Original Article

New parameters measured via preoperative tonsil photos to evaluate the post-tonsillectomy pain: an analysis assisted by machine learning

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Background: Postoperative pain is the most common complication after tonsillectomy. We aimed to explore new parameters related to post-tonsillectomy pain, as well as to construct and validate a model for the preoperative evaluation of patients' risk for postoperative pain.

Methods: Data collected from patients who underwent tonsillectomy by the same surgeon at Beijing Chaoyang Hospital from January 2019 to May 2022 were analyzed. Preoperative tonsil images from all patients were taken, and the ratios of the distance between the upper pole of the tonsil and the base of the uvula (L1 for the left side and R1 for the right side) to the width of the uvula (U1) or the length of the uvula (U2) were measured. The following six ratios were calculated: L1/U1, R1/U1, LR1/U1 (the add of L1 and R1, and then divide U1), L1/U2, R1/U2, LR1/U2 (the add of L1 and R1, and then divide U2). The post-tonsillectomy pain was recorded. In addition, machine learning (ML) algorithm and feature importance analysis were used to evaluate the value of the parameters.

Results: A total of 100 patients were involved and divided into the training set (60%) and the validation set (40%). All six parameters are negatively correlated with post-tonsillectomy pain. The accuracy, sensitivity, and specificity of the model were 75.0%, 72.7%, and 77.8%, respectively. LR1/U1 and LR1/U2 are the most valuable parameters to evaluate post-tonsillectomy pain.

Conclusions: We have discovered new parameters that can be measured using preoperative tonsil images to evaluate post-tonsillectomy pain. ML models based on these parameters could predict whether these patients will have intolerable pain after tonsillectomy and manage it promptly.

Keywords: Tonsillectomy; chronic tonsillitis; postoperative pain; post-tonsillectomy pain; machine learning (ML)

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Introduction

Tonsillectomy is a surgical procedure performed to remove the tonsils, which are located on both sides of the throat. The tonsils are part of the immune system and help to protect the body from infection. However, in certain cases, the tonsils themselves can be infected and become swollen, causing a range of symptoms including severe sore throat, difficulty in swallowing, and fever. If the patients are suffering from recurrent tonsillitis, adenotonsillar hypertrophy, recurrent peritonsillar abscess, adenotonsillar hypertrophy, sleep-disordered breathing, a tonsillectomy may be recommended as a treatment option (1).

Postoperative pain is the most common complication after tonsillectomy and most patients require active intervention, such as painkillers, to alleviate the pain (2). Effective management of post-tonsillectomy pain can increase patient satisfaction, reduce hospital stays, and minimize the risk of complications such as bleeding and infection (3). Therefore, there have been many studies attempting to reduce postoperative pain in patients undergoing tonsillectomy. Some researchers have proposed using anesthesia analgesics and steroids during the perioperative period to manage postoperative pain (4-6), while others have used postoperative ingestion of ice water (7,8) or honey (9) to alleviate the pain.

However, there is relatively minimal literature on postoperative pain assessment in patients with proposed tonsil surgery. Conducting adequate preoperative pain assessment can help predict which patients will be more likely to experience intolerable pain after the surgery. Developing contingency plans for these patients, such as actively using pain relief medications or using effective pain management measures, can reduce the risk of postoperative bleeding. Additionally, adequate communication with such patients to manage their postoperative psychological expectations can also reduce doctor-patient conflicts, increase patient satisfaction, and relieve mental and physical discomfort as well as increase their quality of life during the perioperative period for these patients.

In clinical practice, we have observed a possible association between the location of the upper pole of the tonsil and the uvula and postoperative pain in tonsillectomy patients, but preoperative measurement of the distance between the upper pole of the tonsil and the uvula can be difficult. Therefore, we hope to measure the ratios between different positions and distances in preoperative pharyngeal and tonsil images. By analyzing the correlation between these ratios and postoperative pain, new parameters may be found for the preoperative evaluation of postoperative pain after tonsillectomy. We present this article in accordance with the STARD reporting checklist (available at https://gs.amegroups.com/article/view/10.21037/gs-23-248/rc).

Highlight box

Key findings

- New parameters which can be measured using preoperative tonsil images to evaluate post-tonsillectomy pain were proposed.
- A new model for post-tonsillectomy pain prediction was established and validated.

What is known and what is new?

- Postoperative pain is the most common complication after tonsillectomy and most patients require active intervention, such as painkillers, to alleviate the pain.
- The current study discovered new parameters and constructed a new model to predict post-tonsillectomy pain.

