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Assessment of hiatus defect size in hiatal hernia patients using computed tomography

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ABSTRACT

Objectives: The aim of this study is to investigate the hiatus defect diameter by measuring on multi-detector computed tomography images in hiatal hernia patients.

Methods: The multi-detector computed tomography images of 50 patients and 50 individuals in control group included in this study were investigated. The hiatus surface area (cm²), hiatus antero-posterior and transverse diameters (cm), and the thickness of both diaphragmatic crura (mm) were measured by reformatting contrast-enhanced thoraco-abdomino-pelvic computed tomography images using the region of interest method.

Results: In this study, a significant difference was obtained among groups according to hiatus surface area, hiatus antero-posterior, and transverse diameter measurements, and both left and right diaphragmatic crural thickness measurements (P<0.001). In the patient group, the cut-off values were determined by using ROC analysis, and the values above these cut-off values enabled a hernia diagnosis with high sensitivity and specificity.

Conclusion: Measuring the hiatus surface area on multi-detector computed tomography images could serve as a supplementary criterion for diagnosing of hiatal hernia.

Keywords: Computed tomography, gastroesophageal reflux, hiatal hernia, hiatal surface area

Hiatal hernia (HH) occurs through the herniation of abdominal contents into the mediastinum via an enlarged esophageal hiatus [1]. In the Western hemisphere, it is most associated with Gastroesophageal reflux disease (GERD) [2].

In the study conducted by Shamiyeh *et al*. on cadavers, the mean hiatal surface area (HSA) was measured as 5.84 cm² [3]. In the study by Moten *et al*. [4], patients with HH had a mean HSA of 6.9 cm², while ones without HH had a mean HSA of 2.5 cm². It was observed that the frequency of GERD was higher in patients with HH [4].

HH is classified as 3 subtypes. Type 1 is a sliding type HH, where the gastroesophageal junction (GEJ) moves over the hiatus due to the laxity of the phrenoesophageal ligament [1, 2]. Type 1 is the most associated with GERD. It is also the most frequently observed HH type, with reported rates ranging 10%-80% [2]. Type 2 is characterized by the normal position of the GEJ, but the fundus of the stomach moves upwards through the hiatus. This type is rare and constitutes less than 5% of cases. Type 3 involves both the GEJ and the stomach fundus shifting into the mediastinum. This type is generally observed in elderly

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adults and more commonly in women [1, 2].

HH and GERD are diagnosed through symptom scoring, upper gastrointestinal system endoscopy (GISE), and barium radiographs [5]. However, there is a limited correlation between barium radiographs with intraoperative findings, and the herniated volume of the stomach, and there is no consensus on the use of barium radiographs in the diagnosis [5]. Additionally, possessing the defect diameter is significant in terms of antireflux treatment [6]. The presence of a wide hiatus preoperatively can result in surgical failure and possessing the hiatus diameter can lead to the use of primary surgical repair methods in such cases with large defects [6].

Recently, the widespread use of multi-detector computed tomography (MDCT) and multiplanar reconstruction images for investigation and measuring HSA enable a more precise determination of associated conditions and the normal range of HSA. Furthermore, MDCT permits visualization of the structure, thickness, and variations of the right and left diaphragmatic crura thickness (DCT) [7].

In patients with HH, the main symptom occurs due to GERD, and the initial approach in treatment is commonly antireflux therapy, which aims to manage symptoms [8]. However, definitive treatment is achieved via surgery [8]. Surgical options include Nissen fundoplication (NF), Toupet fundoplication (TF) (in the presence of esophageal dysmotility), Door fundoplication (DF), or NF with primary surgical mesh repair [8].

In this study we aimed to investigate the accuracy of preoperative MDCT images in diagnosing HH by measuring the HSA, hiatus AP and transverse diameters (TD), and both DCT. Furthermore, we aimed to observe the association between these measurements and the accuracy of HH diagnosis, the type of surgery performed, and the relationship between GERD and defect size.

METHODS

This retrospective study was conducted in accordance with the Declaration of Helsinki as well as reviewed and approved by the ethics committee of our hospital (Approval date: 05.07.2023 and no: 2011-KAEK-25 2023/07-26).

