HAYDARPAŞA NUMUNE MEDICAL JOURNAL

DOI: 10.14744/hnhj.2021.04379
Haydarpasa Numune Med J 2023;63(1):8–15

hnhtipdergisi.com

ORIGINAL ARTICLE

Comparison of Various Measures for Anticipating Difficult Laryngoscopy in Turkish Population: An Observational Study

Derya Özden Omaygenç[1], Oylum Selçuk[2]

[1]Department of Anesthesiology, University of Health Sciences Türkiye, Istanbul Haseki Training and Research Hospital, Istanbul, Türkiye
[2]Department of Anesthesiology, University of Health Sciences Türkiye, Istanbul Training and Research Hospital, Istanbul, Türkiye

Abstract

Introduction: Difficult laryngoscopy (DL) was established as the most accurate determinant of difficult intubation. Here, we sought to assess the diagnostic value of various bedside tests for predicting DL. We also aimed to create a regression model in this context.

Methods: 137 patients were included in the study. Demographic features and eight diagnostic variables were evaluated for DL predictivity. These were retrognathia, presence of buck teeth, modified Mallampati test (MMT), upper lip bite test (ULBT), sternomental distance, interincisor distance (IID), thyromental distance, and neck circumference. DL was identified by Grade III-IV view during laryngoscopy according to the Cormack-Lehane classification.

Results: The frequency of DL was 27% (n=37) in our sample population. Among predictive tests, IID was lower in patients with DL, while mean MMT score, frequency of retrognathia, and that of Grade 3 in ULBT were significantly higher. According to the results of logistic regression analyses IID (Odds Ratio [OR]: 0.504, Confidence intervals [CI] 95% [0.260–0.978], p=0.043), MMT score (OR: 2.001, CI 95% [1.159–3.454], p=0.013), and presence of retrognathia (OR: 0.108, CI 95% [0.019–0.613], p=0.012) were determined as independent predictors of DL. Our predictive model (two out of three factors: IID ≤4 cm, MMT score≥3, and retrognathia) anticipated DL with a sensitivity of 35.1%, a specificity of 91%, a negative predictive value of 79.1%, and an accuracy of 75.9%.

Discussion and Conclusion: None of the bedside tests or their dual combinations had considerable success for predicting DL in our study. Considering this fact and variation of the predictive performance of bedside tests for DL among different ethnicities, we composed a distinctive regression model. This model anticipated DL with reasonable specificity and accuracy rates.

Keywords: Cephalometry; endotracheal intubation; ethnicity; laryngoscopy; regression analysis; retrognathia.

Failed intubation is a major cause of morbidity and mortality in anesthetic procedures. Predicting difficult intubation (DI) before induction of anesthesia may improve the outcome mainly through providing the presence of trained and well-equipped personnel in the operation room[1-5]. In this sense, difficult laryngoscopy (DL) was established as the most accurate determinant of DI[6]. The prevalence of DL was reported in a wide range between 1% and 20% due to diversifying definition of the outcome, selected population (obese, parturient, subjects with restricted cervical mobility, etc.), method of choice, individually determined cutoff values, and ethnic considerations[3-6].

Cormack-Lehane (CL) classification is the most commonly used scale for identifying the difficulty in the laryngeal

Correspondence (İletişim): Derya Özden Omaygenç, M.D. Department of Anesthesiology, University of Health Sciences Türkiye, Istanbul Haseki Training and Research Hospital, Istanbul, Türkiye
Phone (Telefon): +90 505 442 47 19 **E-mail (E-posta):** drderyaozden@yahoo.com
Submitted Date (Başvuru Tarihi): 11.05.2021 **Revised Date (Revize Tarihi):** 21.06.2021 **Accepted Date (Kabul Tarihi):** 02.07.2021

view. However, the laryngeal view can only be graded after insertion of the laryngoscope with adequate muscle relaxation by this method[3,6]. Therefore, various bedside investigations were suggested for anticipating DL. Unfortunately, none of these single airway tests consistently reached reasonable sensitivity and diagnostic accuracy rates[2-4,6]. Although the precision success was enhanced by combining two or three modalities or incorporating them into various diagnostic models, obtaining an optimal predictive method seems unlikely, particularly when the low incidence of DI was considered[2,3,5].

