Mobile Application-based Approach for the Measuring of Internal Nasal Structures

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Аннотация. **Внутренний носовой клапан (ВНК) - одна из основных причин обструкции носового воздушного потока. Незначительные изменения площади поперечного сечения области носового клапана могут иметь значительное влияние на воздушный поток, что, в свою очередь, влияет на функцию носа и проходимость дыхательных путей. В последние годы широко используется измерение ВНК на основе данных КТ, но не всем пациентам можно оперативно выполнить КТ. 111 пациентам, перенесшим эндоназальную операцию с сентября 2018 по январь 2020 года, измерили площадь поперечного сечения внутреннего носового клапана и устья клиновидной пазухи с использованием нового подхода. Во всех случаях мы использовали мобильное приложение. Средняя площадь поперечного сечения внутреннего носового клапана до септопластики составляла 20-40 мм^2. В долгосрочной перспективе мы использовали это мобильное приложение для измерения площади поперечного сечения и оценки увеличения площади после процедур. С помощью него была легко показана динамика закрытия соустья клиновидной пазухи. Новый подход на основе мобильного приложения быстр и прост для использования. Такое приложение полезно для определения площади поперечного сечения, а также для анализа этой площади в динамике.**

Ключевые слова: носовой клапан, эндоскопия, мобильное приложение, клиновидная пазуха

I. Introduction

The internal nasal valve (INV) forms an important anatomical landmark. INV consists of the caudal border of the upper lateral cartilage and the anterior end of the inferior turbinate [1]. This area has the narrowest area cross-sectional area of the entire respiratory tract. The vestibular part of the nasal cavity is the place of highest nasal resistance to airflow. The internal nasal valve is one of the main causes of nasal airflow obstruction. Minor changes in the cross-sectional area of the nasal valve region may significantly impact airflow, which in turn affects nasal function and the perception of airway patency. The average angle of the INV in a Caucasian range from 10° to 15° and inter-racial variance is well recognized, in part due to the size of the inferior turbinate [2]. The collapse of the valve is thought to obey Bernoulli's principle and, as such, is a common cause for nasal obstruction Bernoulli's principle of fluid dynamics states that as air enters the narrowed segments, acceleration occurs, leading to a drop in intraluminal pressure. This phenomenon tends to collapse the lateral nasal wall, where minor septal deviations, weakened soft tissues, or malformed lateral crura can greatly impact nasal airflow [3].

The causes of nasal breathing disorders such as nasal septum deviation, chronic rhinitis, sinus diseases can predispose to the development of Eustachian tube and middle ear pathology, inflammatory diseases of the pharynx, larynx, and lower respiratory tract. Nasal obstruction affects the functional state of the cardiovascular system and leads to a whole complex of neurological disorders. Therefore, one of the main goals of internal nasal valve surgery is to improve nasal breathing. The nasal valve areas were described in the clinical consensus statement from the American Academy of Otolaryngology-Head and Neck Surgery as the cross-sectional area of the nasal cavity with the greatest overall resistance to airflow [4].

As a result, improving airflow through the nasal valve region is an active area of interest for ENT-doctors who perform septoplasty. This operation is part of the surgical armamentarium used to treat nasal congestion [5]. Septoplasty is a commonly performed procedure sufficient to correct nasal obstruction. The effects of septoplasty on the nasal valve have been a subject of many studies [6]. It is necessary to evaluate septoplasty by measuring the internal nasal valve and increasing the cross-sectional area. Spielman et al. were presented a systematic review that nasal valve surgery research is too focused on the technique rather than patient outcomes. Mainly the authors pointed out the deficiencies in using objective measures for assessing nasal airflow to evaluate the efficacy of treatment [7].

Existing methods for assessing nasal valve insufficiency are non-specific and subjective. For example, Cottle's maneuver or Bachman's test involves pulling the nose wing in the upper-lateral direction, which is more relevant in the pathology of the external nasal valve rather than the internal one [8, 9]. Several studies have successfully used acoustic rhinometry or active anterior rhinomanometry to detect changes in cross-sectional area and airflow, respectively, of the nasal valve. These measures were objective and reproducible methods that can be used for assessing pre and postoperative results. In [10, 11] Constantinides et al used head out body displacement plethysmography measurements to conclude that in 27 patients, septorhinoplasty caused changes in nasal valve function. Patients with normal nasal airflow resistance usually had an asymptomatic increase in nasal resistance after cosmetic rhinoplasty. Patients with abnormal resistance to nasal airflow and increased resistance before surgery reduced their resistance to nasal airflow to normal or close to normal levels after surgery. Surgeons used various subjective means to measure changes in nasal airflow in the form of surveys and questionnaires. These surveys and questionnaires were used to compare objective indicators with a patient's perception of nasal airflow [12]. However, there was no mobile method available for objective measuring of the internal nasal valve structures.