What is the implication, and what should change now?

- Post-tonsillectomy pain should be well evaluated to make more precise treatment for the patients, this study offers a new way to predict post-tonsillectomy pain before surgery.

Methods

General information

The enrollment process of the study participants is shown in *Figure 1*. A retrospective analysis was conducted on adult patients with chronic tonsillitis who underwent tonsillectomy by the same surgeon (first author) in our hospital between January 2019 to May 2022. A total of 154 patients were identified, among them, 10 patients who received uvulopalatopharyngoplasty (UPPP) treatment and 6 patients with tonsil masses were excluded. In a previous study by our team, to explore the effect of cold-water irrigation on the coblation site for post-tonsillectomy pain (10), 38 patients have received cold-water irrigation treatment. To avoid the potential bias caused by different irrigation methods, these 38 patients were also excluded from this study. Finally, a total of 100 patients' data were included for analysis. As our center routinely conducts ear, nose and throat (ENT) examinations and saves image data for all patients as part of their medical records, we have collected tonsil images for all 100 patients. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics

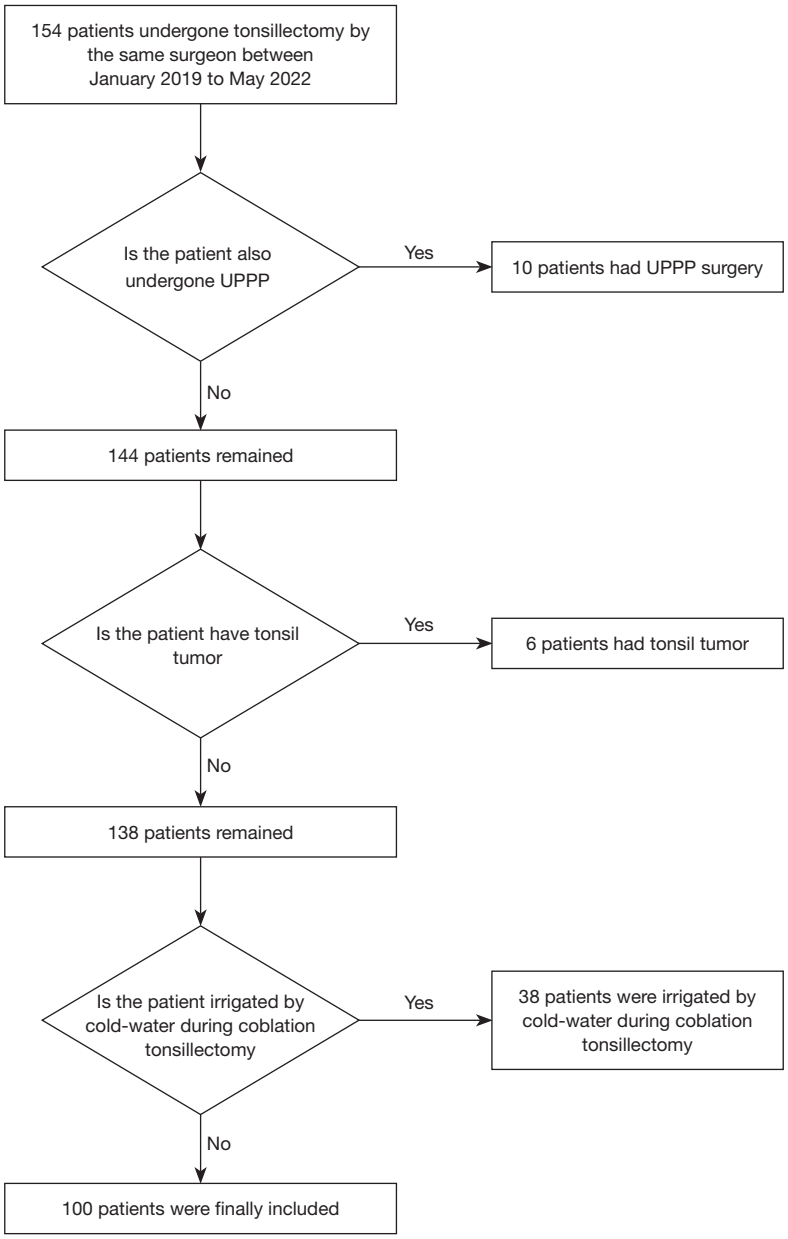

Figure 1 The workflow of the included patients. UPPP, uvulopalatopharyngoplasty.

committee of Beijing Chaoyang Hospital (No. 2022-602), and all the patients signed the informed consent form.