Here, we sought to identify the determinants of DL in Turkish patients using eight different variables (including structural abnormalities, pre-defined tests, and cephalometric measures) in addition to demographic features. We also aimed to create a predictive model with the help of this comprehensive dataset.

Materials and Methods

Study Qualification and Patient Selection

Adult patients (ASA I-II), to whom an elective surgery under general anesthesia was planned, were assessed for inclusion. One-hundred and sixty consecutive patients were evaluated and 15 of them were excluded at the preoperative examination. Criteria for exclusion were: History of craniofacial surgery or restriction of cervical mobility, edentulous patients, and pregnant women, patients who did not have a proper mouth opening (<3 cm), and those who might require awake intubation or rapid sequence induction. At the last step 8 patients had to be excluded due to the cancellation of the surgery or change in the anesthetic strategy. Ultimately, 137 patients constituted the sample population.

The study was approved by the local ethical committee of Bakırkoy Dr. Sadi Konuk Training and Research Hospital (Protocol no: 2019/210, Date of approval: May 06, 2019) thus, comply with the ethical standards stated by the recent version of the Declaration of Helsinki. Written informed consent was received from all of the participants. The study was registered at clinicaltrials.gov (Identifier: NCT04711018).

Noninvasive Tests and Cephalometric Measures

At the pre-operative interview, the height and weight of the participants were measured and body mass index (BMI) was calculated by the Du Bois method. The presence of retrognathia (reduced temporomandibular joint-incisor distance) and buck teeth was noted. Modified Mallampati test (MMT) was performed in the sitting position. Patients were asked to open their mouths as much as they could and protrude the tongue without phonation. MMT is an easily-applied test which enables the direct visualization of pharyngeal structures and assessing the size of the tongue with reference to the oral cavity. A scale ranging between 1 and 4 points is used and scores of 3 or 4 are considered as predictors of DL. In the former, only the base of the uvula and soft palate can be observed, whereas none of the pharyngeal structures can be visualized in the latter[7]. Upper lip bite test (ULBT) is another commonly used method that helps to assess the range of mandibular movement. ULBT is performed in the neutral position of the head and graded as 1–3 according to the extension ability of lower incisors, where grade 3 is a determinant of DL: 1-lower incisors can bite the upper lip beyond the vermilion, 2-lower incisors cannot be extended up to the vermilion but they still can bite the upper lip, and 3-lower incisors cannot bite the upper lip at all[8].

Anatomical landmarks and pre-described cutoff values of cephalometric measures used in this study are as follows:

Sternomental distance (SMD): The distance between the mentum and upper border of the manubrium sterni when the head is fully extended and the mouth is closed. A minimum SMD measurement of 12.5–15 cm is an indicator of adequate cranial and cervical mobility[9]. The evidence-based standard cutoff value was accepted as 13.5 cm[1,2].

Thyromental distance (TMD): The distance between mentum and the thyroid notch when the head is fully extended. A measurement of 6–6.5 cm and lower was designated to be associated with DL[3,10,11]. The literature derived cutoff value for TMD was set to 6.5 cm[3].

Interincisor distance (IID): The distance between upper and lower incisors when the mouth is fully opened.

Neck circumference (NC): It was measured at the level of the cricoid cartilage, perpendicular to the cervical axis. The pre-defined cutoff value of NC was taken as 43 mm[12].

Standart cutoff values of the tests drawn from the literature as well as the values obtained from the ROC analyses of our sample population were used while assessing the sensitivity specificity rates.

Anesthesia Procedure and Evaluation of DL

The patients were premedicated with 0.03 mg/kg and oxygenated with the help of a bag-mask. Anesthesia was induced by consequent administration of 2 mcg/kg fentanyl, 1 mg/kg lidocaine, 2 mg/kg propofol, and 0.7 mg/kg rocuronium bromide thereafter. Two minutes after induction, the laryngoscopy was performed by the same experienced anesthesiologist (who was blinded to pre-operative measurements) with the help of an appropriate size Macintosh blade. The patient's head was held in the sniffing position at that time. External manipulation was not used for improving the view. CL classification was used for grading laryngeal view of which Grade I represented the full view of glottis and Grade II stood for visualization of only the posterior commissure of laryngeal aperture. Grade III and Grade IV corresponded to the visualization of only the epiglottis and only soft palate; respectively. A CL-class of III or IV was identified as DL[6].

