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Research Article

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Determination of the Lund-Mackay Score in the Asymptomatic Population: The Mean Lund Score in Children and Adults without Symptoms and Signs of Rhinosinusitis

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Abstract

Objective: Computed tomography (CT) plays an important role in the diagnosis and management of chronic rhinosinusitis (CRS). Among the CT-based staging systems, the Lund–Mackay score (LMS) exhibits a strong linear correlation between the nasal symptom severity and radiographic disease. This study aimed to determine the baseline (normal) LMS of patients without symptoms or signs of CRS. It also explored whether a measurable increase in the adenoid thickness to nasopharyngeal cavity (AT/NC) ratio correlates positively with LMS in these patients.

Materials and Methods: Between 2014 and 2023, 1418 individuals without clinical findings of rhinosinusitis who were scheduled for otologic procedures underwent temporal bone CT scans at a tertiary academic hospital. These cases were retrospectively analysed using a cross-sectional design.

Results: Of the 1661 patients in the radiologic database, 1418 met the inclusion criteria, including 718 males and 700 females; 946 were adults and 472 were children. The cohort's mean age was 28.23 years. The mean LMS was 2.5 among pediatric and 1.8 among adult patients. The AT/NC ratio did not correlate with LMS in either group.

Conclusion: Our study determined the incidental LMS in adults (1.8) and children (2.5). The maxillary sinus was the most frequently abnormal, followed by the anterior ethmoid sinuses. In the absence of CRS symptoms or acute/subacute upper respiratory infections, adenoid hypertrophy may not significantly predict the severity of the sinus disease.

Keywords Lund score · computed tomography · chronic rhinosinusitis · sinus staging · asymptomatic population

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INTRODUCTION

Computed tomography (CT) of the paranasal sinuses plays a significant role in the evaluation and diagnosis of chronic rhinosinusitis (CRS) (1). While CT is not typically required for the clinical diagnosis of rhinosinusitis, it remains the most reliable imaging modality for confirming CRS and guiding potential surgical interventions (2). It helps clinicians to make an objective evaluation that complements the subjective findings of physical examination and nasal endoscopy in diagnosing CRS. In addition, CT is the only imaging modality that provides detailed anatomical data about the sinonasal anatomy for endoscopic sinus surgery (3). Computed tomography is essential for both diagnosing CRS and creating an anatomical roadmap if surgical intervention is required.

Due to the crucial role of CT in diagnosing and managing CRS, CT-based staging systems have become increasingly prominent. In 1997, the American Academy of Otolaryngology Task Force on Rhinosinusitis proposed the Lund–Mackay system for radiologically staging CRS on CT images (4). Studies comparing radiographic staging systems for CRS have shown that the Lund–Mackay score (LMS) demonstrates the strongest linear correlation between nasal symptom severity and radiographic disease (5-7). The LMS quantifies the radiographic findings on the paranasal sinus CT scan with a total score ranging from 0 to 24. Because it is both simple and reliable, LMS has been recommended for radiologically staging CRS (4, 8). Although patients without CRS are expected to have an LMS close to 0, the mean score in asymptomatic populations has not been clearly established.

Some studies have examined LMS in the asymptomatic population (3, 9). Ashraf et al. reported a mean LMS of 4.26 in an asymptomatic adult cohort, and Hill et al. reported a mean LMS of 2.81 in an asymptomatic pediatric cohort (3, 9). In a recent meta-analysis examining radiological abnormalities of the paranasal sinuses in asymptomatic cohorts, Razi et al. identified only five studies involving 532 patients that had used the LMS as an outcome. They reported that the overall LMS was 2.24 across the cohorts in these five studies (10).

This study aimed to determine the baseline (normal) LMS in adult and pediatric patients without symptoms and signs of CRS. It also aimed to explore whether a measurable increase in the adenoid thickness to the nasopharyngeal cavity (AT/NC) ratio correlates positively with the LMS, an indicator of sinus disease severity, in these patients. This study is notable for its large number of patients, as it includes more than the cumulative number of patients in previous studies.

MATERIALS AND METHODS

Study population

This retrospective cross-sectional study included 1418 patients aged 8 months to 87 years without a clinical diagnosis of rhinosinusitis who underwent CT of the temporal bones before otologic surgery over 10 years (2014–2023) at a tertiary academic medical centre. These 1418 patients were selected from among 1661 patients based on the eligibility criteria below, with 243 excluded from this study. The study was approved by Marmara University, Clinical Research Ethics Committee for Clinical Research (Date: June 1, 2023, No: 09.2023587).