Patient Population

A total of 50 patients who presented to the General Surgery department between September 2019 and December 2022 and, were diagnosed with HH based on their symptoms, preoperative gastroscopy results, and MDCT findings, all of which were subsequently confirmed by the surgery outcomes, were randomly included in the patient group. The control group consisted of 50 individuals who presented to the general surgery clinic with complaints of abdominal pain and based on the results of computed tomography, did not show evidence of hiatal hernia. Participants in the control group were randomly selected to match the age and gender distribution of the patient group.

The demographic data (gender, age), blood parameters (hemoglobin, albumin, MCV, chloride), preoperative gastroscopy data (gastroscopic Z-line, gastroscopic hiatus level, gastroscopic hill grade), MDCT images, and esophageal manometry results for reflux were investigated. Measurement results of hiatus AP and TD (cm), HSA (cm²), the right and left DCT (mm), and the type of hernia (type 1, 2, or 3) were surveyed. The presence of GERD was investigated clinically, manometrically, and radiologically respectively.

As inclusion criteria for the study.

1. Age 18 years or older.
2. Confirmed diagnosis of HH via GISE and MDCT.
3. Availability of preoperative CT images, GISE results, and manometry results in the hospital system.

As exclusion criteria.

1. Younger than 18 years old or older than 80 years old.
2. Absence of preoperative CT images and GISE results in the hospital system.
3. Absence of confirmed diagnosis of reflux through manometry

Analysis of CT Images

All abdomen CT scans were performed using a 128-slice multi-detector-row CT scanner (Toshiba Aquillion, Japan). For measurements, preoperative thin-slice MDCT images available in the hospital system were investigated. The images were acquired at deep inspiration with a slice thickness of 1.25 mm in