Statistical Analysis

The data in this study were presented as mean±standard deviation and percent (number of cases) for continuous and categorical variables, respectively. The normality of continuous variables was assessed with the Shapiro–Wilk test. According to the state of following a normal distribution, unpaired-t and Mann–Whitney-U tests were utilized for distinguishing the variables between patients with and without DL. The parameters revealing a difference between these groups, with a significance level of $p<0.10$, were further tested in binary logistic regression analysis to determine the predictive performance. Multiple logistic regression analysis was used to establish the independent predictors of DL with the parameters found to be potentially associated with DL in the previous analysis. In line with the findings of regression analyses, a diagnostic model comprising of retrognathia, MMT score of 3 or 4, and IID (≤4 cm) was developed for anticipating DL. If two of these three features were met, the patient was assumed to have DL. Ultimately, the prediction ability of the model was validated by an additional ROC analysis.

The ROC analyses were also performed to detect the cut-off values of cephalometric measures. These values and standard cutoff levels derived from the literature search, combination of the tests, and our diagnostic model was assessed for their predictive performances. Sensitivity, specificity, diagnostic accuracy, positive likelihood ratio, positive predictive value, and negative predictive value of these items were calculated. Statistical Package for the Social Sciences (SPSS version 22.0, SPSS Inc., Chicago, IL, USA) was used for these assessments.

Results

The data of one-hundred and thirty-seven patients were assessed. The mean age of the participants was 45±11.1 and 67.9% of them were female. The frequency of DL was 27% (n=37) in our sample population. The demographic characteristics were comparable between patients with and without DL (Table 1). More than one attempts were required for intubation of seven patients (4.4% of the entire population) in the DL + group and video laryngoscope was used in two of these cases.

Among predictive tests, IID was lower (cm, 4.5±0.7 vs. 4.1±0.7, p<0.01), and MMT score (1.93±0.76 vs. 2.35±0.86, p=0.01), frequency of retrognathia (%, 2 vs. 18.9, p<0.001), and observing Grade 3 in ULBT (%, 15 vs. 32.4, p=0.02) were

Table 1. Demographic characteristics of the sample population. BMI, body mass index; DL, difficult laryngoscopy

	Overall (n=137)	DL – (n=100)	DL + (n=37)	p
Age, years; Mean±SD *	45±11.1	44.6±11.4	46±10.5	0.532
Gender, female; % (n)	67.9 (93)	66 (66)	73 (27)	0.438
BMI, kg/m^2; Mean±SD *	29.1±4.7	29.2±4.7	28.8±4.7	0.638
ASA class, Mean±SD †	1.6±0.5	1.6±0.5	1.6±0.5	0.706

* Unpaired-t test was used for comparison. † Mann-Whitney-U test was used for comparison.

Table 2. Comparison of patients with or without difficult laryngoscopy by means of anatomic features, diagnostic tests, and cephalometric measures

	DL – (n=100)	DL + (n=37)	p
Buck teeth, % (n)	5 (5)	10.8 (4)	0.223
Retrognathia, % (n)	2 (2)	18.9 (7)	<0.001
ULBT Grade 3, % (n)	15 (15)	32.4 (12)	0.023
MMT score; Mean±SD †	1.9±0.8	2.4±0.9	0.009
SMD, cm; Mean±SD *	15.6±2.4	14.8±2.1	0.066
IID, cm; Mean±SD †	4.5±0.7	4.1±0.7	0.004
TMD, cm; Mean±SD †	8.5±1.6	8.3±1.4	0.447
NC, cm; Mean±SD †	38.9±4	39.5±4.8	0.815

DL: difficult laryngoscopy; IID: interincisor distance; MMT: modified Mallampati test; NC: neck circumference; SMD: sternomental distance; TMD: thyromental distance; ULBT: upper lip bite test. * Unpaired-t test was used for comparison. † Mann-Whitney-U test was used for comparison.

significantly higher in patients with DL (Table 2).

ROC analysis identified a significant relationship of DL only with IID (AUC: 0.658, p=0.005) and SMD (AUC: 0.618, p=0.035) among all cephalometric measures (Fig. 1). A cut-off value of 4 cm was identified for IID, and that of 15.5 cm was selected for SMD.