Eligibility criteria

The patients' electronic medical records and temporal bone CT scans were screened against the eligibility criteria. The exclusion criteria were as follows: (i) no coronal plane imaging, (ii) severe motion artefacts, (iii) incomplete imaging of the complete set of sinuses, (iv) a history of or under evaluation for CRS, (v) cystic fibrosis, (vi) craniofacial malformations, (vii) facial fractures, (viii) previous nasal surgery, (ix) upper respiratory tract infections within 1 month before the CT scan, and (x) possible otitis media with effusion in which the middle ear and/or mastoid cavity was full of fluid on the CT scan.

Lund-Mackay scoring system

A senior radiologist and senior otorhinolaryngologist reviewed the CT scans according to the Lund–MacKay system (4). In this system, the sinuses (maxillary, anterior ethmoid, posterior ethmoid, frontal, and sphenoid) on both sides are scored as normal (0), partially opacified (1), or totally opacified (2), and the ostiomeatal complex (OMC) is scored as unobstructed (0) or obstructed (2). Therefore, the total LMS ranges from 0 to 24. The LMS was calculated for each patient by examining the paranasal sinuses on temporal CT scans before ear surgery. Given the possibility that temporal CT scans may not fully capture all paranasal sinuses, a correction was applied, and the corrected LMS was calculated according to the formula previously described by Nazri et al. (11):

$$\text{Corrected LMS} = \frac{obtained\ LMS}{24-(\Sigma correction\ factor)} \times 24$$

where the "correction factor" equals 1 for a partially unseen sinus and 2 for a wholly unseen sinus. The correction factor was not applied to the sporadic agenetic sinuses and to the sinuses of pediatric patients that were not visible because they had not yet developed; however, these sinuses were noted.

Measurement of the adenoid tissue

The adenoid tissue was measured in the sagittal reformatted CT images. The AT/NC ratio was calculated as previously described by Fujioka et al. (12). In the sagittal plane, the distance between the outermost point of convexity of the adenoid shadow and the basioccipital was divided by the distance between the sphenobasioccipital and the posterior end of the hard palate.

Assessment of the CT scans

All CT scans were performed on a 128-slice scanner (Ingenuity Core 128, Philips Healthcare) with the following parameters: tube voltage=120 kV, effective tube current=80–160 mAs, slice thickness=0.6–1.0 mm, pitch=0.5, and rotation time=0.28 s. The field of view was adjusted from the hard palate to above the end of the frontal sinuses. The scan direction was craniocaudal, and multiplanar reconstruction was performed on all images. Each image was analysed by a senior radiologist and senior otorhinolaryngologist involved in this study. The images were graded using the Lund–Mackay system, and two reviewers assigned a consensus LMS to each patient (4).

Statistical analysis

The data were analysed using SPSS Statistics (version 23.0; IBM Corp., Armonk, NY, USA). The conformity of the variables to a normal distribution was assessed visually (histograms) and analytically (Kolmogorov–Smirnov test). Continuous variables are reported as the mean±standard deviation, and categorical variables are reported as the frequency (percentage). The correlations between the variables were assessed using Spearman's rank correlation coefficient (r_s). Variables were compared between groups using Student's *t*-test if normally distributed or the Mann–Whitney U-test if non-normally distributed. A *p*-value of <0.05 was considered statistically significant.

RESULTS

Of the 1661 patients in the radiologic database, 1418 met the eligibility criteria, of whom 718 were male and 700 were female. In addition, 946 were adult and 472 were pediatric patients. The mean age in the study cohort was 28.23 years (10 months to 87 years; Table 1). The patients' high-resolution CT scans (slice thickness=1 mm) performed before otologic surgeries were examined. Their surgery types were as follows (Table 1): cochlear implantation (n=541, 38.2%), tympanoplasty (n=402, 28.3%), mastoidectomy (n=328, 23.1%), and exploratory tympanotomy (n=147, 10.4%).

