HOW DEEP DO YOU GO? CLINICAL PREDICTION OF NASOPHARYNGEAL DEPTH BASED ON FACIAL MEASUREMENTS

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Abstract

Objectives: Nasopharyngeal (NP) depth prediction is clinically relevant in performing medical procedures, and enhancing technique precision and safety for patients. Nonetheless, clinical predictive variables and normative data in adults remain limited. This study aimed to determine normative data on NP depth and its correlation to external facial measurements. Methods: A multicenter cross-sectional study obtained data from adults presenting to otolaryngology clinics at five sites in Canada, Italy, and Spain. Investigators compared the endoscopically measured depth from sill to nasopharynx along the nasal floor to the facial measurements "curved distance from the alar-facial groove along the face to the tragus" and "distance from the tragus to a plane perpendicular to the philtrum." When sinus CT images were available, the distance from the nasopharynx to nasal sill was also collected. Results: 371 patients participated in the study (41% women; 51 years old, SD 18). The average endoscopic depth was 9.4 cm (SD 0.86) and 10.1 cm (SD 0.9) for women and men, respectively ($p<0.001$; 95% CI 0.46 to 0.86). Perpendicular distance was strongly correlated to NP depth ($r=0.775$; $p<0.001$), with an average underestimation of 0.1 cm (SD 0.65; 95% CI 0.06 to 0.2). The equation: ND(cm) = perpendicular distance*0.773 + 2.344, generated from 271 randomly selected participants, and validated on 100 participants, resulted in a 0.03 cm prediction error (SD 0.61; 95% CI -0.08 to 0.16). Conclusions: Nasopharyngeal depth can be accurately approximated by the distance from the tragus to a plane perpendicular to philtrum. The generated predictive equation was most accurate but not likely clinically relevant.

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Conclusions : Nasopharyngeal depth can be accurately approximated by the distance from the tragus to a plane perpendicular to philtrum. The generated predictive equation was most accurate but not likely clinically relevant.

Keywords: Nasopharynx, Nasopharyngeal Depth, COVID-19, Temperature monitoring, Diagnostic Testing, Evidence-Based Practice.

Key Points:

- The distance anteriorly from the tragus to a plane perpendicular to the philtrum is a reliable method of estimating nasopharyngeal depth
- The average nasopharyngeal depth in adult men is 10.1 cm and 9.4 cm in adult women
- Nasopharyngeal depth prediction based on the distance along the curvature of the face from the tragus to the alar-facial groove results in an overestimation of 2 cm regardless of patient sex.
- The tragus-to-philtrum coronal plane distance has nearly a 1:1 ratio with the nasopharyngeal depth
- The association between tragus-to-philtrum coronal plane distance and nasopharyngeal depth is persistent regardless the sex and ethnicity.

Introduction

Anatomical knowledge and precise nasopharyngeal (NP) depth determination are crucial in the safety and accuracy of several medical procedures including but not limited to nasopharyngeal swabs, nasogastric tube placement, and nasopharyngeal temperature probe positioning.[1,2,3]

Suboptimal NP depth prediction can impact nasopharyngeal (NP) swab accuracy, which is the gold standard for diagnostic testing of respiratory pathogens, including Bordetella pertussis, Neisseria meningitidis, influenza, respiratory syncytial virus, and SARS-CoV-2.[6,7] Conversely, swab over-insertion can increase the risk of bleeding, discomfort and complications in the procedure.[8,9] NP temperature probe considered standard for perioperative temperature monitoring in patients receiving anesthesia requires target insertion depth for precise placement in the upper or mid-nasopharynx,[10] since improper positioning may result in inaccurate core temperature reporting.[11]

Although previously reported in the literature, the average adult NP depth remains inconsistent amongst studies, without correlation of clinical predictors.[1,10] This multi-site cross-sectional study was performed to acquire NP depth normative data in adults and assess for predictors of this anatomical distance.

Materials and Methods

Study Design and Population This prospective cross-sectional study involved adult patients presenting to participating otolaryngology clinics in Canada, Italy, and Spain, from May to August 2021. STROBE Statement was used as a guideline for reporting the results.

