Towards the standardisation of lung sound nomenclature

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ABSTRACT Auscultation of the lung remains an essential part of physical examination even though its limitations, particularly with regard to communicating subjective findings, are well recognised. The European Respiratory Society (ERS) Task Force on Respiratory Sounds was established to build a reference collection of audiovisual recordings of lung sounds that should aid in the standardisation of nomenclature. Five centres contributed recordings from paediatric and adult subjects. Based on pre-defined quality criteria, 20 of these recordings were selected to form the initial reference collection. All recordings were assessed by six observers and their agreement on classification, using currently recommended nomenclature, was noted for each case. Acoustical analysis was added as supplementary information. The audiovisual recordings and related data can be accessed online in the ERS e-learning resources. The Task Force also investigated the current nomenclature to describe lung sounds in 29 languages in 33 European countries. Recommendations for terminology in this report take into account the results from this survey.

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Introduction

René Théophile Hyacinthe Laënnec first presented his invention of the stethoscope at the Necker Hospital (Paris, France) in September 1816 [1]. Almost 200 years later, this instrument is "the old warrior of medicine … it clings tenaciously, resisting retirement" [2]. While an array of more elaborate and expensive technologies for the diagnosis of chest diseases has emerged over time, auscultation of the lung still provides valuable, immediate and low-cost information to the experienced clinician.

The value of lung auscultation is limited by the fleeting nature of breath-related sounds, the subjectivity of perception and the difficulty in using a standardised terminology to describe and document the auditory findings. With the advance of computer technology, objective acoustical analysis of respiratory sounds has become practical [3]. In 2000, a Task Force of the European Respiratory Society (ERS) on Computerized Respiratory Sound Analysis presented a definition of terms [4]. The focus of this terminology was on the computerised acquisition and processing of respiratory sounds.

In the English-speaking world, Laënnec's original characterisation of adventitious lung sounds as "rales", with qualifying descriptors relating to their "wet" and "dry" character [5], has been superseded by the terms of "crackles" (for brief, snapping, "discontinuous" sounds) and "wheezes" (for longer, musical, "continuous" sounds) [6]. In 1977, an *ad hoc* committee of the American Thoracic Society and the American College of Chest Physicians on pulmonary nomenclature suggested the use of "crackle", subclassified as "fine" or "coarse" depending on their perceived high or low pitch, "wheeze" for a high-pitched whistling or hissing sound, and "rhonchus" for a low-pitched continuous snoring-type sound [7]. At a symposium of the International Lung Sounds Association in 1985, this nomenclature was presented also in corresponding French, German, Japanese, Portuguese and Spanish terms [8]. Most recently, these terms were included in a summary of normal and adventitious lung sounds that also included "bronchial breathing", "stridor", "pleural friction rub" and "squawk" [9].

The adoption of this terminology has been slow and not uniform. Significant variation still exists among healthcare professionals [10, 11] and in medical publications [12, 13]. Patients and caregivers may have a different understanding of these terms and use other descriptions altogether [14, 15]. This has significant implications on their communication with healthcare professionals and on the estimation of asthma prevalence [16].

Presenting audiovisual recordings of respiratory sounds to parents of young children with reported wheeze can help them to clarify the nature of the observed symptoms [17]. Video questionnaires have successfully overcome part of the language-related difficulties in population studies of asthma [18]. The initial move to form the present Task Force on Respiratory Sounds within the ERS therefore came from paediatric pulmonary clinicians who proposed to establish a reference collection of audiovisual recordings of respiratory sounds, appreciating the influence of respiratory sounds on disease classification in young children [19]. The objectives for this project were: 1) to establish a database of highest quality audiovisual recordings of respiratory sounds as a reference to standardise nomenclature; 2) to provide objective characterisation of all recordings, using established acoustic parameters; and 3) to offer descriptions of all recordings based on consensus by an expert panel.

The envisioned purposes of this ERS reference collection of respiratory sounds were to unify nomenclature at national and international levels, serve as a resource in the education and examination of healthcare professionals, and educate lay audiences about the assessment of respiratory health. The collection of information on lung sound nomenclature in the countries of Europe then became an additional objective.

Method

At the initial meetings of Task Force members, five centres with interest in acquiring audiovisual recordings of respiratory sounds were identified: Athens, Greece (K.N. Priftis, Paediatrics), Murcia, Spain (L. Garcia-Marcos, Paediatrics), Winnipeg, MB, Canada (H. Pasterkamp, Paediatrics), Zwolle, the Netherlands (P.L.P. Brand, Paediatrics) and Tromsø, Norway (H. Melbye, General Medicine). Each centre obtained ethics approval at their institution and prepared consent forms in their required formats.