Table 1. Demographics of the study group

		n	%	Mean	Minimum	Maximum
Sex	Female	700	49.4			
	Male	718	50.6			
Age group	Child	472	33.3			
	Adult	946	66.7			
Age				28.23 years	10 months	87 years
Type of surgery	Cochlear implantation	541	38.2			
	Tympanoplasty	402	28.3			
	Mastoidectomy	328	23.1			
	Exploratory tympanotomy	147	10.4			

The mean LMS was 2.5 among the pediatric patients (left side=1.3, right side=1.2) and 1.8 among the adult patients (left side=0.9, right side=0.9; Table 2). The distribution of LMS is shown for the entire cohort in Figure 1 and separately for adult and pediatric patients in Figure 2.

Table 2. Overall mean Lund score distribution among children and adults

	Age group				
	Child		Adult		
Lund score	Mean	Standard deviation	Mean	Standard deviation	P value
Maxillary	0.7	1.0	0.7	0.7	0.493
Anterior ethmoid	0.5	0.9	0.4	0.4	0.235
Posterior ethmoid	0.5	0.9	0.3	0.3	0.105
Osteomeatal complex	0.5	1.2	0.1	0.1	≤0.001
Frontal	0.1	0.4	0.1	0.4	0.014
Sphenoid	0.3	0.7	0.2	0.4	0.057
Left Lund-Mackay score	1.3	2.2	0.9	0.9	0.407
Right Lund-Mackay score	1.2	2.1	0.9	0.9	0.767
Total Lund-Mackay score	2.5	4.1	1.8	1.8	0.952

Regarding specific sinus involvement, the maxillary sinus was the most frequently abnormal (31.4%), followed by the anterior ethmoid sinus (21.4%), posterior ethmoid sinus (17.7%), sphenoid sinus (8.6%), OMC (6%), and frontal sinus (3.7%). The percentage of abnormal sinuses in adult and pediatric patients is shown in Table 3.

Table 3. Overall percentage of sinus abnormalities among patients

	Age group		
Sinus	**Child**	**Adult**	**All patients**
	%	**%**	**%**
Maxillary	29.8	32.1	31.4
Anterior ethmoid	23.1	20.6	21.4
Posterior ethmoid	20.1	16.5	17.7
Osteomeatal complex	12.5	2.7	6.0
Frontal	2.3	4.5	3.7
Sphenoid	10.7	7.4	8.6

Sinus abnormality: a Lund score of 1 or above in the described sinus

LMS was measured for each surgical group. The mean scores were 2.4 for the cochlear implantation group, 1.7 for tympanoplasty, 2.0 for mastoidectomy, and 2.1 for exploratory tympanotomy. There was no statistically significant difference in LMS scores among the different types of surgery (p=0.450) (Table 4).

We examined the relationship between adenoid hypertrophy and the mean LMS in adult and pediatric patients. The database contained sagittal reformatted CT images for 383 patients: 315 adult and 68 pediatric patients. We calculated the AT/NC ratio for these 383 patients. The mean total LMS correlated negatively with age among the pediatric patients (p<0.006). However, the mean total LMS was not correlated with the AT/NC ratio and adenoid size among the pediatric patients (Table 5). In contrast, the mean total LMS correlated positively with adenoid size among the adult patients (p<0.009). However, the mean total LMS was not correlated with the AT/NC ratio and age among the adult patients (Table 5).

We conducted a sub-analysis to determine whether a relationship existed between adenoid hypertrophy and a mean total LMS of <4 (Group 1) vs. ≥4 (Group 2; Table 6). In the pediatric patients, the adenoid size and AT/NC ratio did not significantly differ between the groups. In the adult patients, while the AT/NC ratio did not differ significantly between the groups, the adenoid size was significantly greater in Group 2 than in Group 1.

DISCUSSION

Computed tomography plays an important role in both diagnosing and managing CRS. In patients with rhinosinusitis who do not respond to medical therapy, computed tomography is frequently used to assess the extent of the disease and assist in surgical decision-making.

The prevalence of sinus abnormalities on CT scans has been explored in both symptomatic individuals and those without clinical complaints. According to the cohort characteristics, between 27% and 42% of individuals without a previous diagnosis of chronic rhinosinusitis may have some degree of sinus opacification (13, 14). Furthermore, studies examining CT findings in patients with paranasal sinus symptoms have often failed to establish a correlation between symptom severity and the degree of abnormality in CT images (15). A clear definition of what constitutes a “normal” range on the Lund–Mackay scale appears to be warranted based on these findings. This type of information may be valuable as a diagnostic reference for CRS, especially in cases where the clinical presentation is ambiguous or non-specific. Such baseline values may also be used to determine an acceptable degree of residual disease on CT images following medical management or operative intervention.