All adults (at least 18 years old) presenting to participating otolaryngology clinics with a pre-existing need for nasopharyngoscopy were screened for inclusion in the study. Exclusion criteria included an inability to understand the consent process, severe nasal obstruction at clinician's discretion, previous facial cosmetic surgery, history of middle facial third orthognathic surgery or fractures, previous head and neck oncologic resection, or facial reconstruction altering measurement sites. Participants provided written consent before entering the study.

This study was performed in two steps. The primary objective was to gather normative data on nasopharyngeal depth in adults and assess its correlation with external facial measurements. Subsequently, we developed and validated a clinical predictor to aid in nasopharyngeal swab test performance.

Assessments

Self-reported participant demographics were collected, including age, sex, and ethnicity. The availability of a previous computed tomography (CT) scan of the sinonasal region was noted if present.

External facial measurements

Using a flexible surgical ruler, two external facial measurements were assessed in cm: the distance along the curvature of the face from the tragus to the alar-facial groove, and the distance anteriorly from the tragus to a plane perpendicular to the philtrum (Figure 1-A and 1-B). These variables are henceforth referred to as curved and perpendicular distances, respectively.

Nasopharynx depth (Nasoendoscopy)

Direct measurement of nasopharynx depth (ND) was performed using a flexible video endoscope by carefully bringing it into contact with the posterior wall of the nasopharynx along the floor of the nasal cavity. The point of the endoscope at the nasal sill was noted, and the instrument was removed. ND was determined by measuring the distance from the marked point to the tip of the endoscope in cm (Figure 2).

CT scan measurement

When a sinus CT scan was available, the distance in cm from the nasopharynx to the nasal sill was assessed along the floor of the nose in the axial plane.

Statistical analysis

Descriptive statistics were expressed in mean and standard deviation for continuous variables where normal distribution was assumed, whereas count and percentages were used to present the categorical ones. Statistical analysis was conducted using the program SPSS for Windows (version 20.0, Chicago, IL).

Step 1

All four measurements were presented as mean and standard deviation for the total group, and again for each sex. An independent samples T-test was used to compare groups, reported as a difference of mean, 95% CI and p-value. An analysis of variance (ANOVA) was performed for each sex to compare variables between ethnic groups.

Considering ND as the gold standard in the study, curved and perpendicular distances were compared against the ND by subtracting each participant's measurement from their ND. The resulting variables represented an error estimation between each facial measurement and ND (i.e., Δ Perpendicular = Perpendicular - ND; Δ Curved = Curved - ND; Δ CT scan = CT scan - ND). Thus, negative error estimation values show an underestimation of ND, whereas positive values express ND overestimation.

In addition, we analyzed the correlation between ND, facial measurements, CT distance, ethnicity, sex, and age using the Pearson correlation analysis (r).

Step 2

The second step investigated the extent to which each clinical variable could function as a predictor for nasopharyngeal depth. A random number sequence generator was used to randomly select a group of 271 participants. Their data was input into multiple linear regression analyses to determine whether the external facial distances significantly predicted ND while controlling for sex and age. Then, the generated regression equations were validated using the remaining 100 study participants data by calculating the prediction error compared to the actual assessed ND for each participant (error = actual − predicted). The regression models' errors were presented as mean, standard deviation and 95%CI.

Results

A total of 371 participants were enrolled in the study from five sites, with a preponderance of men (59%) and an average age of 51 years (SD 18) (Table 1). From these, 153 participants had sinus CT images available.

Step 1

The endoscopic assessment presented an average ND of 9.8 cm (SD 0.9) and CT distance of 8.4 cm (SD 0.9) for the total sample. In turn, the external facial distances assessed in this study showed an average curved distance of 11.8 cm (SD 0.9) and a perpendicular distance of 9.6 cm (SD 1). All four variables were significantly higher for men (Table 2).