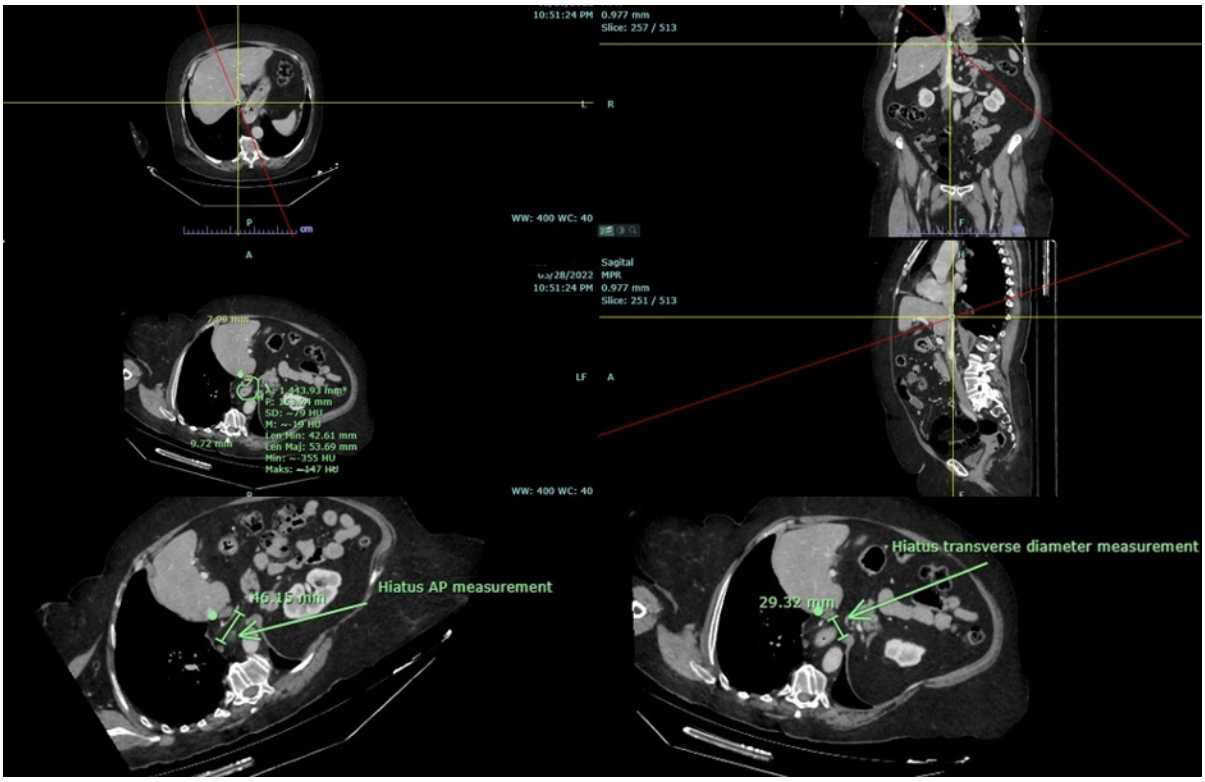

Fig. 1. Measurement of the hiatal surface area on axial, coronal, oblique axial, and sagittal computed tomography images with the corrected angle (Measurements of hiatus antero-posterior and transverse diameter using reformatted oblique axial images are shown).

the form of Intravenous contrast-enhanced thoraco-abdomino-pelvic CT. Multiplanar reformat (MPR) images of each MDCT scan were obtained, and the measurements were performed based on the reconstructed images adjusted to the appropriate angle of the hiatus (Fig. 1). This method is similar to the measurement technique used in a previous study by Moten *et al*. [4]. On a suitable image of the esophageal hiatus obtained, the AP and TD of the hiatus were initially measured, followed by the measurement of HSA in an elliptical shape that fits the esophageal hiatus, using the Region of Interest (ROI) measurement tool in an elliptical manner (Fig. 1). Additionally, the right and left DCT were measured. Radiological evidence of reflux was assessed by examining content retention.

Statistical Analysis

IBM Statistical Package for the Social Sciences (SPSS) version 22 for Windows, Chicago, IL, USA, was used for all statistical analyses. The Kolmogorov-Smirnov test was conducted to test the homogeneity of distributions among groups. Mean values, standard deviations, and median values of normally distributed and non-normally distributed groups were calculated. T-test was performed to compare age averages and gender distributions between the patient and control groups. The cut-off values for right and left DCT, HSA, hiatus AP, and TD were determined using ROC analysis. Sensitivity, specificity, and the area under the curve (AUC) with a 95% confidence interval (CI) were also calculated. All variables were included in the univariate analysis. Explanatory factors with a $P \leq 0.2$ in this step were entered into the multivariate analysis. Results were given as odds ratio (OR) and 95% CI. The association between the presence of hernia with HSA, Hiatus AP, and TD as well as right and left DCT was assessed using Spearman's correlation test. The association between hernia types and GERD was analyzed using the Pearson-Chi Square test. Differences were considered statistically significant at $P<0.05$.

RESULTS

Fifty patients (24 females and 26 males) with mean age of 55.27±11.93 in patient group and 50 individuals (35 females and 15 males) with mean age of 50.74±13.71 in the control group were included in the study (Table 1).

ROC analysis was conducted to determine the cut-off values for HSA, hiatus AP diameter, and TD, as well as the right and left DCT. The cut-off for HSA was acquired as 2.8 cm² in ROC analysis and the hernia can be diagnosed with 87.7% sensitivity and 100% specificity for ones with HAS >2.8 cm^2 (AUC: 0.961, P<0.001) (Fig. 2). The cut-off of hiatus AP diameter was found to be 1.4 cm and hernia diagnosis can be carried out with 91.8% sensitivity and 92% specificity for ones with AP diameter >1.4 cm (AUC: 0.964, P<0.001) (Fig. 2). The cut-off for Hiatus TD was obtained as 1.7cm and individuals with hiatus TD >1.4 cm can be diagnosed with hernia with 83.6% sensitivity and 98% specificity (AUC: 0.960, P<0.001) (Fig. 2). The cut-off for right DCT was acquired as 4.4mm and HH can be diagnosed with 75.5% sensitivity and 66% specificity for individuals with right DCT >4.4 mm (AUC: 0.756, P<0.001) (Fig. 2). Finally, the cut-off of left DCT was determined as 4.5 mm and HH can be diagnosed with 63.3% sensitivity and 86% specificity in individuals with left DCT >4.5 mm (AUC: 0.786, P<0.001) (Fig. 2).