Our study provides valuable insights into the distribution of LMS in children and adults without symptoms or signs of rhinosinusitis. Our findings, which show a mean total LMS of 2.5 in children and 1.8 in adults, contribute to the growing body of evidence examining the role of LMS in both symptomatic and asymptomatic settings. The LMS has been proven helpful in evaluating the progression of sinus disease and guiding treatment decisions. However, less attention has been given to the baseline or “normal” LMS in asymptomatic populations,

Table 4. Comparison of Lund-Mackay Scores across different types of surgery

		Total Lund-Mackay score						
		Count	Mean	Standard deviation	Median	Minimum	Maximum	p value
Type of surgery	Cochlear implantation	541	2.4	3.8	0	0	20	
	Tympanoplasty	402	1.7	2.5	1	0	20	
	Mastoidectomy	328	2.0	2.9	1	0	20	
	Exploratory tympanotomy	147	2.1	3.0	1	0	14	0.450

particularly in children. Our study fills this gap by offering a benchmark for comparison with symptomatic patients.

Table 5. Correlation analysis between the total mean Lund-Mackay score and age adenoid size and AT/NC ratio in pediatric and adult study groups

		Total Lund-Mackay score in pediatric group	Total Lund-Mackay score in the adult group
Age	r	−0.127	0.052
	p	0.006	0.108
	N	472	942
AT/NC ratio	r	−0.110	0.094
	p	0.371	0.095
	N	68	315
Adenoid size	r	−0.044	0.120
	p	0.719	0.033
	N	68	314

AT/NC: Adenoid thickness–nasopharyngeal cavity ratio

Chen et al. found a mean total LMS of 0.96 among 490 adults without symptoms and signs of rhinosinusitis, compared to 8.72 among 119 adult patients diagnosed with rhinosinusitis with a right total LMS of 4.35 and a left total LMS of 4.37 (16). They found that patients with a bilateral total LMS of >5 or a unilateral total LMS of >4 were beyond 97.7% of the general population. Conversely, Bhattacharrya et al. found a mean total LMS of 4.3 among asymptomatic patients (n=130) and 9.8 among symptomatic patients with CRS who underwent surgery (n=171) (1). For CT scans, they found that a cut-off of ≥3 for a "normal" LMS provided 92% sensitivity and 46% specificity for CRS, while a cut-off of ≥4 provided positive and negative predictive values of 89% and 57%, respectively. The low negative predictive value (57% when adopting the cut-off value of the normal Lund score as 4) in the study of Bhattacharrya et al. showed that the cut-off value of the normal Lund score should be below 4 to have a higher ratios of negative predictive value (1). Based on assessments of the receiver operating characteristic curve and positive and negative predictive values, they concluded that an appropriate LMS cut-off for distinguishing normal and abnormal findings on sinus CT scans in their cohort was between 2 and 3. Our study supports this conclusion, as the mean LMS was 2.5 for pediatric and 1.8 for adult patients without signs or symptoms of CRS in our cohort. Ashraf and Bhattacharrya also found a mean total LMS of 4.26 among 199 asymptomatic adults aged 17–90 years (3).

However, the range of "normal" LMS in a general asymptomatic population remains debated, and studies exploring this issue have reported a "normal" LMS of between 1 and 4 (3, 11, 17, 18). A systematic review by Razi et al. indicated that the mean LMS among asymptomatic populations was estimated at 2.24 (95% confidence interval [CI]: 1.61–2.87), and around 15% of these individuals exhibited a score equal to or exceeding 4 (10). The 2020 European Position Paper on Rhinosinusitis and Nasal Polyps also reported that an LMS of >5 had a positive predictive value of 96% for CRS (19).

The mean total LMS was slightly higher in pediatric than in adult patients in our cohort (2.5 vs. 1.8). This difference may be attributed to young children experiencing 6-8 viral upper respiratory tract infections yearly, with up to 10% of these cases complicated by acute bacterial sinusitis (10). Allergic rhinitis is also highly prevalent, affecting approximately 20% of children by adolescence. Hill et al. found a total LMS of 2.81 among 192 children without symptoms and signs of rhinosinusitis aged 1-18 years (9). While their results were similar to ours for the pediatric patients, they found that pediatric patients seemed to have a lower LMS than in their previous study on adults (mean LMS=4.26) (3). In their systematic review, Razi et al. reported similar results to our study, with a lower mean LMS in adults (1.74) than in children (2.12) (10).

