Target insertion depth of nasopharyngeal temperature probes in children: A prospective observational study analyzing magnetic resonance images

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Abstract

Background: Core temperature monitoring is indispensable to prevent children from perioperative thermal perturbations. Although nasopharyngeal measurements are commonly used in anesthesia and considered to reflect core temperature accurately, standardized target depths for probe insertion are unknown in children.

Aims: Our primary goal was to determine a target depth of nasopharyngeal temperature probe insertion in children by measuring distances on magnetic resonance imaging (MRI). Secondary aims were to correlate these measurements with biometric variables and facial landmark-distances to derive formulas estimating target depth.

Methods: We conducted a prospective observational study in children ≤12 years undergoing cranial MRI with anesthesia. We documented patient characteristics and measured the landmark-distances nostril-mandible, nostril-tragus, and philtrum-tragus on patient’s faces. On MRI, the target point for the probe tip was considered to be the site of the nasopharyngeal mucosa with the closest proximity to the internal carotid artery. After its determination in the transverse axis and triangulation to the sagittal axis, we measured the distance to the nostril. This distance, defined as target insertion depth, was correlated with the patient characteristics and used for univariate and multiple linear regression analysis.

Results: One hundred twenty children with a mean age of 4.5 years were included. The target insertion depth ranged from 61.8 mm in infants to 89.8 mm in 12-year-old children. Height correlated best (ρ = 0.685, 95%-CI: [0.57–0.77]). The best-fit estimation in millimeters, “40.8 + height [cm] x 0.32,” would lead to a placement in the target position in 67% of cases. A simplified approach by categories of 50–80, 80–110, 110–130, and >130 cm height with target insertion depths of 60, 70, 80, and 85 mm, respectively, achieved similar probabilities.
1 | INTRODUCTION

Perioperative temperature perturbations are common in neonates, infants, and young children. Continuous core temperature measurement is essential in guiding temperature management and preventing hypo- and hyperthermia in such a susceptible patient population. Although a precise core temperature measurement is of utmost importance, only few methods and measurement sites have proven accurate enough. While exact core temperature is best measured in the pulmonary or iliac artery, those sites are usually not feasible in noncardiac surgery. Alternatively, esophageal probes give accurate temperature core estimates when placed in the distal third between the left atrium and the descending aorta, even though they still carry the risk of complications such as tracheal displacement and consequent respiratory adverse events.

When the use of esophageal probes is precluded because of interference with the surgical field or because laryngeal mask anesthesia is planned, nasopharyngeal probes present a widely used, minimally invasive, and accurate alternative method of core temperature measurement in children. It is recommended to position the nasopharyngeal probe tip where the mucosa is in closest proximity to the internal carotid artery, since temperature measurements at this location in the upper nasopharynx correlates well with core temperature values. While in adults, the optimal insertion depth from the nostril to the nasopharynx-carotid-point (NCP) is 9 to 10 cm, in children, the ideal insertion depth for nasopharyngeal probes remains to be established.

Primary goal of the current research was to prospectively determine a target depth of nasopharyngeal temperature probe insertion in children by measuring the distance from nostril to the NCP through magnetic resonance imaging (MRI). Secondary aims were to correlate these measurements with biometric variables and facial landmark-distances in order to derive practical formulas that could easily estimate the targeted depth.

2 | METHODS

The current research was approved by the Institutional Review Board of the University Medical Centre Goettingen (No. 23/02/20) on February 20, 2020, and registered in the German Clinical Trials Register (DRKS-ID: DRKS00021007) on March 6, 2020. Patients were enrolled from March to September 2020. The study methodology is a secondary analysis planned a priori from our previously published research that determined the optimal targeted nasopharyngeal airway insertion depths in children through MRI. We adhered to the STROBE guidelines for reporting observational studies.

Detailed study methodology has been reported previously, and written parental or legal guardians informed consent was obtained before enrolment. We included children up to and including 12 years of age, requiring procedural sedation or monitored anesthesia care whenever MRI was indicated to rule out or follow-up a variety of brain pathologies. Exclusion criteria were facial, nasal, or airway pathologies that would have altered distance measurements.

