Case Report

The use of wireless technology for thoracic physical examination: a pilot case based on a literature review

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Abstract: Auscultation is a standard method of physical examination used by physicians and is widely accepted by doctors and patients for its simplicity, repeatability and non-invasiveness. Artificial intelligence is the 'new integrated frontier' of the thoracic examination, yet there are still concordance discrepancies in obstructive pulmonary diseases; on the contrary, for fibrotic diseases, the degree of concordance increases significantly, as shown by previous clinical studies conducted mainly in children. However, there are data in the literature that appear to be very discordant on certain types of lung noises, such as wet crackles and dry noises; therefore, the application of these devices in daily use in outpatient and hospital settings needs to be further expanded.
The integrated data allowed us to make the right diagnosis, also avoiding costs for the national health system and possible invasive procedures such as bronchoscopy, which today remains the "gold standard" for the histological diagnosis of sarcoidosis with lung localisation. Integrated technology could improve the diagnostic capacity in restrictive lung diseases, as shown in this clinical case. Several randomised controlled trials are still needed to increase the significance of this initial integrated

research work performed.

Keywords: Artificial Intelligence, AI, Thoracic Objective Examination, Obstructive and Restrictive Pulmonary Diseases, CT Chest, Crackles

Introduction

Lung sounds have been valuable indicators of respiratory health and disease since ancient times. Laënnec's stethoscope increased their diagnostic importance, but other methods, more sensitive and specific for respiratory assessment, have largely replaced auscultation in clinical lung diagnosis. We are now witnessing the next stage in the evolution of lung assessment by acoustic means[1].The coming years are likely to see an integration of respiratory sound analysers with computerised spirometry[2]. Lung auscultation with traditional stethoscopes has been used for decades, but has limitations in detecting breath sounds, especially the crackles that commonly occur in restrictive respiratory diseases. There are now proposed and recognised applications that allow the physician to record, store, play back and analyse respiratory sounds directly on the smartphone, complementing the common objective chest examination. In simulated scenarios, for fine crackles, an accuracy ranging from 84.86% to 89.16%, a sensitivity ranging from 93.45% to 97.65% and a specificity ranging from 99.82% to 99.84% have been evaluated in several studies. ranging from 99.82% to 99.84%. The detection of coarse crackles proved to be more challenging in the simulated scenarios. In the case of real data, the results demonstrate the feasibility of using a mobile application developed in a clinical environment to help the expert assess a subject's lung sounds[3]. A number of studies have attempted to objectively describe the audio-logical characteristics of wheezing and crackles in adults and particularly in children using auscultation with a digital stethoscope (DS)[4]. In some studies, a computerised stethoscope has been described that has new ways of analysing and displaying information and works in real time, classifies breath sounds into generally accepted categories and classifies sounds when different sounds are present simultaneously[5]. Electronic stethoscopes offer several advantages over traditional acoustic stethoscopes, including noise reduction, greater amplification and the ability to store and transmit sounds. However, the acoustic characteristics of electronic and acoustic stethoscopes can differ significantly, introducing a barrier for clinicians in switching to electronic stethoscopes[6]. With the optimised artificial intelligence (AI) detection thresholds, the positive percentage agreement (PPA) for crackle detection was 0.95 and the negative percentage agreement (NPA) was 0.99 for Clinicloud recordings; for Littman-collected sounds, the PPA was 0.82 and the NPA was 0.96. The PPA and NPA for breath detection were 0.90 and 0.97 respectively (Clinicloud auscultation), with PPA 0.80 and NPA 0.95 for Littman recordings.

One study concludes that AI can detect crackles and rales with a reasonably high degree of accuracy from respiratory sounds obtained from different digital stethoscopy devices, although some device-dependent differences exist[7]. With the integration of AI in medical care, independent validation of AI capabilities and weaknesses is important to ensure quality control[8]. Lung auscultation is a fundamental part of the physical examination for the diagnosis of respiratory diseases. The standardisation of the nomenclature of respiratory sounds, along with advances in the computational analysis of these sounds, have improved the usefulness of this technique. However, the performance of lung auscultation has been questioned due to the variable concordance between health professionals[9]. AI has recently emerged as an alternative method to many conventional methods. The implementation of AI techniques for analysing respiratory sounds can help physicians in the diagnosis of lung diseases. The most commonly used AI techniques for analysing respiratory sounds are ANN(artificial neural network) and k-nn(k-nearest neighbors). ANN has the ability to adapt well to complex non-linear data and to classify these data accurately and efficiently[10]. One study in particular by Grzywalski T et al., developed a diagnostic algorithm with AI integrated with the thoracic physical examination, which improved sensitivity and specificity in the paediatric thoracic examination, reaching values close to 100% diagnostic specificity and sensitivity[11].