Measurement parameters

All included patients took a sitting position, trying to open their mouth and gently press the tongue with a tongue depressor, and making an "[ɑ:]" sound as much as possible to ensure that the tonsil photos taken each time are as consistent as possible. The endoscopy system was used to collect the pictures. The collection and measurement of all pictures were completed by the same doctor. An open-source image editing software "GIMP" (https://www.gimp.org) was used to measure the parameters.

Since it is hard to measure the specific values of the tonsils when the patients are awake, we chose to analyze the ratio of the parameters measured through the photos of the tonsils. In this way, the measured ratio is constant regardless

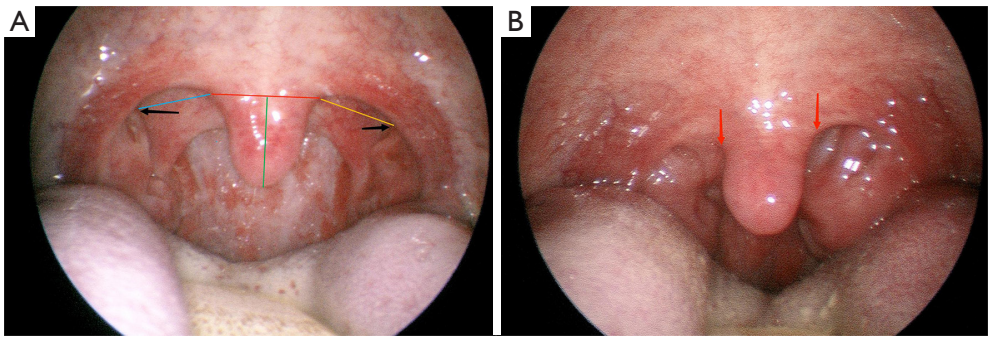

Figure 2 Example plots of the tonsil measurement parameters. (A) The red line refers to the width of the uvula (U1), the green line refers to the length of the uvula (U2), the blue line refers to R1, yellow line refers to L1, the black arrow shows the up tole of the tonsils. (B) If the up tole of the tonsils were close to the uvula or could not be exposed, L1 or R1 would be recorded as 0. The red arrows show an example of both side of the tonsils were hard to distinguish the up tole of the tonsils.

of how the image is scaled. Thus, the width of the uvula root of the patient is recorded as U1, the distance between the midpoint and the lowest point of the free edge is recorded as U2, the distance between the right root of the uvula and the upper pole of the right tonsil is recorded as R1, and the distance between the left root of the uvula and the upper pole of the left tonsil is recorded as L1 (*Figure 2A*). If superior tonsils were close to the uvula or could not be exposed, L1 or R1 would be recorded as 0 (*Figure 2B*). The final parameters were calculated, respectively. They are: L1/U1, R1/U1, LR1/U1 (the add of L1 and R1, and then divide U1), L1/U2, R1/U2, LR1/U2 (the add of L1 and R1, and then divide U1).

Surgical treatment

All cases included in this study were operated on by the same surgeon (first author) to avoid study bias caused by differences in surgical proficiency. All patients underwent bilateral tonsillectomy using a coblation technique, with the surgical cavity washed with normal saline at room temperature. During the operation, the anesthesiologist will give one flurbiprofen axetil to each patient. After the operation, if the patient has no pain that is intolerable, he will not give analgesics routinely. No local anesthetic was used during the surgery.

Postoperative pain assessment

In this study, postoperative pain was assessed for all patients in the following process: all patients were discharged after 3 days of hospitalization and were asked about their degree of sore throat and whether they required pain relief medication on the day of surgery, the first day, the second day, and the third day after surgery. If the patient considered the pain "tolerable" on postoperative days 0–3, postoperative pain tolerance was recorded and marked as "0". If the patient experienced intolerable pain and required pain relief medication, postoperative pain intolerance was recorded and marked as "1". In other words, if patients report unbearable pain and require painkillers within three days, they will be classified as the "postoperative pain group (marked as 1)". Otherwise, they are classified as the "non postoperative pain group (marked as 0)".