2.1 | Protocol

We collected the following variables for each patient: age, sex, height, weight, American Society of Anesthesiologists physical status classification and indication for MRI. The following distance measurements of facial landmarks were performed with a tape measure (Skin Marker, Symmetry Surgical®) and recorded by investigators involved in this study:

- Nostril-mandible—from the middle of the nostril to the angle of the ipsilateral mandible;
- Nostril-tragus—from the middle of the nostril to the ipsilateral tragus of the ear;

Conclusions: Height-based formulas could be a valuable proxy for the insertion depth of nasopharyngeal temperature probes. Further clinical trials are necessary to investigate their measurement accuracy.

KEYWORDS

anesthesia, body temperature, child, nasopharynx, temperature

Clinical Implications

What is already known?

Nasopharyngeal temperature probes are minimally invasive and routinely used to monitor perioperative core temperature.

What this article adds?

Based on biometric variables, landmark-distances and magnetic resonance imaging measurements in 120 children aged 0 to 12 years, we determined a target insertion depth of nasopharyngeal probes in children and derived a formula to estimate optimal insertion depth.
• Philtrum-tragus— from the philtrum to the tragus of the ear.

Magnetic resonance imaging was performed with T1-3D-MPRAGE (Magnetization Prepared Rapid Acquisition with Gradient Echoes) and sagittal T2-weighted Turbo-Spin-Echo sequences. No additional sequences were required for study purposes.

2.2 | Imaging analysis

The nasopharynx-carotid-point was defined as the closest spot of the nasopharyngeal mucosa to the internal carotid artery. We measured the distance of the nostril to the NCP on MRI using the proprietary measurement tool of General Electric PACS® (version 6.0, General Electric). First, the NCP was determined on transversal T1 axis. After triangulation of this point to sagittal T1 axis, the distance of the nostril to the NCP was measured through the inferior nasal meatus and defined as target insertion depth [see Figure 1 for an illustration].

2.3 | Outcomes

Our primary outcome parameter was the target insertion depth to reach the NCP from the nostril according to age. Secondary outcomes included correlations of this distance with patients’ characteristics age, sex, height, and weight as well as with the measured nostril-mandible, nostril-tragus, or philtrum-tragus landmark-distances. We additionally derived formulas to best predict insertion depth by calculating their probabilities of tip placement at the NCP. Successful placement of the temperature probe was defined as probe tip located within a range of 10% around NCP.

2.4 | Statistics

Since we collected data as part of our previously published trial, no power analysis or sample size calculation was needed.

Outcomes are reported as mean and standard deviation according to age. Differences between females and male patients were assessed using the t-test with unequal variances. Exploratory analysis was performed to assess the correlations between the target insertion depth to reach the NCP from the nostril and the patient’s characteristics using Pearson’s correlation coefficient (ρ) and univariate linear regression. Correlation coefficients are reported with 95%-confidence interval (CI) and regression lines are shown with 95%-pointwise CI. Parameters of the linear regression are reported with estimate and SE. Multiple linear regression analysis with stepwise backward selection, based on Akaike’s information criterion (AIC), was used to derive a formula for the insertion depth to reach the NCP using all measured variables as independent variables. Data were analyzed using R version 4.0.5 (The R Foundation for Statistical Computing).

3 | RESULTS

Data of 120 children were analyzed (see Figure 2), whose characteristics are presented in Table 1. Because of incomplete measurements of nostril-mandible, nostril-tragus, and philtrum-tragus in 18 children, data of only 102 children were available for their univariate analysis and for the stepwise analysis.

The target insertion depth measured from the nostrils to the NCPs ranged from 61.8 mm (standard deviation of 7.4) in infants to 89.8 mm (10.4) in 12-year-old children. Table 2 shows mean measurements according to age. No significant difference in targeted insertion depth was found between females and males (p = .509).