II. Mobile Application for Measuring Internal Nasal Structures from Endoscopic Images

To resolve the nasal valve examination issue, we have developed a special mobile application based on an image processing algorithm. First, a 0° endoscope was marked at 1 cm with tape and placed precisely at the columella-nasal sill in the front plane. In addition, the endoscope was located inside the nasal cavity in the “7 o'clock” position. These positions capture an endoscopic image of the internal nasal valve. Then a calibration tool with a known diameter is installed at the level of the cross-sectional area in the internal nasal valve. After the correct installation of the endoscope and calibration tool, the surface area within the traced contours was measured using the mobile App. First, the calibration tool was highlighted on the mobile phone screen, and then the area itself.

Using OpenCV-based [13] image processing algorithms, the application independently measures the airway part of the nasal valve and gives out the number. The number is replaced with absolute units (cm or mm) based on the calibration tool data. This is how we calculate the nasal valve square.

For the application to work correctly, it is needed to purchase a special endoscope cover. This cover will help get an image directly into a smartphone without interference and noise.

Below is the main functionality of the mobile application:

- recording of patients and data about them;
- making an appointment by dates;
- entering the anamnesis of patients;
- photography and image processing of the nasal cavity using an OpenCV-based algorithm;
- the ability to share the original or processed photo, as well as generate a report in PDF format and send it to another device.

The application consists of 6 main screens:

1. The “Home” screen (Fig. 1). Previously recorded patients are showed on it. By default, patients are sorted alphabetically. It is also possible to register new patients using the main screen.

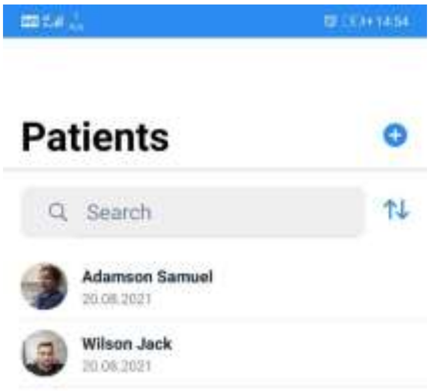

Fig. 1. The “Home” screen of the mobile App

2. The “Patient registration” screen (Fig. 2). This screen shows patient data, and gender is selected. It is possible to record additional information about the patient (chronic diseases, allergies, anamnesis, etc.), as well as add or make a patient, for convenient display on the “Main” screen.

Fig. 2. The “Patient registration” screen of the mobile App

3. In Fig. 3 it is shown the “Patient” screen. On this screen, the user can see the patient data filled in earlier and the dates of past, current, and future appointments.

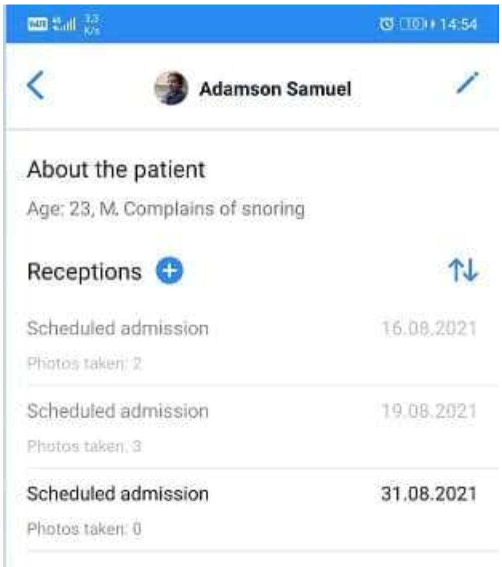

Fig. 3. The "Patient" screen of the mobile App

4. The "Observation" screen (Fig. 4). Here the user can select a tool to calibrate the algorithm, write additional patient data for a specific appointment, and take new photos of the patient's nasal passages.

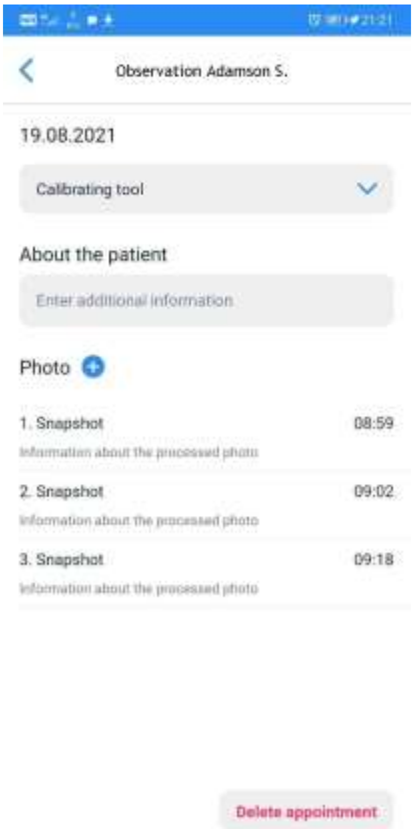

Fig. 4. The "Observation" screen of the mobile App

5. In Fig. 5 it is shown the "New Snapshot" screen. A camera has been added to the screen, as well as sliders for zoom, focus, and illumination. In addition, the user must choose which part of the nasal cavity he is currently shooting and take a picture. After the user has taken a snapshot, it is processed by the OpenCV-based algorithm and displayed on the "Result" screen (Fig. 6).

6. The "Result" screen also displays the original photo, calibration tool, part of nasal cavity, and area of internal nasal structures.