Establishment of prediction models and feature analysis using machine learning (ML) algorithms

Artificial intelligence (AI) technology includes ML and deep learning, and this study mainly uses ML technology. The Python programming language (Version 3.9) and the SKLearn ML package were used to establish the model in this study. The algorithm used was linear discriminant analysis (LDA), with 60% of the dataset as the training set and 40% as the validation set. The accuracy, sensitivity, specificity, and the area under the receiver operating characteristic (ROC) curve (AUC) were used to evaluate the testing performance of the model and a confusion matrix was displayed. Shapley Additive Explanation (SHAP) was used to analyze the contribution of each measured parameter of the tonsil to the model to confirm which features had predictive value for postoperative pain.

Table 1 Demographic data of the enrolled patients

Demographics	Value
Age (years)	33.3±9.5 (range, 18–64)
Sex (F/M)	44/56
BMI (kg/m^2)	25.1±3.9
Height (cm)	171.2±7.8
Weight (kg)	73.9±14.5

Data are presented as number or mean ± standard deviation. F, female; M, male; BMI, body mass index.

Table 2 The relationship between each parameter and post-tonsillectomy pain*

Parameter	r	P
Age	0.175	0.082
Sex	–0.040	0.691
BMI	0.097	0.337
Height	0.000	0.997
Weight	0.070	0.487
Ltonsil	0.154	0.125
Rtonsil	0.086	0.397
L1/U1	–0.391	0.000
R1/U1	–0.316	0.001
LR1/U1	–0.377	0.000
L1/U2	–0.304	0.002
R1/U2	–0.224	0.025
LR1/U2	–0.282	0.004

*, using Spearman analysis. BMI, body mass index; Ltonsil, the degree of the left tonsil; Rtonsil, the degree of the right tonsil.

Statistical analysis

All data obtained in this study were analyzed using SPSS 20.0 software, including age, measured parameters, etc. The correlation between each clinical parameter and the pain score was analyzed using Spearman correlation analysis, and $P<0.05$ was considered statistically significant.

Results

General demographic data statistics

A total of 100 patients were included in the study, with their basic demographic characteristics shown in *Table 1*. Among them, 56 were male, 44 were female, and their ages ranged from 18 to 64 years old with a mean age of 33.3±9.5 years old. The mean height was 171.2±7.8 cm, the mean weight was 73.9±14.5 kg, and the mean body mass index (BMI) was 25.1±3.9 kg/m^2. Fifty patients required pain medication due to difficulty in tolerating postoperative pain (loxoprofen sodium), while the other 50 patients were able to tolerate postoperative pain without medication.

Relationship between each parameter and post-tonsillectomy pain

Spearman correlation analysis was used to analyze the correlation between all included demographic data and tonsil measurement parameters and postoperative tonsil pain. Results are shown in *Table 2* and *Figure 3*. Age, gender, patient height, weight, BMI and the degree of hypertrophy of the tonsils were not significantly correlated with postoperative tonsil pain. All six tonsil measurement parameters showed a significant negative correlation with postoperative tonsil pain, including L1/U1 ($r=-0.391$, $P=0.000$), R1/U1 ($r=-0.316$, $P=0.001$), LR1/U1 ($r=-0.377$, $P=0.000$), L1/U2 ($r=-0.304$, $P=0.002$), R1/U2 ($r=-0.224$, $P=0.025$), and LR1/U2 ($r=-0.282$, $P=0.004$).

ML modeling results and feature importance analysis

This study successfully established a ML model for predicting postoperative pain after tonsillectomy, with accuracy, specificity, sensitivity and AUC values of 75.0%, 77.8%, 72.7% and 75.0%, respectively. The confusion matrix and ROC curve are shown in *Figure 4A* and *Figure 4B*, respectively. The SHAP feature importance analysis results (*Figure 5*) indicate that LR1/U1 has the largest contribution to the model, meaning it has a greater predictive value for postoperative pain after tonsillectomy. The next important features are LR1/U2, R1/U2, R1/U1, L1/U1 and L1/U2.