The best correlation with the target insertion depth measured from the nostrils to the NCPs was with height (ρ = 0.685 [95%-CI: 0.57–0.77], p < .001), followed by weight (ρ = 0.630 [95%-CI: 0.51–0.73], p < .001) and age (ρ = 0.597 [95%-CI: 0.47–0.70], p < .001). All three investigated landmark-distances measured at the patients’ faces were inferiorly correlated, with nostril-tragus (ρ = 0.586 [95%-CI: 0.44–0.70], p < .001) from philtrum-tragus (ρ = 0.529 [95%-CI: 0.37–0.66], p < .001) and nostril-mandible (ρ = 0.509

![FIGURE 1](image-url) Illustration of measurement in a 3-years-old girl. Left: Determination of the target point (NCP) where the nasopharyngeal mucosa is in closest proximity to the internal carotid artery (ICA) on transversal T1 axis. Right: Measurement of distance from the nostril to the NCP on sagittal T1 axis.


For height, the univariate linear regression revealed an intercept of 40.81 (SE = 3.33) and slope of 0.32 (SE = 0.03). Therefore, the formula to best predict the target depth measured from the nostrils to the NCPs in millimeters was “40.8 + height [cm] × 0.32.” This would lead to a correct positioning in 67% of patients. A simplified and thus more practical formula without intercepts of “height [cm] × 0.7” would lead to a correct positioning in 44%. Another simplification method that grouped patients by their height achieved almost similar rates of a placement in the target position like the univariate formula (see Table 3).

Using stepwise analysis (n = 102), the formula to best predict the target depth measured from the nostrils to the NCPs in millimeters was “33.3 + height [cm] × 0.27 + philtrum-tragus [mm] × 0.12.” Adding philtrum-tragus to the formula improved the AIC from 441.46 to 441.45.

**TABLE 1** Participant characteristics. Values are numbers or mean (SD)

| Overall | 120 (55 female) |
|---------|-----------------|
| Age (year) | 4.5 (3.3) |
| Height (cm) | 102 (23.9) |
| Weight (kg) | 17.4 (8.6) |

ASA physical status
- I | 23 |
- II | 77 |
- III | 20 |

Reason for MRI exam
- Developmental disorder | 32 |
- Brain malformation | 28 |
- Brain tumor | 23 |
- Epilepsy | 11 |
- After cardiac arrest | 2 |
- Other | 24 |

\[95\%-CI: 0.35–0.64], \ p < .001. \ Figure 3 displays the scatter plots of correlations.

The target depth of nasopharyngeal temperature probe insertion, measured from the nostrils to the point closest to the internal carotid artery, ranged from 62 mm in infants to 90 mm in children up to and including 12 years. Since height achieved the best correlation as a proxy for the required insertion depth, the derived formula of “40.8 + height [cm] × 0.32” would lead to a correct positioning in two-thirds of the patients. The pragmatic approach by height categories achieved similar probabilities and might be easier to apply in clinical practice.

Defining NCP and measuring the distance from nostrils on radiologic images has been mainly used in adults. Its advantage is to be noninvasive compared with nasal endoscopy or insertion of a gadolinium-filled gastric tube as previously reported. The plausibility of our results is supported by studies in adults, where NCP was found in the upper nasopharynx at a depth of 91 to 94 mm in females and 97 to 101 mm in males from the nostrils. In contrast, we did not find any sex-specific difference, although those are known for growth rate of nasopharyngeal length during early childhood.

We consider as the most relevant finding, that in children the distance from the nostrils to NCP has a moderate to strong correlation with height. It is unclear whether identifying stronger correlations in children is even possible due to their different proportions, interindividual growth and development stages of the upper airway. This is especially true for a younger age, smaller height or lower weight. Since we are missing measurements of landmark-distances in 18 children for our multiple analysis, its correlation coefficient could be underrated, but likely not to a clinically meaningful extent. Since the multiple regression formula including philtrum-tragus improved the AIC only by 0.01, we consider it equally accurate to use the univariate formula with the height only.