As per consideration of all variables together in multivariate analysis, the most significant association was between the hiatus AP diameter, and TD with the diagnosis of hernia (Fig. 2).

Subsequently, univariate and multivariate analyses were conducted for HAS, hiatus AP and TD as well as right and left DCT. In both analyses, significant differences were observed in both individual and the dependent variables (Table 2).

A significant correlation between reflux with HSA, hiatus AP, right and left DCT, TD, and esophagoscopic hill grade was determined. It was observed that as HSA, hiatus AP, TD, and esophagoscopic hill grade increased, the risk of reflux formation also increased (P<0.001).

In consideration of the distribution of hernia among patients, type 1 HH was observed in 27 individuals, type 2 HH in 6 individuals, and type 3 HH in 17 individuals respectively. As per the association between HH types and GERD, GERD was noticed in 24 individuals with type 1. There was a statistically significant increase in the frequency of GERD compared to the other group (P<0.001).

In terms of the surgical procedures, NF was performed in 44 individuals, TF in 2 individuals, NF with mesh repair in 3 individuals, and DF in 1 individual. Among the patients who underwent NF, the mean defect diameter of HSA was 10.93±11.49 mm, while the mean value for 3 patients who underwent NF with mesh repair was 46.33±13.6 5mm, indicating a larger defect size in individuals who underwent mesh repair. However, statistical analysis for surgeries apart from NF was not significant due to the restricted quantity of patients.

DISCUSSION

HH occurs as a result of the widening of the esophageal hiatus, leading to the herniation of the GEJ and various layers of the stomach into the mediastinum [6]. HH, which is quite common in the population, can be easily detected with increased screening frequency and more frequently used MDCT. This study proposes that the diagnosis of HH can be carried

Table 1. Demographic characteristics of patients and control groups

Characteristics	Total	Patients Group	Control Group
Gender			
Male	41	26	15
Female	59	24	35
Age (years)			
Mean ± standard deviation	53.47±13.10	55.27±11.93	50.74±13.71