Regarding specific sinus involvement in our cohort, the maxillary sinus was the most frequently affected (31.4%), followed by the anterior ethmoid sinuses (21.4%), posterior ethmoid sinus (17.7%), sphenoid sinus (8.6%), OMC (6%), and frontal sinus (3.7%). The percentages of abnormal sinuses were similar between adult and pediatric patients for all the

Table 6. Relationship between the total mean Lund-Mackay score, AT/NC ratio, and adenoid size in pediatric and adult study groups when the cut-off value for the Lund score was set to the value of 4

		Mean total Lund-Mackay score				
		<4		≥4		
		Mean	Standard deviation	Mean	Standard deviation	p
Pediatric study group	AT/NC ratio	.498387839	.178974402	.412154258	.201780987	0.149
	Adenoid size	11.10	3.88	10.40	3.99	0.554
Adult study group	AT/NC ratio	.290984397	.120680135	.326023497	.151907489	0.105
	Adenoid size	7.37	3.16	8.67	4.10	0.047

AT/NC: Adenoid thickness-nasopharyngeal cavity ratio

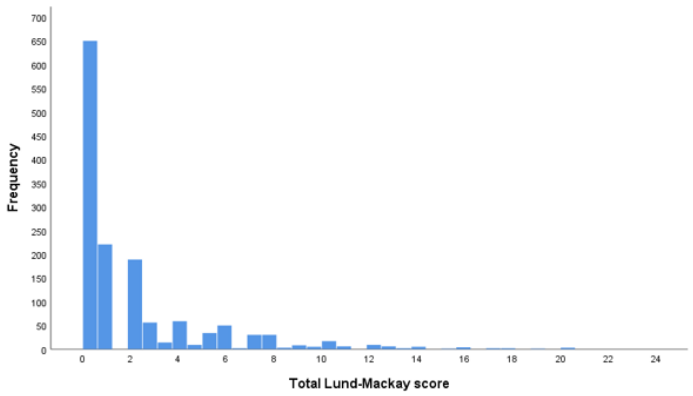


Figure 1. Total Lund-Mackay score distribution of all patients

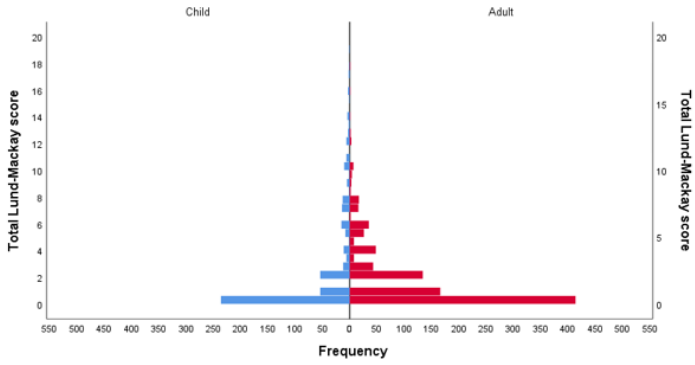


Figure 2. Total Lund-Mackay score distribution for children and adults

sinus groups except the OMC. For the OMC, the percentage of abnormal sinuses was 12.5% among the pediatric patients and 2.7% among the adult patients. Our results differ from those of Ashraf et al., who found a higher percentage of abnormal sinuses, with the anterior ethmoid sinuses most frequently affected (48.2%), followed by the posterior ethmoids (44.8%), maxillary sinuses (35.2%), OMC (25.4%), sphenoid sinuses (21.1%), and frontal sinuses (7.6%) (3). In their meta-analysis, Razi et al. reported an expected overall prevalence of maxillary retention cysts of 13.01% (95% CI: 8.33%–18.55%) across general asymptomatic populations, with no difference between adults and children (10). They also reported that 17.73% (95% CI: 8.67%–29.08%) of the general asymptomatic population is expected to have mucosal thickening of ≥2 mm, with no difference between adults and children. Previous reports on incidental sinus opacification have documented incidence rates between 20% and 70% (20-22). Kim et al. found that the incidence of incidental sinus opacification was 28.8% (107/372) among patients undergoing septoplasty or septorhinoplasty, with the maxillary sinus being the most commonly involved (73/107, 68.2%) (17). The definition of sinus opacification varies between studies, which may cause proportional differences in sinus involvement among them. In our study, we considered any mucosal abnormality causing an LMS of ≥1 for that sinus region as an abnormality.