Discussion

It is important to evaluate post-tonsillectomy pain before the surgery to ensure that the patient is mentally prepared and will receive proper pain management. This study successfully identifies some measurement parameters that can be used for preoperative evaluation of post-

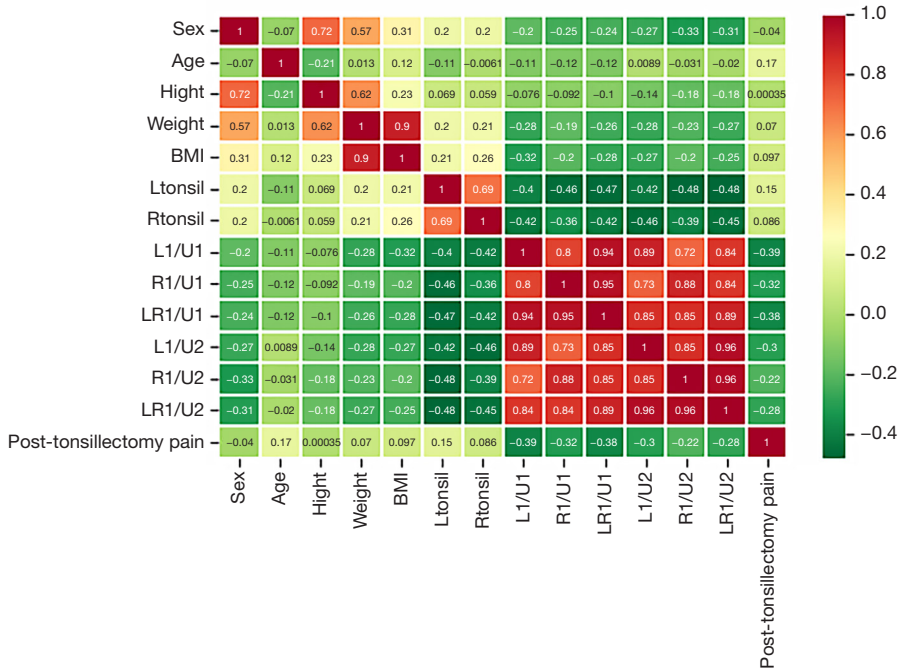

Figure 3 Correlation heatmap presentation: the relationship between each parameter and post-tonsillectomy pain. BMI, body mass index; Ltonsil, the degree of the left tonsil; Rtonsil, the degree of the right tonsil.

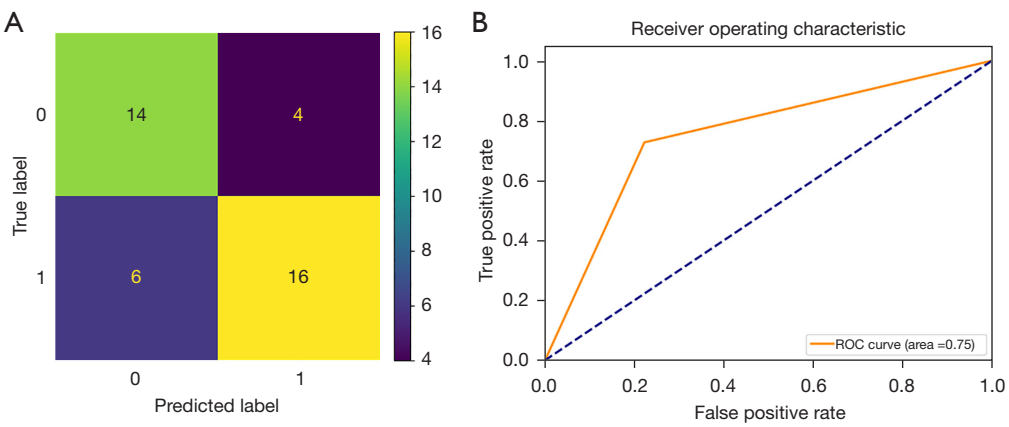

Figure 4 Test results of the machine learning model of the test set. The confusion matrix (A) and the ROC curve (B), where the AUC is 75.0%. ROC, receiver operating characteristic; AUC, area under the ROC curve.

tonsillectomy pain. These parameters have a significant correlation with post-tonsillectomy pain, and ML models based on these parameters may be used for post-tonsillectomy pain evaluation. By conducting SHAP feature importance analysis, we further discovered that LR1/U1 and LR1/U2 are the most important predictive measurement parameters for post-tonsillectomy pain.