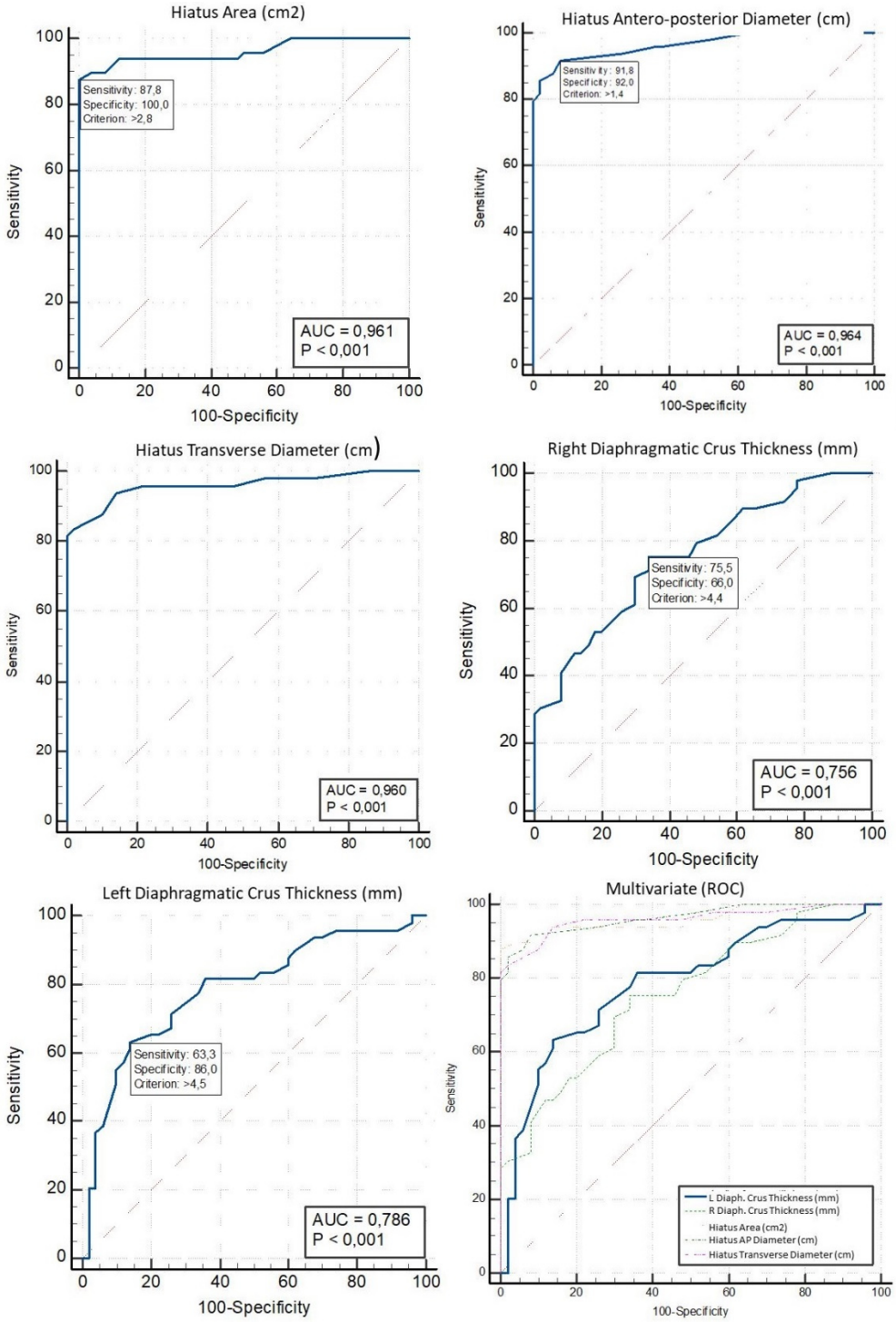

Fig. 2. ROC analyses.

out precisely by measuring HSA, Hiatus AP diameter, and TD using the MDCT in individuals underwent HH surgery.

In this study, the median value of HSA measurement in 50 individuals of patient group was 12.83±3.26 cm², and a cut-off value of 2.8 cm² was acquired. HH could be diagnosed with high sensitivity and specificity in ones with HSA >2.8 cm². In the control group, the median value of HSA was measured as 1.65±0.26 cm². There was a statistically significant difference between the two groups (P<0.01). In a study conducted by Quyang *et al*. [6], the mean value of

Tablo 2. Measurement results on MDCT in patients with hiatal hernia

	Univariate analysis		Multivariate analysis	
	OR (95% CI)	P Value	OR (95% CI)	P Value
Hiatus area (cm^2)	6.41 (2.39-17.15)	**<0.001**	25.04 (0.87-715.62)	0.06
Hiatus AP diameter (cm)	371.20 (13.36-103.11)	**<0.001**	3.47 (0.00-1.63)	0.22
Hiatus transverse diameter (cm)	427.55 (23.71-770.83)	**<0.001**	10.48(1.22-89.57)	0.03
Right diaphragmatic thickness (mm)	2.42 (1.59-3.69)	**<0.001**	10.01 (0.80-124.64))	0.07
Left diaphragmatic thickness (mm)	2.68 (1.69-4.23)	**<0.001**	6.34(0.46-87.39)	0.06
OR=odds ratio, CI=confidence interval, AP=Antero-posterior				

HSA in patients with HH was 6.9cm², whereas in patients without HH, it was 2.5cm². Similar to our study, it was anticipated that HSA could be significantly used for diagnosing HH.

In a study by Moten *et al*. [4], the diagnosis of HH could be carried out with 81% sensitivity and 88% specificity in individuals with HSA >3.5 cm². The results acquired in our study are similar to the previous studies. However, the determination of cut-off values additionally for Hiatus AP and TD sets our study apart and makes it stand out. This aspect becomes significant as it provides a more easily measurable parameter in cases where HSA measurement may not be feasible due to time constraints. In the patient group, the mean Hiatus AP diameter was 3.59 cm with a cut-off value of 1.4 cm, and the mean Hiatus TD was 3.55 cm with a cut-off value of 1.7 cm. In the control group, the mean Hiatus AP diameter was 1.12 cm, while the mean TD was 1.22 cm. There was a significant difference observed among groups (P<0.01).