Clinical case presentation

A caucasian female of 67 years old, came to my attention for reported episodes of nocturnal dyspnoea, nocturnal cough, wheezing, moderate exertional dyspnoea mMRC: 3 (Medical Council Research dyspnoea scale). She was being treated with ICS/LABA in single administration + LAMA, Montelukast, although the patient had no clinical or symptomatic benefit. In past anamnesis: Allergy to NSAIDs type II, (Antibiotics: Cephalosporin, Penicillin, Sulfonamides, Pyramidonics), Salicylates, Barbiturates. nasal polyposis reported. No use of ACE-inhibitors. Non-smoker, insulin-dependent DM in therapy with Metformin x 2/day, systemic hypertension, Previous presumptive diagnosis of Overlap Sydrome (asthma + COPD - ACOS) in atopy (did not perform bronchoreversibility test). He presented for overnight cardio-respiratory monitoring, which in the opinion of the pulmonary specialist was not indicative of OSA and no treatment was given (AHI:6.7) with AHI supine/not supine >2:1. Obesity, coronary stent placement two years ago, on current Clopidogrel therapy, hypercholesterolemia and hypertriglyceridemia. Performed simple and global spirometry, took laboratory tests, which showed respectively (see tables 1 e 2):

FEV1%	FVC%	FEV1/FVC	PEF	FEF_{25-75}%	RV	TLC%	RV/TLC%
71%	86%	89%	61%	35%	/	/	/
66%	79%	82%	67%	39%	124%	93%	135%

Table 1: Comparison between the first simple spirometry carried out in September 2022 and the global one in February 2023

FEV1%: Percentage of predicted value of FEV1

FVC%: Percentage of predicted value of FVC

FEV1: Maximum Expiratory Volume at first second

FVC: Forced vital capacity

TLC: total lung capacity

RV: Residual volume

RV/TLC: ratio of total lung capacity to residual volume expressed as a percentage of the predicted value

$FEF_{25-75\%}$: forced expiratory flow between 25 and 75% of FVC

Autoimmunity panel	Results	General blood tests	Results
ANA	Negative	GOT	23
P-ANCA	Negative	**Glycemia**	**214mg/dl**
ENA	Negative	Anti-phospholipid antibodies	Negative
C-ANCA	Negative	**Creatininaemia**	**1,01mg/dl**
Rheumatoid factor	9	**Azotemia**	**60**
Calciuria	**290mg/24h**	Coagulation	Negative
Anti-CCP	Negatives	D-Dimer	Negative
Lysozyme	16	LAC (lupus anticoagulant)	Negative
ACE	<1	**Glycated hemoglobin**	8,8%
CPR	2	WBC count	**230 Eosinophils**
ESR	30	GPT extension	30

Table 2 Laboratory tests brought to control

Comment on the tables: the diabetic and obese patient, despite the marked maximal therapy, still has a prevailing obstructive component with reduction of lung volumes and air trapping also due to poor therapeutic adherence. Since the last spirometry test she has gained weight (gaining three kilos more), with evident reduction of lung volumes.

Legend:

ANA: antinuclear antibodies

ANCA: antineutrophil cytoplasmic antibodies

ENA: extractable nuclear antigen

Anti-CCP: anti-cyclic citrullinated peptides

ACE: Angiotensin-converting enzyme

CRP: C-reactive protein

ESR: Erythrocyte sedimentation rate

GOT: glutamic-oxaloacetic transaminase

LAC: lupus anticoagulant

GPT: glutamate pyruvate transaminase

He also presented a chest CT scan of February 2023 which showed: calcific centrlobular nodules and calcific ilo-mediastinal lymphadenomegaly with associated areas of diffuse air entrapment and bilateral bronchial ectasia. On auscultation of the chest with the Eko Core stethoscope (Figure 1), diffuse "velcro" crepitations were present over the entire area, associated with obstructive findings on forced expiration (moans and hisses). At the outpatient visit, the lung noises were recorded and fully assessed on audio with the chest CT finding brought in for examination by the patient. The patient was then framed with the following clinical diagnoses: bronchial asthma with hyper-eosinophilia and nasal polyposis, associated with bilateral bronchial ectasia clinically not well controlled with reduced lung volumes, stage II sarcoidosis with pulmonary involvement (diffuse pulmonary lymphadenopathy and nodules with calcifications) and renal involvement, mild sleep apnoea syndrome prevalent in supine position associated with obesity: BMI (body mass index) 31, for which positional therapy was prescribed, type II diabetes mellitus not well controlled, worthy of diabetological and nephrological re-evaluation.

Figure 1: Eko Core system, smartphone interface, web interface and stethoscope and respective QR Code that allows you to hear with earphones the finding that has been auscultato to the thoracic physical examination of the patient in question. By framing the QR code it is possible to hear the finding of the thoracic objective examination carried out on the lady.

Discussion

Auscultation is a standard method of physical examination used by physicians and is widely accepted by doctors and patients for its simplicity, repeatability and non-invasiveness. Auscultation can be classified as direct or indirect. Direct auscultation connects the ear directly to the body wall of the examinee, while indirect auscultation uses a stethoscope[12].

Early diagnosis of respiratory problems is important to prevent chronic respiratory diseases and to intervene at an early stage. Respiratory sounds include valuable information regarding the physiology and pathology of lung and airway obstruction[13]. The first approach used in the non-invasive diagnosis of respiratory disease involves the clinical history and auscultation with a stethoscope. The presence of crackling sounds, considered incidental and discontinuous lung sounds (LS), is a during auscultation. However, their detection is highly dependent on the skill and expertise of the operator. Computerised methods have been proposed to overcome the limitations of audio-visual crackle detection, automated detection based on signal processing techniques such as time-frequency analysis or time-varying autoregressive modelling. such as time-frequency analysis or time-varying autoregressive modelling[14]. In some clinical studies, the EKO Core technology used in this case description has been used to help create a digital memory for surviving family members by recording the heart sounds of dying children. Specifically, patients approaching the end of life use music therapy (MTHS) by recording the child's heartbeat and modifying environmental noise to isolate the heartbeat. Surveys were administered to family members in which all indicated that they would recommend the MTHS programme to other families faced with end-of-life decisions[15]. In a Korean clinical study, to test the accuracy of chest auscultation analysis in clinical practice, it was analysed how accurately medical students, trainees, residents and fellows classify breathing sounds. Several test sets were made with normal sounds and three types of abnormal lung sounds: crackles, rales and buzzes. The classification based on the learning curve that emerged is able to detect abnormal lung sounds with an AUC of 0.93 and an accuracy of 86.5%. of 86.5%[16]. Similar results were obtained in the categorisation of abnormal sounds into subcategories: crackles, rattles, or buzzes. Considering that this is the result of analysing sounds recorded in a real clinical field with various noises, these are impressive results. We believe that these accuracies are adequate for primary screening and follow-up testing of patients with respiratory diseases[17].

In another American paediatric clinical study, breath sound recordings were collected in a clinical setting with typical baby noises, cries, voices and movements. The artificial intelligence algorithm was able to fully analyse 93.3 per cent of the recordings, with an accuracy mostly similar to that of experienced paediatric pulmonologists The AI algorithm in distinguishing crackles and wheezing was 83.9 and 78.2 per cent, 79.3 and 57.5 per cent, and 64.6 and 66.4 per cent, respectively[18].