Currently, there is relatively little research focused on predicting postoperative pain in tonsillectomy patients before surgery. Existing literature has indicated that coblation surgery results in less postoperative pain compared to traditional electric knife or bipolar tonsillectomy, and the use of coblation technique for tonsillectomy has gradually become widely applied (11,12). However, even with the use of coblation technology, many patients still experience postoperative throat pain, suggesting further assessment

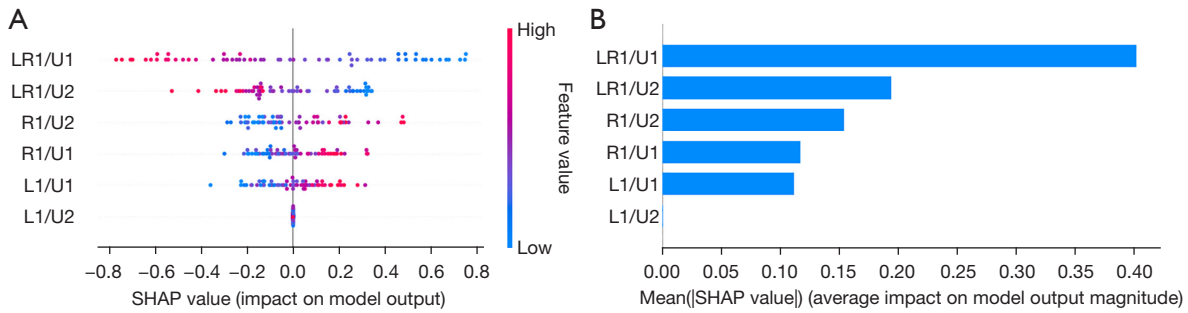

Figure 5 SHAP feature importance analysis demonstrates the contribution of each feature to the model, LR1/U1 and LR1/U2 are the most important predictive measurement parameters for post-tonsillectomy pain. SHAP, Shapley Additive Explanation.

of postoperative pain in patients undergoing tonsillectomy with coblation is of practical and theoretical value.

The parameters measured in this study mainly reflect the positional relationship between the upper pole of the tonsil and uvula. Since the tonsils are bilateral, this positional relationship on both sides should be taken into consideration. We found that all the aforementioned measurement parameters were negatively correlated with postoperative pain, indicating that the farther the distance between the upper pole of the tonsil and uvula, the less pain experienced by the patient after surgery. This may be due to the extent of mucosal injury during surgery: if the tonsils are farther away from the uvula, there is less possibility of edema caused by injury to the uvula during surgery, and it is more helpful in preserving the mucosa around the tonsils. García *et al.* have shown that in tonsil surgery, the active protection of the mucosal tissue around the tonsils can help to reduce the postoperative pain in patients (13).

AI technology has been widely used in medicine, including the field of otolaryngology (14). The AI technology used in this article is a type of ML algorithm called LDA. LDA is a classical linear learning method that has been widely used in the establishment of predictive models in the medical field (15). In this study, an LDA algorithm was used to establish a post-tonsillectomy predictive model, and the model performance of the testing machine was satisfactory, which may be helpful in predicting postoperative pain in tonsillectomy patients.

There are some advantages to this study. Firstly, this study has discovered new measurement indicators that can predict post-tonsillectomy pain. Secondly, these indicators can be measured and calculated from throat photos collected from the patients before the surgery, enabling the prediction of postoperative pain before the surgery. Finally, we have also established a predictive model for post-tonsillectomy pain using ML algorithms based on these measurement parameters. Based on the prediction results, physicians can communicate with patients in advance and develop strategies to manage postoperative pain.

However, there are also some limitations to this study. Firstly, the sample size included in this study is still relatively small. Secondly, the subjects included in this study were from a single center and all surgeries were performed by the same physician, and further multi-center studies with larger sample sizes could be conducted in the future. This study only analyzed adult tonsillectomy patients, and the value of these parameters in predicting postoperative pain in children with tonsillectomy needs further research. In addition, this study did not consider the impact of endophytic tonsils on post tonsillectomy pain, and further in-depth research will be conducted in this area in the future.

Conclusions

In conclusion, these new tonsil measurement parameters can provide valuable information in evaluating post-tonsillectomy pain. Besides, the proposed ML models constructed based on these parameters could also be used to predict whether these patients will have intolerable pain after the surgery and can help in developing personalized pain management plans for individual patients.

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Footnote

Reporting Checklist: The authors have completed the STARD reporting checklist. Available at https://gs.amegroups.com/article/view/10.21037/gs-23-248/rc

Data Sharing Statement: Available at https://gs.amegroups.com/article/view/10.21037/gs-23-248/dss

Peer Review File: Available at https://gs.amegroups.com/article/view/10.21037/gs-23-248/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://gs.amegroups.com/article/view/10.21037/gs-23-248/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics committee of Beijing Chaoyang Hospital (No. 2022-602), and informed consent was obtained from all individual participants included in the study.

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