Fig. 5. The "New Snapshot" screen of the mobile App

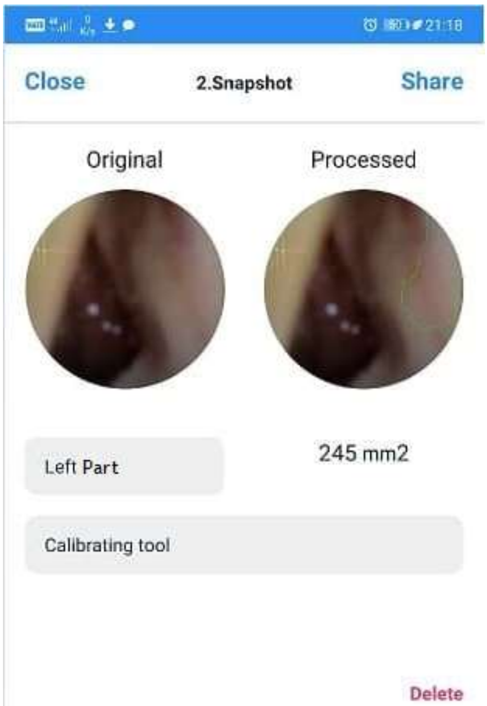

Fig. 6. The "Result" screen of the mobile App

Our observations have shown that this technique can be used to measure any object in the frontal plane. Such object was a natural anastomosis with a sphenoid sinus [14].

III. Material and methods

We have developed a mobile application with manual marking of the measurement object to assess the state of the nasal cavity's anatomical holes based on the patient's individual parameters. This is necessary to determine the treatment tactics and dynamic monitoring, as well as to reduce the measurement time in the pre and postoperative period.

The study was conducted on the basis in the ENT Department at Pavlov First Saint Petersburg State Medical University in the period from September 2018 to January 2020. 111 patients were included, 25 (22.5 %) underwent endoscopic sphenotomy, and 86 (77.4 %) were performed septoplasty.

86 patients who underwent endonasal septoplasty from September 2018 to January 2020 measured the cross-sectional area of the internal nasal valve using a new method. In all cases, we used the mobile application. The medium cross-sectional area of the internal nasal valve prior to septoplasty was 20–40 mm^2. In the long term, we used this mobile App to measure the cross-sectional area and estimate the increase in area after procedures.

During the surgery on the nasal cavity, only sphenoid ostium is located in the frontal plane compared to other sinuses [15]. This arrangement allows you to visualize the anastomosis with the sphenoid sinus through an endoscope 0° without distortion of the endoscopic picture [16]. The same technique was performed to measure the natural ostium of the sphenoid. This process helps the surgeon with the objectivity of the sphenoidotomy classification.

IV. Results

Outcomes of septoplasty were successful. Measured value areas after septoplasty averaged 91±32 mm^2 (min 49 mm^2; max 110 mm^2). In the early and long-term postoperative period, we noted that the average area of the internal nasal valve raised by 48 % (Fig.7).

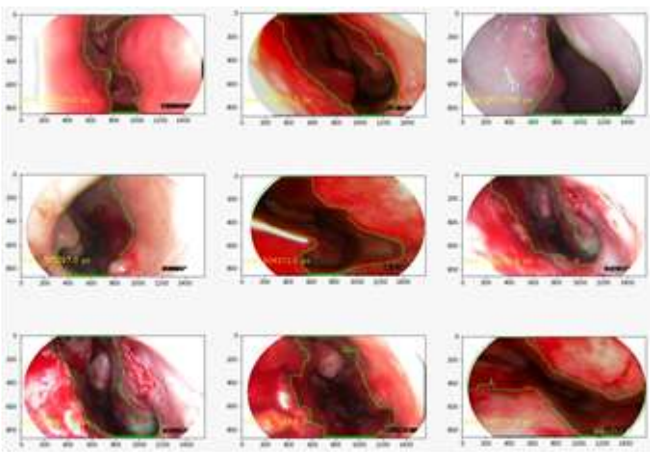

Fig. 7. The nasal valve measurement with the use of the mobile App

Using a mobile application helped to increase the effectiveness of procedures by eliminating the subjective component and implementing objective, numerical changes in the nasal cavity.

In the case of the sphenoid sinus, the mobile App allowed measurements on the same patients. This was required to track the tendency to stenosis of the anastomosis (Fig. 8). The average value of the reduction in the area of the anastomosis was +/- 20 %.

Fig. 8. The minimal enlarge of the left sphenoid sinus ostium. Computed tomography of the patient

V. Conclusion

The new mobile App proved to be a fast and easily performed method. This application is useful for determining the cross-sectional area as well as to analyze this area in the dynamics.

The developed mobile App allows to obtain the necessary measurements in absolute units (mm^2), and therefore, based on the individual parameters of the patient's nasal valve, it is possible to determine the area of the INV sufficient for nasal breathing. The data analysis shows that the endoscopic mobile-based method of measuring INV can be used as an objective tool in addition to CT, considering their proven relationship.

For sphenoid sinus surgery, this application allowed for an objective comparative dynamic of natural ostium healing.

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