SMD, IID, MMT score, Grade 3 ULBT, and presence of retrognathia were involved in the regression analysis. All of these tests but not SMD exhibited a significant relationship with DVL, thus involved in multiple regression analysis. Eventually, IID (Odds ratio [OR]: 0.504, CI 95% [0.260–0.978], p=0.043), MMT score (OR: 2.001, CI 95% [1.159–3.454], p=0.013), and presence of retrognathia (OR: 0.108, CI 95% [0.019–0.613], p=0.012) were determined as independent predictors of DL (Table 3). When the predictive performance of single tests was considered, SMD ≤15.5 cm had the highest sensitivity (67.6%) and retrognathia had the highest specificity (98%). Dual combinations of MMT, SMD, and IID had low sensitivity and moderate-high specificity rates. Our predictive model anticipated DL with a sensitivity of 35.1%, a specificity of 91%, an accuracy of 75.9%, a positive predictive value of 59.1%, a negative predictive value of 79.1%, and a positive likelihood ratio of 12.3. The model had the highest positive likelihood ratio among the

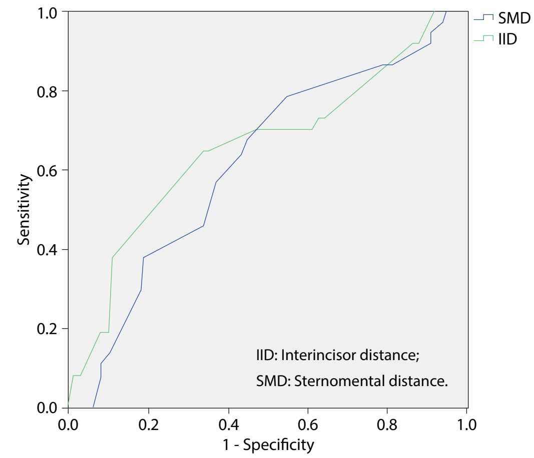

Figure 1. ROC analysis curves representing the diagnostic accuracy of measures for predicting difficult laryngeal visualization. AUC for interincisor distance was 0.658 (p=0.005) and AUC for sternomental distance was 0.618 (p=0.035).

Table 3. Results of the logistic regression analyses performed for predicting difficult laringoscopy

	Odds Ratio	Confidence Interval 95%	p
Binary Logistic Regression analysis			
Sternomental Distance	0.856	0.723-1.012	0.069
Interincisor Distance	0.429	0.229-0.806	0.008
Modified Mallampati Test score	1.981	1.199-3.273	0.008
Retrognathia	0.087	0.017-0.444	0.003
Upper Lip Bite Test Grade 3	2.720	1.128-6.560	0.026
Multiple Logistic Regression analysis			
Interincisor Distance	0.504	0.260-0.978	0.043
Modified Mallampati Test score	2.001	1.159-3.453	0.013
Retrognathia	0.108	0.019-0.613	0.012
Upper Lip Bite Test Grade 3	0.695	0.248-1.945	0.489

Table 4. Predictive performance of diagnostic tests for estimating difficult laryngoscopy. Both cut-off values derived from ROC analysis and literature review were included in the analysis for SMD and IID

Predictive test	Sensitivity (%)	Specificity (%)	Accuracy (%)	(+) LHR	PPV (%)	NPV (%)
MMT score (3 or 4)	48.6	75	67.9	6.7	41.9	79.8
ULBT (Grade 3)	32.4	85	70.8	4.8	44.4	77.3
SMD ≤ 15.5 cm	67.6	55	58.4	5.6	35.7	82.1
SMD ≤ 13.5 cm	37.8	81	69.3	4.9	42.4	77.9
IID ≤ 4 cm	64.9	66	65.7	10.5	41.4	83.5
TMD ≤ 6.5 cm	16.2	86	67.2	0.1	30	73.5
NC ≥ 43 cm	18.9	91	71.5	2.4	43.8	75.2
SMD + IID *	43.2	82	71.5	8.6	47.1	79.6
MMT + SMD *	32.4	87	72.3	6.3	48	77.7
MMT + IID *	29.7	92	75.2	9.5	57.9	78
Retrognathia	18.9	98	76.6	10.9	77.8	76.6
Regression model †	35.1	91	75.9	12.3	59.1	79.1

IID: interincisor distance; LHR: likelihood ratio; MMT: modified Mallampati test; NC: neck circumference; SMD: sternomental distance; TMD: thyromental distance; ULBT: upper lip bite test. * The cut-off values derived from ROC analysis were used for assessing the performance of combination of tests. † Regression model included MMT score of 3 or 4, IID≤4 cm, and presence of retrognathia. Two out of these three variables were sought for a positive result.

entire list of the tests and their combinations (Table 4). The diagnostic accuracy of the model was also validated with ROC analysis (AUC: 0.63, 95% CI [0.52–0.74], p=0.02).