Considering the endoscopic ND assessment as a reference, Δ Perpendicular averaged -0.1 cm (SD 0.65, 95% CI -0.2 to -0.06), representing an underestimation of true ND. Conversely, Δ Curved averaged 2.0 cm (SD 0.83, 95% CI 1.9 to 2.1), representing an overestimation. In turn, Δ CT scan averaged -1.2 cm (SD 0.8, 95% CI -1.3 to -1.07). The overarching estimations held true on subgroup analysis for men and women and therefore, inferences of ND error estimation for each of these three variables persist regardless of participant sex (Table 2).

The perpendicular distance was the most strongly correlated with ND ($P<0.001$, $R=0.775$). Nonetheless, curved and CT distances also showed a significant correlation to the endoscopic ND ($P<0.001$, $R=0.598$, and $P=0.001$, $R=0.541$, respectively). Self-reported ethnicity or age did not exert statistical significance on any variable assessed on sub-group ANOVA (men and women).

Step 2

The stepwise multiple regression analysis to predict ND based on the external facial distances controlled for age and sex and resulted in three regression models and showed that 64% of the variance in ND can be accounted for by the perpendicular distance alone ($F(1,269) = 493.31$, $p<0,0001$) – model 1. Similarly, perpendicular and curved distances were listed on model 2, being responsible for 66% of the variance in ND ($F(2,268) = 263.65$, $p<0,0001$). On model 3, sex and both facial distances were included, accounting for 66% of ND variance ($F(3,267)= 179.98$, $p<0,0001$). Age was removed as a variable in all regression models.

The three models were then tested against the data of the remaining 100 participants, as ND = Perpendicular distance*0.773 + 2.344 (model 1), ND = Perpendicular distance*0.672 + Curved distance*0.171 + 1.28 (model 2), and ND = Perpendicular distance*0.662 + Curved distance*0.147 + Sex*1.7 + 1.56 (model 3). The ND prediction error using model 1 was 0.03 cm (SD 0.61; 95% CI -0.08 to 0.16), while model 2 presented an average overestimation of 0.03 cm (SD 0.58; 95% CI - 0.78 to 0.15). In turn, model 3 resulted in a mean of 0.9 cm (SD 1; 95%CI 0.7 to 1.1).

Discussion

To date, there is no consensus on nasopharyngeal depth normative data or a reliable method to estimate it in adults. Our results showed that the average nasopharyngeal depth in adult men is 10.1 cm (SD 0.9) and 9.4 cm in adult women (SD 0.86). Among the external facial distances analyzed, the distance anteriorly from the tragus to a plane perpendicular to the philtrum was the most strongly correlated to the nasopharyngeal depth. This clinical measurement can predict the nasopharyngeal depth quite accurately, with an average error estimation as small as 0.1 cm. Self-reported ethnicity or age, does not seem to interfere with this premise.

Both the New England Journal of Medicine and the Centers for Disease Control have advocated for the performance of NP swab by inserting along the floor of the nose until resistance is met, or to a distance equivalent of the ear canal to the nose; however, they do not further specify the directionality (along the curvature of the face or perpendicular from the ear), nor do they give specifics about what part of the ear or nose to start and end the measurement, the average distance, or evidence for this recommendation. In the performance of a nasopharyngeal swab, premature resistance from irregularities including nasal deviation, polyposis, and inferior turbinate hypertrophy could lead to sub-optimal swab insertion depth. Conversely, overestimation of the nasopharyngeal depth or incorrect directionality can increase the risk of complications ranging from epistaxis to the injury of the skull base in rare cases, especially for inexperienced providers.[8,9] Attempts to train healthcare workers on proper NP swab technique have improved procedural accuracy and self-confidence using group training sessions and simulation.[12,13] Heterogeneous NP depth insertion among guidelines[14] for this procedure have implications extending beyond the test accuracy, and these measurements should help standardize what is regarded as a "nasopharyngeal swab". However, since the performance of these swabs is based on tactile feedback along the patient's nasal cavity, estimating individualized NP depth seems necessary as a pretest method to predict the appropriate depth of swab insertion and appropriately label the performed swab (mid-turbinate versus anterior nasal versus nasopharyngeal).