Previous studies have demonstrated a significant association between chronic otitis media (COM) and CRS. However, the presence of COM does not appear to have a significant impact on LMS in patients diagnosed with CRS (23). In this study, LMS values were evaluated across various surgical subgroups, and no statistically significant differences were observed among the four surgical types (p=0.450).

An increase in the size of the adenoid tissue might lead to sinonasal problems by obstructive effects on sinus drainage and ventilation. Anatomical obstruction due to adenoid hypertrophy may lead to a greater burden of sinus involvement. In this context, larger adenoids would be expected to create mechanical obstruction, impairing mucociliary clearance and predisposing the sinus cavities to infection or inflammation, resulting in a higher LMS. Fujioka et al. introduced the adenoid-nasopharyngeal (A/N) ratio, which represents the proportion of the adenoid size relative to the nasopharynx (12). This classical index is used to assess the extent of adenoid hypertrophy and can reflect the degree of nasopharyngeal obstruction (24, 25). Additionally, the relationship between adenoid hypertrophy and pediatric CRS has been extensively studied and confirmed over recent years (26). Our study explored whether a measurable increase in the adenoid tissue correlates with higher LMS, an indicator of sinus disease severity, in pediatric and adult patients without signs or symptoms of CRS. However, our findings revealed no significant relationship between the AT/NC ratio and the total mean LMS in both adult and pediatric patients, suggesting that, without clinical symptoms of CRS or acute or subacute upper respiratory tract infections, adenoid hypertrophy may not significantly predict the severity of sinus disease.

We excluded patients with loss of aeration in the middle ear and mastoid cavity on CT scans, as these findings may indicate recent otitis media or upper respiratory tract infections. This exclusion criterion may explain why, contrary to previous reports, LMS values did not differ between patients with higher and lower A/N ratios in our cohort. For instance, Li et al. reported that patients with otitis media with effusion had both higher A/N ratios and higher LMS and that children with adenoid hypertrophy and serous otitis media were more likely to have CRS compared with those with adenoid hypertrophy alone (27). The absence of such patients in our cohort may account for the lack of association between the A/N ratio and LMS observed in our study.

CONCLUSION

Our study showed that the mean incidental LMS was 1.8 in adults and 2.5 in children. These results may indicate that, in future research, patients with CRS should be evaluated using a new LMS, calculated by subtracting the scores of the asymptomatic population. The review also noted that abnormalities were most commonly observed in the maxillary sinuses, with the anterior ethmoid sinuses being the second most affected site. Finally, without the clinical symptoms of CRS or acute or subacute upper respiratory tract infections, adenoid hypertrophy may not significantly predict the severity of the sinus disease.

Main points

1. The Lund–Mackay score (LMS) demonstrated the strongest linear correlation between nasal symptom severity and radiographic disease.
2. The incidental LMS in adult (2.5) and pediatric (1.8) patients without signs and symptoms of rhinosinusitis.
3. Without clinical symptoms of rhinosinusitis or acute or subacute upper respiratory tract infections, adenoid hypertrophy may not significantly predict the severity of sinus disease.

Ethics Committee Approval	Ethics committee approval was received for this study from the ethics committee of Marmara University, Clinical Research Ethics Committee for Clinical Research (Date: June 1, 2023, No: 09.2023587).
Informed Consent	Due to the retrospective design of the study, informed consent was not taken.
Author Contributions	Conception/Design of Study- O.A., Y.G., Ö.D., M.U., E.I., F.A., Ö.F.K., R.N.T.; Data Acquisition- O.A., Y.G., Ö.D., M.U., E.I., F.A., Ö.F.K., R.N.T., Ş.K.; Data Analysis/Interpretation- O.A., Y.G., Ö.D., M.U., E.I., F.A., Ö.F.K., R.N.T., Ş.K.; Drafting Manuscript- O.A., Y.G., Ö.D., M.U., E.I., F.A., Ö.F.K., R.N.T., Ş.K.; Critical Revision of Manuscript- O.A., Y.G., Ö.D., M.U., E.I., F.A., Ö.F.K., R.N.T., Ş.K.; Final Approval and Accountability- O.A., Y.G., Ö.D., M.U., E.I., F.A., Ö.F.K., R.N.T., Ş.K.
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