Application of complex formulas, even though potentially useful in clinical trials, seems unlikely to be implemented in daily pediatric anesthesia practice. While distances for esophageal temperature probe insertion were reported to be more precisely predictable
by a formula,\textsuperscript{17} we could show that this does not apply to the target depth of nasopharyngeal temperature probe insertion. Other authors also investigated landmark-methods for the prediction of nasopharyngeal probe insertion depth. In four neonatal patients, Ko et al. inserted gadolinium-filled gastric tubes with the "nose-ear-distance" and found that the tube-tips projected onto the end of the nasopharyngeal probe insertion depth. In four neonatal patients, authors also investigated landmark-methods for the prediction of nasopharyngeal temperature probe insertion. Other advantages: First, it is easily accessible and may be more convenient than rectal measurement, which also lags core temperature over time of the measurements, particularly during rapid thermal perturbations.\textsuperscript{2} Second, placement of a nasopharyngeal temperature probe is feasible in conjunction with laryngeal masks as well as with regional anesthesia and deep monitored anesthesia care under spontaneous breathing. The latter cases require an extra careful placement to avoid placing the probe too deep in the hypopharynx with the risk of triggering laryngeal reflexes. Several misplacements have been previously described in adults. Therefore, van Zundert et al. recommended the placement under direct laryngoscopic vision by advancing the probe just past the soft palate and then withdrawing it until it is no longer visible,\textsuperscript{18} but this may not be feasible in non-intubated children. A reasonable compromise for a universally valid positioning for both intubated and spontaneously breathing children could be to place the probe tip within the corridor of the NCP and the end of soft palate. This would prevent both inaccurate measurement because of a too proximal placement in the nasal cavity\textsuperscript{11,19} and irritation of glottic structures because of a too distal position in the hypopharynx.

Regardless of the method used to calculate the insertion depth of a nasopharyngeal temperature probe, incorrect positioning results in measurement errors. The lack of data to guide insertion in children suggests that standardized insertion is unlikely to happen in clinical practice. Our derived univariate formula or the simplified suggestion by height groups could prove helpful to clinicians and improve current practice. To clinically validate a correct probe placement, it may be helpful to vary the probe position around the determined target depth while closely monitoring temperature changes until a stable temperature measurement is achieved.

### LIMITATIONS

We included children with potential or previously diagnosed cerebral pathology, resulting in a potential bias against a "healthy"

| TABLE 2 Target insertion depth measured from the nostrils to the NCPs according to age. Values are numbers or mean (SD) |
| --- |
| Age | n (females) | Nostril-NCP (mm) | Height (cm) | Weight (kg) | Nostril-mandible (mm) | Nostril-tragus (mm) | Philtrum-tragus (mm) |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 0 | 18 (10) | 61.8 (7.4) | 66.1 (7.4) | 7.1 (1.7) | 73.4 (7.9) | 89.1 (0) | 90.5 (10.5) |
| 0–6 months | 8 (6) | 63.6 (8.7) | 62.9 (8.1) | 6.3 (1.9) | 68.7 (7.7) | 85.6 (0) | 82.8 (12.1) |
| 7–12 months | 10 (4) | 60.4 (6.2) | 68.7 (5.9) | 7.7 (1.4) | 76.9 (6.5) | 92.2 (0) | 96.3 (3.5) |
| 1 years | 12 (5) | 67.8 (7.9) | 82.1 (5.3) | 11.0 (1.4) | 85.9 (4.4) | 100.0 (5.5) | 102.6 (8.8) |
| 2 years | 22 (7) | 71.8 (8.1) | 91.8 (7.4) | 13.4 (2.5) | 90.1 (8.8) | 102.8 (5.5) | 106.0 (9.5) |
| 3 years | 13 (6) | 74.6 (7.2) | 101.4 (8.4) | 16.0 (2.8) | 98.8 (6.5) | 106.4 (4.5) | 108.6 (14.2) |
| 4 years | 9 (5) | 68.7 (10.4) | 104.2 (7.9) | 17.7 (4.9) | 95.0 (12.5) | 106.4 (9.6) | 109.7 (11.8) |
| 5 years | 11 (4) | 82.7 (6.9) | 113.4 (4.3) | 20.3 (2.1) | 95.9 (6.4) | 109.4 (7.3) | 110.6 (11.8) |
| 6 years | 12 (5) | 79.0 (14.2) | 119.2 (7.7) | 22.2 (4.4) | 98.6 (6.7) | 113.2 (5.6) | 115.5 (9.3) |
| 7 years | 2 (1) | 82.5 (2.1) | 126.0 (2.8) | 24.0 (2.8) | 102.5 (3.5) | 117.5 (3.5) | 120.0 (14.1) |
| 8 years | 6 (3) | 84.8 (8.6) | 135.7 (6.6) | 31.7 (9.5) | 101.7 (8.8) | 114.2 (7.4) | 118.3 (7.5) |
| 9 years | 6 (5) | 82.8 (5.5) | 138.0 (14.5) | 31.1 (8.8) | 101.7 (7.6) | 110.0 (5) | 120.0 (11.8) |
| 10 years | 3 (2) | 77.0 (8.9) | 134.3 (16.2) | 29.3 (14.6) | 100.0 (14.1) | 120.0 (0) | 122.5 (10.6) |
| 11 years | 4 (2) | 89.8 (10.4) | 135.5 (14.4) | 26.4 (8.2) | 105.0 (10) | 115.0 (10) | 125.0 (10) |
| 12 years | 2 (1) | 82.5 (0.7) | 135.5 (6.4) | 29.5 (0.7) | | | |