An instructional video was recorded to demonstrate the preparation of a standardised setup for data acquisition. Briefly, the tubing of a professional grade stethoscope was cut off at a length of 10 cm from the head piece to allow the insertion of a small microphone. This modified stethoscope assembly was then connected to a video camera with external microphone input and capability for high-definition video recording. Sounds were monitored *via* headphones during recording (figure 1). A similar setup had previously been useful to record an instructional video for parents of young children [20].

The protocol asked for the acquisition of ideally 1 min of continuous audiovisual recording in a quiet location with proper lighting. Audiovisual files were anonymised by avoiding the inclusion of facial

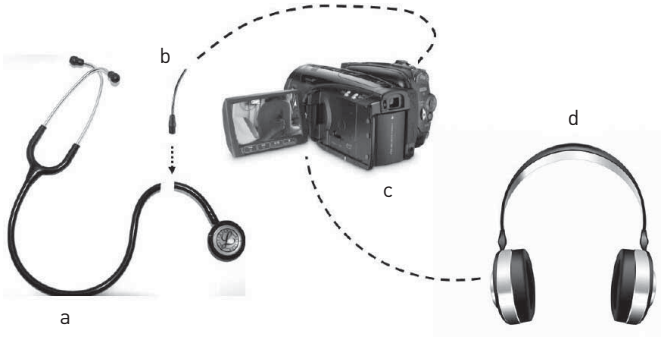

FIGURE 1 Schematic of recording setup. a) Stethoscope, b) insertion of microphone, c) video camera, d) headphones for monitoring.

features in the frame when recording at the anterior chest. File names followed a numbering scheme and naming convention that only identified the centre where the recording was acquired.

Quality assurance required that ⩾15 s of continuous recording could be extracted from the audiovisual file, that there was minimal artefact, that the respiratory phases were visible and that a sound of interest could be demonstrated. To be included in the reference collection, approval by at least three of the four centres that were not involved in the recording was required (see supplementary data for the online questionnaire to collect evaluations).

The respiratory sounds of files selected for the reference collection were described by six expert members of the Task Force (H. Pasterkamp, H. Melbye, K.N. Priftis, L. Garcia-Marcos, M. Everard and P.L.P. Brand). The online questionnaire for quality assurance was minimally changed to collect their subjective impressions (see supplementary data). Objective acoustical analysis of the selected files was performed for the online presentation of the reference collection at the ERS e-learning pages (see supplementary data for technical details).

The audiovisual recordings of the reference collection were formatted for streaming online at dedicated ERS e-learning pages (figure 2). Their presentation includes information on expert opinion and observer agreement. The description of objective computerised analysis and respective graphs can be accessed by opening related pages (figure 3). These pages also offer an option to download an open access programme for computer analysis and a version of the recordings that is compatible with this software.

Collaborators in the survey of lung sound nomenclature in European countries had either volunteered at ERS Assembly meetings to participate in this project or were identified from the ERS directory as national representatives. In the recruitment of collaborators we took into account publications or otherwise documented interest in this area. We aimed to achieve national representation in both paediatric and adult respiratory medicine and a larger number of participants from the most populous countries. The goal was to obtain two replies from each country in this first attempt at gathering the information. Invitations were sent by email with a link to an online questionnaire. The English nomenclature in that questionnaire was based on the recent review in the *New England Journal of Medicine* [9].

Results

From a total of 72 recordings acquired to date, 20 met the quality assurance criteria and were accepted by at least three out of four evaluators. Most of the rejected recordings had been obtained from children and contained movement-related noises that did not allow the extraction of ⩾15 s without significant artefacts.

FIGURE 2 Example of case presentation. Reproduced from [21].