Considering the degree of association between the distance anteriorly from the tragus to a plane perpendicular to the philtrum and ND on our study's correlation and regression analyses, this perpendicular distance seems to be the most appropriate external facial measurement for predicting NP depth. These results can support updated instructional guidelines on effective nasopharyngeal swab procedures.

Our ND results are in line with a study from Lim et al. (2014) which assessed nasopharyngeal depth for temperature probe positioning in 200 participants from Korea (mean age 52 yrs., SD 12) via nasoendoscopy and reported an average ND of 9.4 cm (SD 0.6), and 10 cm (SD 0.5) in women and men, respectively.[10] They also measured the distance from philtrum to tragus along the facial curvature, similar to the "curved" distance in our study, as a potential predictor of ND. However, while the reported endoscopic depth is similar to our results, their participants' curved distance was 3 cm longer than ours for both women and men. In their study, measurements were performed in the supine position and beyond the alar-facial groove to the midline philtrum, which could account for the difference. In addition, the authors showed a weak correlation between ND and curved distance. They did suggest a regression model to predict ND using curved distance, though it was not validated. Lastly, the authors stated that the difference from their "curved distance" to ND was, on average 5 cm, suggesting that prediction of ND could be made by simply subtracting 5 cm from the tragus-to-philtrum distance. Since their measurement parameters differ from our study, this delta cannot be compared to our Δ Curved.

Nasopharyngeal depth in adults was also assessed by Callesen et al. (2021) in 109 adult participants in Denmark (mean age 34 yrs., SD 13) using a nasal swab guided by a video endoscope on the opposite nostril; however, they did not correlate this with any external measure.[1] Their results showed an overall ND of 9.4 cm (SD 0.64), lower than our total sample's ND (i.e., 9.81 cm, SD 0.94). Based on their results, the authors suggested a minimum swab insertion depth of 8 cm in adults. Although we acknowledge that a minimum value could reduce the odds of sub-optimal swab insertion on nasopharyngeal tests in adults, a clinical predictor for individualized ND is more practical. According to our results, predicting NP depth before procedures when appropriate is simple and straightforward.

The CT distance assessed in our study does not seem to be a good clinical predictor since it may result in ND underestimation of 1.2 cm (SD 0.8) and it relies on availability of sinus CT images. However, Lee et al. (2014) assessed the distance from the nares to the closest proximity portion of the nasopharyngeal mucosa through the inferior meatus in sagittal images of 100 patients' CT scans (females 50 yrs., and males 52yrs.).[11] Their results show an average ND of 9.1 cm (95% CI 8.1 to 10.2) and 9.7 cm (95% CI 8.6 to 1.8) for women and men, respectively, which are considerably higher than ours and more realistically approximate our average ND results. The difference is likely accounted for by measurements in the sagittal plane, which differs from the axial view used in our study, which increases variability based on tilt. Due to missing sagittal plane reconstructions in a number of subjects, we elected to use axial images. Accordingly, future CT measurements should be conducted in the sagittal plane for consistency among studies.

We acknowledge that the generalizability of our results is limited to adults belonging to our normally distributed study population. As such, the ratios between external facial measurement and NP depth can be expected to differ in those excluded from study participation, including those with a history of mid-face surgery and craniofacial abnormalities. Additionally, our findings should not be generalized to children whose craniofacial ratios continue to change with sinus development and facial elongation until adulthood. It is noted that although our findings do not demonstrate a significant ethnicity-related variation in NP depth, our sample was predominantly Caucasian. Validation in other populations would help to broaden applicability.

The consistency between our nasopharyngeal depth data and previously published studies from other countries reassures that our results are likely similar throughout adult populations. Our predictive method gains validity from measurements made by otorhinolaryngologists with considerable experience in nasal endoscopy and anatomy, and consistency amongst data collection sites confirms a robust and reproducible methodology. The narrow difference from NP depth to perpendicular measurement allows for simple external estimation by any healthcare provider.