Abbreviations: m, months; y, years.

\textsuperscript{a}Including data of only 102 children.
As this study was a secondary analysis of our previously published trial, we did not perform a specific sample size calculation for this purpose. Because of the observational study design, we reported a heterogeneous distribution of patients according to age. This may limit the validity of the results that are age-specific. Thus, our results may not be applicable for small children with...
height < 50 cm such as neonates or preterm infants. We defined a tolerance range of 10% around the NCP, extrapolated from the proportions of the measurements for optimal placements in adults by Lee et al. Probabilities for placements in the target corridor vary depending on this tolerance range, but choosing 10% seems clinically reasonable to avoid placements in the nasal cavity or the lower nasopharynx. As for any single-center studies, results might differ elsewhere.

6 | CONCLUSIONS

The distance from the nostril to the nasopharynx-carotid-point, as a target insertion depth for nasopharyngeal temperature probes, can best be predicted by height in children. The formula "40.8 + height (cm) x 0.32" or the pragmatic approach by height categories could serve as a clinically meaningful approximation. Future trials should investigate the actual accuracy of temperature measurements from probes placed via these techniques and how to validate proper probe placement clinically.

AUTHORS’ CONTRIBUTIONS

Clemens Miller involved in conceptualization, methodology, formal analysis, data curation, investigation, writing—original draft, writing—review and editing, visualization, and project administration. Anselm Bräuer involved in conceptualization, methodology, writing—original draft, and writing—review and editing. Thomas Asendorf involved in conceptualization, methodology, formal analysis, data curation, writing—review and editing, and visualization. Marielle Ernst and Philipp von Gottberg involved in investigation and writing—review and editing. Juliane Richter involved in investigation, data curation, writing—review and editing. Leif Saager involved in writing—review and editing. Marcus Nemeth involved in conceptualization, methodology, data curation, investigation, writing—original draft, writing—review and editing, and project administration.

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TABLE 3 Simplified method for estimation of target insertion depth for nasopharyngeal temperature probe insertion by height categories and their probabilities of placement in the target position

| Height (cm) | Target depth of insertion (mm) | Probabilities of placement in the target position (%) |
|------------|-------------------------------|-----------------------------------------------------|
| 50–80      | 60                            | 61%                                                 |
| 80–110     | 70                            | 62%                                                 |
| 110–130    | 80                            | 71%                                                 |
| >130       | 85                            | 69%                                                 |

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CONFLICT OF INTEREST

A. Bräuer is a member of the advisory board of 3 M Europe and has received payments from 3 M Germany, 3 M Europe, 3 M Asia Pacific Pte Ltd., The Surgical Company Netherlands and Moeck and Moeck GmbH Germany for consultancy work. L. Saager reports financial relationships with Medtronic, Ireland.

DATA AVAILABILITY STATEMENT

The study data are not publicly available due to institutional policy. Data are available upon reasonable request from the corresponding author.

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