Original Article

Endoscope to Identify A Smoker's Oral Mucosa for Early Obstructive Airway Disease Detection

Budi Yanti[1], Zarfan Fawwaz Muhamad[1], Teuku Fais Duta[1], Muhammad Iqbal Maulana[2], Irmayani[2], Yuli Fatzia Ossa[3], Sherina[3]

[1]Department of Pulmonology and Respiratory Medicine,
Faculty of Medicine, Universitas Syiah Kuala, Banda Aceh, Indonesia
[2]Department of Electrical and Computer Engineering, Universitas Syiah Kuala, Banda Aceh, Indonesia
[4]Faculty of Dentistry, Universitas Syiah Kuala, Banda Aceh, Indonesia

Abstract

Background: The synergistic association between oral cavity disorders and airway disorders in smokers has long been recognized. Periodontal disease and airway obstruction are 20 times more likely in smokers. Smoking causes increased inflammatory cytokines in the oral mucosa; generally, airway obstruction has been associated with increased inflammatory markers in the airway mucosa. This study developed a prototype to visualize smokers' oral mucosa to identify potential airway obstruction disease.

Methods: This study collected many types of oral mucosal lesions that are typically found in smokers, such as leukoplakia, nicotinic stomatitis, black hairy tongue, oral cancer, and smoker melanosis, from various literature and images of the mucosa of patients with a history of smoking who were treated at the hospital. The data is divided into a training, validation, and testing set and then using the PyTorch framework and the UltraLytics library.

Results: This study created a prototype of an endoscope that can detect lesions on the oral mucosa-related airway obstruction disease. Sixty-three percent of the respondents who underwent prototype testing were between the ages of twenty-one and thirty. Of those who smoked, 86% had done so for five to ten years. Sixty percent of the respondents had no COPD diagnosis. The sensitivity of the prototype demonstrated a high rate of 84%. However, the specificity exhibited 57.14%.

Conclusion: Endoscopic detection of the oral mucosa can be used for early screening of suspected obstructive airway disorders in smokers. This tool could enhance screening for smoking's effects on the mouth and prevent early obstructive airway diseases.

Keywords: lesion, obstructive airway diseases, oral mucosa, smoking

Corresponding Author:
Budi Yanti | Department of Pulmonology and Respiratory Medicine, Faculty of Medicine, Universitas Syiah Kuala, Banda Aceh, Indonesia | byantipulmonologis@usk.ac.id

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INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD), which is mostly caused by smoking and pollutants, has become the third leading global cause of death.[1] With an estimated 229 million COPD patients worldwide, this number is expected to rise due to the increasing number of smokers, as 90% of COPD cases are attributed to smoking.[2] The proportion of smokers at risk of developing COPD ranges between 20% and 25%. The correlation between smoking and COPD shows a dose-response relationship, indicating that higher exposure to and longer inhalation of cigarette smoke increases the risk of COPD.[3]

Epidemiological studies suggest a synergistic relationship between oral cavity abnormalities and COPD.[4,5] Smoking poses a 5 to 20 times greater risk for COPD and periodontal disease. Moreover, smoking is associated with an elevated level of tumor necrosis factor-α (TNF-α) in the oral mucosal fluid compared to non-smokers. Elevated levels of neutrophil elastase activity, prostaglandin E2 (PGE2), and matrix metalloproteinase-8 (MMP8) are also observed in smokers.[6] Notably, these inflammatory markers are elevated in lung tissue affected by COPD. The inflammatory response in

COPD is dominated by neutrophils and TNF-α, crucial for neutrophil recruitment. Matrix metalloproteinases play a pivotal role in reshaping the airway structure by damaging extracellular matrix components. Additionally, smoking is closely associated with mucosal lesion abnormalities such as leukoplakia, smoker's melanosis, frictional hyperkeratosis, nicotinic stomatitis, black hairy tongue, and squamous cell carcinoma.[7,8]

Early detection of COPD in smokers is crucial for enhancing disease management quality and preventing its progressive severity. Unfortunately, a significant proportion, more than 56%, of COPD cases are underdiagnosed.[9,10] Currently, spirometry is the standard lung function test for COPD diagnosis and early detection. However, several impediments hinder the widespread use of spirometry as an early COPD detector, including limited accessibility, relatively lengthy testing duration, cost implications, and patient reluctance.[11] Consequently, an innovative solution is imperative to overcome these challenges.

The ideal COPD screening tool should be user-friendly, rapid, and cost-effective. Currently, there is no tool designed to visualize the oral mucosa of smokers as a potential COPD detector in Indonesia. Therefore, this study aimed to develop a functional detector capable of identifying suspected COPD by applying computer vision technology to the oral cavity of smokers, integrated with the Internet of Things (IoT). This research holds promise in contributing to the advancement of early COPD screening methodologies, ultimately enhancing patient outcomes and reducing the burden of underdiagnosis.