Conclusion

A reliable method of estimating the nasopharyngeal depth will lend confidence and clarity to healthcare providers of important nasopharyngeal diagnostic tests and will guide other applications relying on accurate blind estimations of this distance, including nasogastric tube placement and NP temperature probe placement. This study has demonstrated a near 1:1 ratio of nasopharyngeal depth to the tragus-to-philtrum coronal plane distance and has confirmed its persistence between sex and ethnicity in subgroup analysis. As such, individually optimized nasopharyngeal depth seems to be a supportive tool for safe NP procedures and can be clinically predicted by simply measuring the distance from the tragus to a plane perpendicular to the philtrum on a lateral view.

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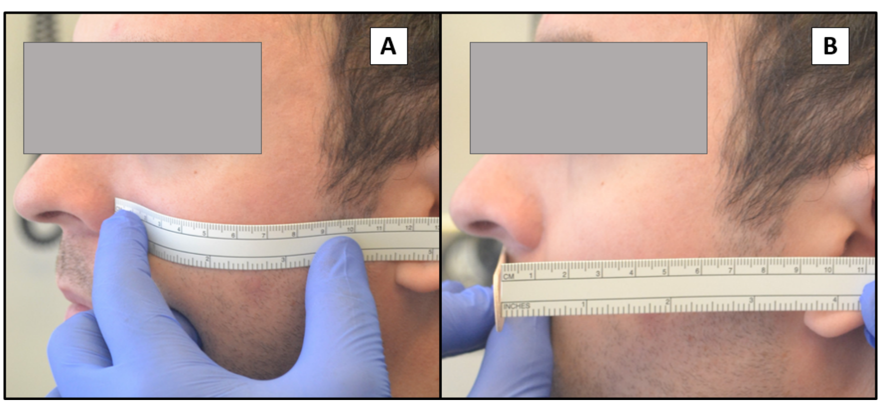
Figure legends

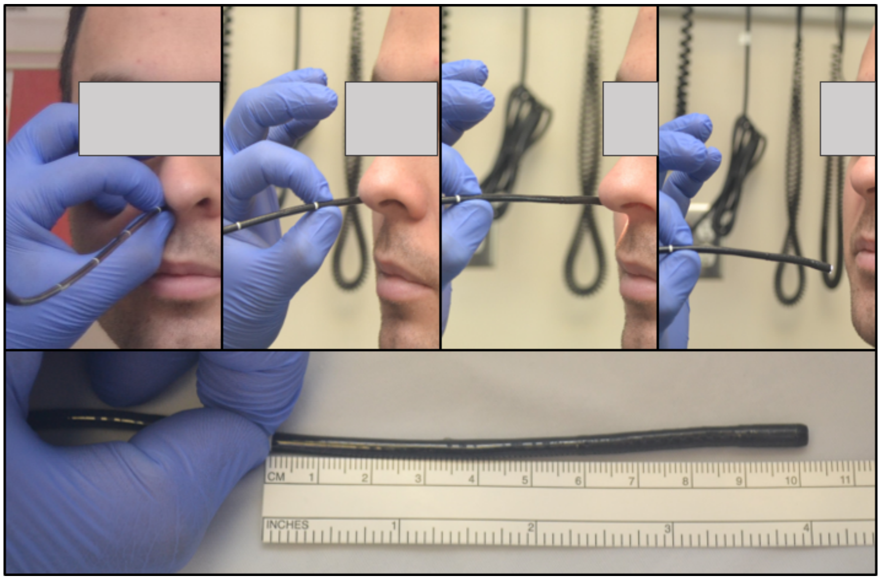
Figure 1

External facial measurements. A. Distance along the curvature of the face from the tragus to the alar-facial groove (Curved measurement); B. Distance from the tragus to the plane perpendicular to the philtrum (Perpendicular measurement).

Figure 2

Nasopharyngeal depth assessment. Distance measured from the nasopharynx to the nasal sill using a flexible video endoscope.





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