.5% of males.

NSD plays an important role in nasal breathing and can cause breathing difficulties, sleep apnea, and facial pain (35). The prevalence of NSD is reported to be between 19.4% and 89.3% in the literature (8, 14, 29, 34, 36, 37), and our results are compatible with this (50%). Variable results between studies may be due to different ethnic origins or different classifications of NSD (38). In the present study, NSD was not classified; only a midline deviation greater than 4 mm was accepted as a deviation, which may be another limitation of the current study. The prevalence of NSD differed between genders in some previous studies. According to Madani *et al.* (39), the prevalence of NSD in male patients was higher than in females, as in the current study ($p = 0.012$), whereas Smith *et al*. (37) showed that NSD was more prevalent in females, although the difference was not significant. On the other hand, Dawood (12), Bora *et al.* (40), Özdemir and Kavak (29), and Shrestha *et al.* (41) showed there was no significant difference in the prevalence of NSD between genders. Özdemir and Kavak found that there was no significant difference between age and the prevalence of NSD. Our results support this finding. Most nasal variations have a high prevalence in patients with NSD (42). While some previous studies found no significant relation between CB and NSD (29, 37), other studies showed a significant relation (23, 43). There was no significant difference between the prevalence of CB and the prevalence of NSD in the current study ($p = 0.675$). To the best of our knowledge, the difference between the prevalence of NSD and NSP has not been evaluated in the literature. In the present study, this situation was investigated and no difference was found between these prevalences. In addition, there was a significant difference and correlation between the prevalence of CB and the prevalence of NSP in the current study.

Conclusion

While CB and NSP are prevalent anatomical variations within the studied population, they do not appear to be significant risk factors for NSD. These findings enhance our understanding of sinonasal anatomy and can aid in the diagnostic and therapeutic processes for patients with nasal and paranasal sinus conditions. Further research with larger sample sizes and diverse populations is recommended to confirm these findings and explore the clinical implications of these anatomical variations in greater detail.

Türkçe öz: *Konka bülloza ve nazal septum pnömatizasyonu prevalansı ve nazal septum deviasyonu ile ilişkisinin konik ışınlı bilgisayarlı tomografi ile değerlendirmesi. Amaç: Bu çalışma, konka bülloza (KB) ve nazal septum pnömatizasyonunun (NSP) nazal septum deviasyonuna (NSD) etkisi olup olmadığını araştırmak Akdeniz bölgesindeki Türk popülasyonun bir alt grubunda KB ve NSP prevalansını belirlemek amacıyla yapılmıştır. Gereç ve Yöntem: 230 hastanın konik ışınlı bilgisayarlı tomografi (KIBT) görüntüleri KB, NSP ve NSD varlığı açısından retrospektif olarak değerlendirildi. KB, üst, orta veya alt konka içinde herhangi bir boyutta pnömatizasyonun varlığı olarak tanımlandı. KB lateralite, NSP, NSD, yaş ve cinsiyet de kaydedildi. Veriler SPSS kullanılarak analiz edildi ve istatistiksel anlamlılık $p<0.05$ olarak kabul edildi. Bulgular: Hastaların %66,5'inde en az bir KB, %59,1'inde NSP ve %50'sinde NSD vardı. Cinsiyet ile KB ve NSP prevalansı arasında anlamlı fark bulunmazken, NSP prevalansı ile yaş arasında anlamlı fark vardı ($p= 0,026$). NSD ile CB ve NSP arasında ilişki yoktu (sırasıyla $p= 0.675$ ve $p= 0.788$) Sonuç: KB ve NSP'nin NSD'ye etkisinin olduğu hipotezine rağmen, bu çalışma NSD ile KB/ NSP arasında bir ilişkisi olmadığını göstermektedir. Anahtar kelimeler: pnömatizasyon; konka bulloza, nazal septum; konik ışınlı bilgisayarlı tomografi; nazal kavite*

Ethics Committee Approval: The study was carried out in accordance with the principles of the Declaration of Helsinki, and ethical approval was obtained from the Ethics Committee of the Faculty of Medicine (approval number: KAEK-230).

Informed Consent: Participants provided informed constent.

Peer-review: Externally peer-reviewed.

Author contributions: BSS, RSG, HTA participated in designing the study BSS, RSG participated in generating the data for the study. BSS, RSG participated in gathering the data for the study. HTA participated in the analysis of the data. BSS, HTA wrote the majority of the original draft of the paper. RSG participated in writing the paper.

BSS, RSG, HTA has had access to all of the raw data of the study. BSS, HTA has reviewed the pertinent raw data on which the results and conclusions of this study are based. BSS, RSG, HTA have approved the final version of this paper. BSS, RSG, HTA guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

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