Discussion

Difficult tracheal intubation is recognized as the main hazard for adverse respiratory events in the perioperative setting. It was proven to be associated not only with increased risk of severe complications such as death and hypoxic brain damage but also with non-major ones like desaturation, airway trauma, and prolonged hospitalization[5,13]. DL was described as the major determinant of DI, even though several different factors might pose additional difficulty for the advancement of the tracheal tube[3,6]. Selvi et al.[6] denoted that sensitivity and specificity of CL scoring was over 95% for predicting DI. Considering the fact that airway challenges regarding the integrity and function of trachea and vocal cords cannot be anticipated with non-invasive tests in the absence of a DI or previous manipulation history, various studies including ours preferred DL as an endpoint instead of DI[1,4,10,14,15].

The incidence of DL was reported in a range between 1 and 20%[4,6]. Shiga et al.[2] detected a rate of 5.8% in their meta-analysis. In a systematic review published by Faramarzi et al.,[16] a DL rate up to 27% was pronounced. Different anthropometric features between ethnic groups, variations in laryngeal view grading, use of external manipulation and stylets, and other procedure-related features might be responsible for this ambiguity[5]. In our study, the DL rate was also relatively higher, but it should be denoted that external manipulation was not used while assessing CL grade.

An association of increased rate of DVL with age and male sex was determined in various investigations[17-19]. Özdilek et al.[20] also claimed that risk factors for difficult mask ventilation and DVL were not the same among genders. There are conflicting results regarding the DVL-obesity relationship in the literature. Morbid obesity was detected to be associated with difficult mask ventilation rather than DVL in a large retrospective analysis[21]. Saasooh et al.[22] denoted that further risk increase with a rise in BMI was not observed over the threshold of obesity (30 kg/m^2). On the other hand, Özdilek et al.[20] found no relationship between DVL and BMI irrespective of the gender. There was no evident correlation between demographic features and DL in our study.

Regarding the multifactorial nature of DL, none of the preoperative tests was solely reported to have conformably high sensitivity and specificity rates[2,3,11]. Moreover, cutoff values and diagnostic accuracy of these tests vary with respect to several confounding factors like BMI, gender, and ethnicity[14,16,20,23]. Hence, iterative validation of these tests and their combinations in different patient groups is essential to confirm their predictivity.

SMD, an indicator of head and neck mobility, has been declared as the most reliable single method for ruling out DI among various tests[2]. Savva presented the highest sensitivity and specificity rates for SMD, 82.4% and 88.6%, respectively. They detected a cutoff value of 12.5 cm to be the optimal predictor of DL[24]. Whereas, in Grecian patients the cutoff value for SMD was determined as 15 cm for predicting DL[25]. Shiga et al.[2] verified the predictive performance of SMD in their meta-analysis but with moderate sensitivity and specificity rates. Al Rhamadani et al.[26] also reported a sensitivity of 66.7%, a specificity of 71.1%, and a negative predictive value of 98.4% for SMD in parturients. When the cutoff value was designated as 13.5 cm, particularly the sensitivity remained considerably low in previous studies investigating the Turkish population[15,20]. The only contradicting report was published by Yildirim et al.,[1] by whom the precision rates were stated to be above 80% for SMD. The authors also declared similar rates for IID (≤4.5 cm) and TMD (≤6.5 cm) in this study. In our analysis, 15.5 cm was established as the cutoff point to represent an increased risk for DL, with moderate sensitivity (67.6%), specificity (55%), and accuracy (58.4%) rates.

A multicenter study that recruited 1676 Turkish participants revealed that only MMT score of 3 or 4 and mouth opening ≤40 mm had fair sensitivity rates among the entire list of tests also including TMD, SMD, and mandibular protrusion. The IID has been demonstrated to be considerably sensitive while predicting difficult airway in the general population as a single measure[15]. However, Savva did not mention a relationship between IID and DL[24]. In our investigation, IID was designated as an independent predictor DL, thus incorporated into the diagnostic model. When the cutoff value was accepted as 4 cm, IID yielded moderate diagnostic precision as a single test with reasonable sensitivity and specificity rates (64.9% and 66%, respectively).