METHODS

This study comprised three stages: dataset collection, design and development of the tool device and application, and testing the accuracy of the tool in screening COPD patients. Dataset collection involved sourcing data from the online Kaggle.com database and clinically from smokers with lesions in the oral cavity. The diagnostic dataset included leukoplakia, nicotinic stomatitis, black hairy tongue, oral cancer, and smoker melanosis lesions obtained from the ‘kaggle’ database (https://www.kaggle.com) and patients who visited Syiah Kuala University Dental and Oral Hospital. This research has been approved ethically by the Faculty of Medicine, Universitas Syiah Kuala, Banda Aceh, and the Health Research Ethics Committee of Zainoel Abidin Hospital (164/ETIK-RSUDZA/2023).

Subsequently, the dataset would undergo augmentation or expansion through techniques such as flip, rotation, crop, shear, hue, saturation, brightness, and blur. The dataset were divided into 80% for the training set, 10% for the validation set, and 10% for the testing set to enhance the device's ability to detect lesions.

Hardware components included an endoscope as the lesion image capturer, an Nvidia Jetson Nano as the processor, a power supply for energy provision, a Tp-link WiFi adapter for wireless network connectivity, and an LCD as a screen for viewing videos or images from the endoscope. The endoscope captured images of lesions in the mouth, the Nvidia Jetson Nano processed the data, and the Tp-link WiFi adapter facilitated the transmission of lesion images to the cloud. To achieve early detection of COPD, the processor received images from the endoscope.

Moreover, computational processing would be conducted using a pre-embedded computer vision model on the processor. The results of early COPD detection were displayed on the LCD screen. The developed software represented a Minimum Viable Product (MVP) featuring predictive capabilities for early detection of COPD using images obtained from the endoscopic camera. This software also functioned as a telemedicine tool; the data from the processor were saved to Firebase for storage, and they were forwarded to Telegram as a mobile chatting application. This process allowed the transmission of endoscopy images to healthcare professionals.

Early suspicion of COPD can be achieved by identifying the involvement of specific oral mucosal lesions associated with smoking. This detection utilized deep learning (DL) technology employing the single-stage object detector method within the PyTorch framework and the UltraLytics library. The DL architecture employed for the screening of COPD was Yolov8.

Following the completion of the prototype, which had the function of detecting oral lesions, the tool underwent trials with smokers and COPD patients who were seeking treatment at the Pulmonary Clinic of Dr. Zainoel Abidin Regional General Hospital (RSUDZA) or the Dental Clinic of the University of Syiah Kuala Dental and Mouth Hospital (RSGM) in Banda Aceh. The success of the device trial was measured by its ability to capture images of oral lesions, to process data using deep learning methods, and to generate detections of oral mucosal lesions suspected as early indications of COPD.

To comprehensively evaluate the performance of the developed tool for screening COPD sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were employed to quantitatively assess the tool's diagnostic capabilities. The gold standard for the diagnostic accuracy test involved patients who were tested using spirometry and assessed according to the Global Initiative for Chronic Obstructive Lung Disease (GOLD) guidelines by pulmonologists to determine whether they were positive or negative for COPD.[12]

RESULTS

In our study, we developed a prototype for the early detection of COPD, integrating key components such as an endoscope, an Nvidia Jetson Nano processor, a Tp-Link WiFi adapter, and an LCD as the user interface. The dataset utilized in this research consisted of 526 images of oral mucosa lesions, representing various conditions. Through augmentation, this dataset expanded to 1332 variations, utilized in the training, validation, and testing phases of the model. Results of the model analysis on the internal dataset indicated that this prototype could detect lesions on the oral mucosa associated with COPD with an overall accuracy rate of 56%. For each type of lesion, accuracy rates were obtained as follows: 99.5% for black hairy tongue, 54.4% for leukoplakia, 52% for oral cancer, 43% for smoker melanosis, 42.4% for frictional keratosis, and 34% for nicotinic stomatitis.

Figure 1. Endoscope prototype: identify the oral mucosa of a smoker for early obstruction of the airway disease

Furthermore, trials with 60 patients were performed to evaluate the performance of the developed tool in real-world settings. Sixty-three percent of the respondents were between the ages of 21 and 30. Eighty-six percent had smoked for five to ten years. There were 36 (60.0%) respondents who were not diagnosed with COPD. This prototype was able to identify smoker's melanosis (11.7%), leukoplakia (6.7%), and black Harry tongue (41.7%) (Table 1).

Table 1. Characteristics of prototype trial participants

Variable	n	%
Age		
21–30 year	38	63.3
31–40 year	13	21.7
41–60 year	9	15.0
History of smoking		
5–10 years	49	81.6
>10 years	11	18.4
Image of oral mucosa identified		
Normal	24	40.0
Black hairy tongue	25	41.7
Leukoplakia	4	6.7
Smoker's melanosis	7	11.7
Diagnosis of COPD		
Yes	24	40.0
No	36	60.0

The sensitivity of the prototype, representing its ability to correctly identify individuals with suspected COPD-related lesions, demonstrated a high rate of 84%. However, the specificity, measuring the ability to correctly identify individuals without suspected COPD-related lesions, exhibited a moderate rate of 57.14%. The NPV was determined to be 58.33%, suggesting the tool's reasonable effectiveness in correctly identifying individuals without COPD-related lesions. On the other hand, the PPV was high at 83.33%, signifying a strong likelihood of correctly identifying individuals with COPD-related lesions (Table 2).