Since the esophageal hiatus is not parallel to the body axis, measurements from axial or coronal images may not yield accurate results. Therefore, measurements were performed using corrected oblique axial images from MDCT. This method is similar to the oblique axial measurement method used by Moten *et al*. [4] and Quyang *et al*. [6].

As the HSA increases in patients with HH of this study, the frequency of reflux also increases. This finding is consistent with the study conducted by Batirel *et al*., where they emphasized that an increase in HSA size leads to a decrease in the tone of the lower esophageal sphincter, resulting in an increase in acid reflux [9]. Similarly, in our study, as HSA increased, a more frequent occurrence of reflux was observed in both the MDCT images and manometry. Franzen *et al*. also stated a similar result in their study, associating an increase in HSA value with an increase in reflux frequency based on manometry and pH results [10]. The lower esophageal sphincter (LES) is a structure located in the GEJ, consisting of a 3-4 cm long segment of smooth muscle with tonic contraction function [11]. Composed mainly of the crural part of the diaphragm, it plays a protective role against GERD [11]. The LES pressure ranges from 10-40 mmHg and is considered one of the classical defense mechanisms against GERD [12]. NF, in addition to hernia repair, includes antireflux effects, and the underlying mechanism involves alterations in LES motor functions [12].

HH can be categorized into 3 types. Type 1, representing the sliding type of HH, occurs due to the looseness of the phrenoesophageal ligament, which leads to the displacement of the gastroesophageal junction (GEJ) above the hiatus. Type 2 involves the normal position of the GEJ, but the stomach fundus displaces upward through the hiatus. Type 3 involves the displacement of both the GEJ and the stomach fundus into the mediastinum [1, 2]. There is an association between hernia type and GERD, with the highest reflux frequency appeared in type 1 HH, which is attributed to the looseness of the phrenoesophageal ligament. In this study, 27 individuals were observed with type 1, 6 individuals with type 2, and 17 individuals with type 3 HH. When considering the association between HH types and GERD, 24 out of 27 patients with type 1 were diagnosed with GERD. This group exhibited a statistically significant increase in the frequency of GERD compared to the other groups (P<0.001). However, there was no statistically significant increase in the frequency of GERD in patients

with type 2 HH and type 3 HH.

The presence of information on the opening and anatomy of the esophageal hiatus is essential for making informed decisions regarding the surgical approach and minimizing the risk of recurrence. In this study, NF was performed in 44 patients, TF in 2 patients, NF with mesh repair in 3 patients, and DF in 1 patient. Among the 3 patients who underwent NF with mesh repair, the mean HSA was acquired as 46.33±13.65 cm², indicating a larger defect size compared to other surgical groups.

Limitations

There are some limitations in this study. Apart from inadequate quantity of patients, there is an unequal distribution of surgical procedures. A cut-off of HSA can be determined with a patient group comprising similar and enough patients for each surgical procedure. Additionally, due to the small number of patients in this study, diaphragmatic crura variations were not investigated, and an adequate sample size could not be obtained for classification in this regard. Prospective studies including diaphragmatic crura variations can provide significant preoperative data to surgeons.

CONCLUSION

The measurement of HAS, hiatus AP and TD using the MDCT can serve as a supplementary criterion in diagnosing of HH. Furthermore, it can offer insight into the association between the defect size and reflux, the correlation between defect size and the chosen surgical approach, as well as the associated variations. This information proves highly advantageous for preoperative planning, optimizing the surgical strategy, and achieving better outcomes for the surgery.

Authors' Contribution

Study Conception: SGGÖ, DD; Study Design: SGGÖ, NKK, DD; Supervision: SGGÖ, DD; Funding: N/A; Materials: N/A; Data Collection and/or Processing: NZ, BB; Statistical Analysis and/or Data Interpretation: SGGÖ, NKK; Literature Review: NZ, BB; Manuscript Preparation: SGGÖ, DD and Critical Review: SGGÖ, DD.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

Financing

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