MMT is one of the most widely used tests for anticipating DL in anesthesia practice. However, MMT did not reach acceptable sensitivity rates in most of the studies. Shiga et al.[2] also emphasized the heterogeneity of the precision ability of this test. Hence, it was rather combined with other tests or involved in the regression models[3,11,27]. In the meta-analysis presented by Shiga et al.[2] a combination of MMT with TMD yielded the highest discriminative power, although the sensitivity remained low. Frerk also suggested this combination but with higher sensitivity and specificity rates[28]. Conceptually, adding MMT to other tests reduced sensitivity while increasing the specificity[1,2,15]. Our findings supported this instance.

ULBT was first proposed by Khan et al.[8] for predicting DL. It has garnered interest with relatively higher accuracy and specificity rates, particularly as compared to MMT. On the other hand, it also showed relatively lower sensitivity with a remarkable variation between different investigations[16]. It should also be denoted that the ethnicity factor might distinctly alter the sensitivity of this test[6,14]. The combination of ULBT with TMD or MMD also yielded increased precision rates in different subgroups[1,5,11,14,16]. Although ULBT was not determined as an independent predictor of DL in our study, it revealed a fairly good predictivity with a specificity rate of 85% and an accuracy of 70.8% despite the low sensitivity (32.4%).

NC was determined as a valuable indicator of DL particularly for obese patients and in the thyroid surgery[12,21,23]. According to Özdilek et al., NC was not a significant predictor neither for DVL nor for difficult mask ventilation[17]. Likewise, NC was found to be indifferent between patients with and without DVL in our study. It should be emphasized that the mean BMI of our population was below 30 kg/m^2.

The TMD reflects the accommodation capacity of mandibular space for the displacement of the tongue with the help of a standard laryngoscope[3,4]. Although measurement of <6.5 cm showed a good agreement with DVL, widely varied sensitivity rates through different studies have also been a matter of concern for TMD[2,5,6]. Moreover, the addition of MMT also resulted in inconsistent changes in predictivity[2,6,29]. The ratio between NC and TMD was also suggested as a better predictor of DVL in a study investigating the obese population[30]. In our study, TMD was not a distinguishing factor between groups either.

Various risk models were suggested for increasing the predictivity of bedside tests. However, due to the complex nature of these models, the assessment process is time-consuming and prone to considerable variability in measurements. IID, MMT, and TMD are predominantly involved tests in these models[3,11,27]. The sensitivity and specificity of the Naguib model and El-Ganzouri risk index were reported at rates of roughly 80%[11,27]. In our diagnostic model, the presence of two out of three factors was claimed to predict DL. These factors were listed as IID≤4 cm, MMT score of 3 or 4, and presence of retrognathia. This model showed an acceptable agreement with DVL (AUC:0.63), and reasonable specificity and accuracy rates.

This investigation has some limitations. First, it should be emphasized that DI is a multifactorial clinical entity of which DL is a reliable but not the only indicator. In addition, the sample population was relatively small since the study was single-centered. On the other hand, this instance helped avoiding the interobserver variations which might have caused remarkable bias during data collection.

Although mean MMT score, frequency of retrognathia, and Grade 3 cases in ULBT were higher and IID was shorter in patients with DL, MMT, IID, and presence of retrognathia were the ultimate factors established as independent predictors of DL in our sample population comprising Turkish participants. We created a regression model based on these findings which anticipated DL with reasonable negative predictive value, and specificity and accuracy rates. Regarding variation of the predictive performance of above-mentioned bedside tests among different ethnicities, our regression model might help anticipating DL in our Turkish patients.

Ethics Committee Approval: The study was approved by the local ethical committee of Bakırkoy Dr. Sadi Konuk Training and Research Hospital (Protocol no: 2019/210, Date of approval: May 06, 2019) thus, comply with the ethical standards stated by the recent version of the Declaration of Helsinki. Written informed consent was received from all of the participants. The study was registered at clinicaltrials.gov (Identifier: NCT04711018).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: D.O.O., O.S.; Design: D.O.O., O.S.; Data Collection or Processing: D.O.O., O.S.; Analysis or Interpretation: D.O.O.; Literature Search: O.S.; Writing: D.O.O., O.S.

Conflict of Interest: None declared.

Financial Disclosure: The authors declared that this study received no financial support.

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