Table 2. Prototype diagnostic test in COPD and Non-COPD

Prediction	Actual		Total
	Normal	Abnormal	
Normal	20	4	24
Abnormal	15	21	36
Sensitivity	: 84%	NPV	: 58.33%
Specificity	: 57.14%	PPV	: 83.33%
AUC	: 0.791		

The Area Under the Curve (AUC) of the Receiver Operating Characteristic (ROC) curve, representing the model's overall performance, was found to be 0.791. This AUC value suggests good discrimination ability, indicating favorable performance across different sensitivity and specificity thresholds (Figure 2).

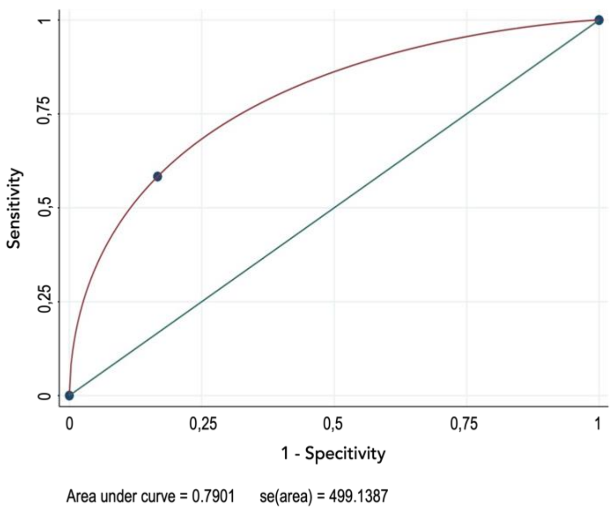

Figure 2. Receiver Operating Curve Graph

DISCUSSION

Early detection of COPD in smokers holds significant implications both clinically and for public health. COPD, often challenging to treat, is, in fact, preventable. Early detection of COPD allows for timely medical intervention, which can slow down disease progression and enhance the quality of life for patients.[13] Therefore, early detection of potential COPD is a crucial step in improving global public health. The rise of technology has significantly supported the healthcare system, particularly with the integration of artificial intelligence as a diagnostic tool. Numerous studies have developed AI-based methods to detect COPD.[14]

Tang et al developed a deep-learning model based on low-dose CT scans to detect COPD.[15] Their study explored the association between COPD and lung cancer, highlighting that inflammation in COPD can cause airway epithelial injury and increase DNA errors, thereby amplifying the carcinogenic effects of cigarette smoke. Using 2,153 datasets, their AI tool achieved an AUC of 0.886, a PPV of 0.847, and an NPV of 0.755 in detecting COPD among ex-smokers and current smokers undergoing CT screening for lung cancer. Similarly, a study by Gonzalez et al also developed a deep learning model based on CT scans, achieving an AUC of 0.886, a PPV of 0.847 and an NPV of 0.755.[16]

In our study, we successfully developed a tool to detect potential COPD through endoscopic examination of lesions on the oral mucosa of smokers. Our tool achieved an accuracy of 0.791, a sensitivity of 0.84, a specificity of 0.5714, an NPV of 0.5833, and a PPV of 0.833. The accuracy varied depending on the type of lesion, with the highest accuracy observed for black hairy tongue lesions (99.5%) and the lowest for nicotinic stomatitis lesions (34%). These variations may be influenced by factors such as complexity, location, size, color, image quality, sample size, and potential human error in assessing the lesions.[17]

LIMITATIONS

Compared to the two previous studies, our study had limitations regarding the number of datasets, with only 526 datasets included. The sample size used for the diagnostic test was also considerably small. Throughout the tool development and artificial intelligence training process, a larger dataset correlated with an enhanced ability of the tool to recognize and differentiate various lesion types.[18] Lesions with similar characteristics, such as "frictional keratosis" and "nicotinic stomatitis," became more challenging for the tool to distinguish, unlike "black hairy tongue" lesions with more distinct features.

Moreover, human error factors also had the potential to impact results. The user's ability to identify lesions and the precise placement of the endoscope in the oral cavity were crucial, as improper positioning could degrade image quality, making it more challenging for the tool to detect and differentiate these lesions. Nevertheless, to enhance result reliability, Internet of Things (IoT) features have been integrated into the tool. These enabled images captured by the endoscope to be transmitted via Telegram, a mobile application, for confirmation by healthcare professionals. Additionally, stored images could enrich the dataset, meaning that an increased number of lesion images will improve the tool's ability to detect lesions.

Overall, although this tool can be used as a lesion detection device on the oral mucosa of smokers as a potential COPD detector, its accuracy level is not yet optimal. Therefore, further development is necessary, including the addition of more datasets and increased direct testing on suspected COPD patients, to improve accuracy, especially for specific lesion types.

CONCLUSION

Endoscopic detection on the oral mucosa can be utilized for early screening of suspected obstructive airway disorders in smokers, potentially enhancing screening for smoking-related effects and preventing early-stage lesions associated with COPD. However, there is still room for improvement in this tool.

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