Studies by cardiology colleagues compared the results of personal auscultation with heart sounds recorded by the EKO Core stethoscope in patients with normal heart sounds, innocent murmurs, and a variety of pathological findings, showing that the Eko recordings had a high percentage of agreement with the results of personal auscultation and echocardiogram, with moderate reliability. Compared to the categorisation of the echocardiogram as 'normal/ecography not deemed necessary' vs 'abnormal', the Core allowed users to correctly categorise sounds with 88-94% agreement, mean (SD) 91% (2) and Cohen's kappa coefficient of 0.55(moderate)[19]. Finally, other studies carried out by another Chinese study group demonstrated how the use of lung auscultation with a new-generation wireless stethoscope is possible in hospitalised patients with SARS-CoV-2 pneumonia and allows the assessment of the auscultatory finding of 'velcro' crackles, which if it is widespread and audible predicts a poor prognosis in severe forms, whereas patients with moderate and severe forms without positive velcro auscultatory noises may have a better prognosis[20]. Finally, some clinical studies have compared fine crackles auscultated at the electronic stethoscope and chest X-ray and high-resolution chest CT (HRTC) images by assessing the degree of sensitivity and specificity of the two integrated methods in the diagnosis of interstitial lung disease (ILD), comparing two parameters: firstly, presence or absence of fine crackles determined by the analysis software; secondly, ILD on X-ray determined by pulmonologists, noting a higher sensitivity of fine crackle detection than that of chest X-ray in discriminating ILD in HRCT, while the specificity of X-ray was higher than that of fine crackles. The diagnostic accuracy was almost similar in sensitivity and specificity when comparing sound analysis with software and HRCT versus chest X-ray. The radiological pattern of usual interstitial pneumoniae (UIP) on HRCT has been reported to be associated with fine crepitus determined by auscultation by physicians[21]. Several clinical studies, state that low ACE levels during sarcoidosis are linked to several factors:

1) chronicisation of the disease with endothelial dysfunction
2) use of drugs (ACE inhibitors, chemotherapy or endothelium-toxic therapy, etc.).

There are also limitations linked to the low specificity and sensitivity of the serum ACE test, and even the serum levels most commonly found in patients with sarcoidosis are normal or reduced[22,23]. In the clinical case examined, the laboratory data were not helpful in the clinical approach to the disease. In this clinical case, the integrated approach with AI, functional and instrumental semeiological data was of great help in the diagnosis, because despite the radiological evidence of calcific central-lobular nodules and mediastinal lymph nodes, the laboratory tests and spirometry distorted the initial diagnostic hypothesis to some extent. The difficulty of the clinical case was that the patient had already been assessed by another pulmonologist colleague, the low ACE levels and the absence of a restrictive deficit on spirometry.

Conclusion

Artificial intelligence is the 'new integrated frontier' of the thoracic examination, yet there are still concordance discrepancies in obstructive pulmonary diseases; in contrast, for fibrotic diseases, the degree of concordance increases significantly, as shown by previous clinical studies conducted mainly on children. The use of mobile phone applications integrated with the stethoscope can improve the sensitivity and specificity of the thoracic objective examination. The data from the technology integrated with instrumental examinations have made it possible to make the right diagnosis, while also avoiding costs for the national health system and possible invasive procedures such as bronchoscopy, which is still the "gold standard" for the histological diagnosis of sarcoidosis with lung localisation. Integrated technology could improve the diagnostic capacity of the restrictive lung model, as shown in this clinical case. The role of the outpatient specialist is crucial in recognising these pathologies, allowing prevention of potentially progressive pathologies; moreover, the integration of instrumental data from chest CT and objective thoracic examination still remain the cornerstones of respiratory disease diagnostics in clinical practice. Application systems on smartphones make it possible to integrate the data, to store physiological and pathological noises, to listen to them with specific filters that qualitatively improve the sound, and to make the distinction in lung noises that is crucial in daily clinical practice. The real strength of the "objective thoracic examination 3.0" lies in integrating all available data (clinical, instrumental, laboratory, functional) to formulate a precision diagnosis, also characterising lung pathologies phenotypically. Electronic auscultation makes it possible to store pathological and physiological lung noises and thus make them comparable over time on a par with first-rate instrumental examinations such as high-resolution CT scans of the chest. However, there are data in the literature that appear to be very discordant on certain types of lung noises, such as wet crackles and dry noises; therefore, the application of these devices in daily use in outpatient and hospital settings needs to be further expanded. There is a need to understand the limitations of the technology and try to complement and not replace the operator in the diagnosis of lung diseases. The applications of integrated technology and AI are wide-ranging, and allow for the assessment of cardiological, pulmonary, paediatric and abdominal noise. The degrees of concordance in terms of sensitivity and specificity in diagnosing interstitial lung disease found in the literature are evident in this 'pilot clinical case'; with values approaching those of the prescribed literature, with specificity and sensitivity of 80% and 90% on the lung pathology in question. The applications of this technology can also be used in the university teaching field in the medical course, as it is possible with this technology to download files in .wav format and generate via third-party applications on the Internet permanent QR codes that can also be audible from smartphones or tablets.

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