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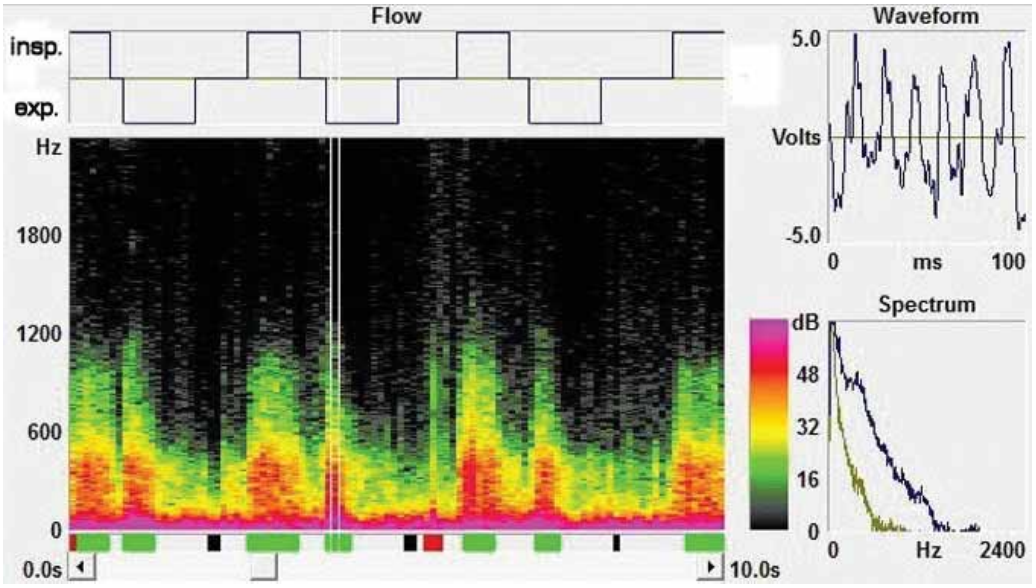

FIGURE 3 Example of acoustical analysis (sonogram). Reproduced from [21].

Table 1 summarises this selection of 10 recordings of paediatric and 10 of adult cases. There were nine female and 11 male patients. Agreement between six expert observers was weakest for three paediatric cases of lower respiratory tract infection with low-pitched wheezes/rhonchi. The fourth case with weak agreement had a pleural rub that was not recognised as such by three out of six observers. Our observations on observer agreement have been presented [22].

The reference collection is now accessible online at the ERS e-learning pages, with streaming of audio and video [21]. The material can be rated and comments can be added and reviewed.

The invitation to complete a questionnaire on lung sound nomenclature in European countries was sent in November 2014, with three iterations to improve the response rate. A total of 66 completed surveys (64

TABLE 1 Summary of selected[#] audiovisual recordings

Case	Age	Sex	Diagnosis	Classification	Agreement	Comment
001	7 years	M	Asthma	Wheeze	Moderate to strong	Crackles also recognised
002	9 years	F	Asthma	Wheeze	Strong	High pitch recognised
003	10 years	M	Bronchitis	Crackles	Moderate	Coarse crackles recognised
004[¶]	7 months	M	Bronchiolitis	Wheeze	Weak	Rhonchi or low-pitched wheeze
005	52 years	F	COPD	Wheeze	Strong	No agreement on pitch
006	4 years	M	Bronchiectasis	Wheeze	Strong	Low pitch recognised
007	5 years	F	Asthma, atelectasis	Wheeze	Strong	No agreement on pitch
008	61 years	F	Emphysema, lung cancer	Wheeze	Strong	Low pitch recognised
009	78 years	M	Lung cancer	Crackles	Moderate	Fine crackles recognised
010	88 years	F	Asthma, COPD	Wheeze	Moderate to strong	Wheeze pitches recognised
011	30 months	M	Pneumonia	Crackles	Strong	Coarse crackles recognised
012	78 years	M	Pulmonary fibrosis	Crackles	Moderate to strong	Fine crackles recognised
013[¶]	6 years	F	Recurrent LRTI	Wheeze	Weak to moderate	Rhonchi or low-pitched wheeze
014[¶]	3 years	F	Acute LRTI	Wheeze	Weak to moderate	Wheeze pitches recognised
015	3 years	F	Pneumothorax	Basic	Strong	No adventitious sounds recognised
016	77 years	M	Pulmonary fibrosis, pneumonia	Wheeze	Moderate	No agreement on pitch
017[+]	69 years	M	Pleural haemorrhage	Other	Weak	Pleural rub recognised
018	71 years	M	Pleural effusion	Other	Moderate	Diminished breath sounds
019	79 years	M	Lung cancer	Basic	Strong	No adventitious sounds recognised
020	66 years	F	Radiation pneumonitis	Crackles	Strong	Fine crackles recognised

M: male; F: female; COPD: chronic obstructive pulmonary disease; LRTI: lower respiratory tract infection. [#]: these 20 recordings met the quality assurance criteria and were accepted by at least three out of four evaluators; [¶]: agreement between six expert observers was weakest in these three cases; [+]: fourth case with weak agreement, which had a pleural rub that was not recognised as such by three out of six observers.

from countries other than the UK) were received from 99 invitees. These represented 33 countries and 29 languages (see supplementary data).

The term "normal lung sounds" was used in 24 out of 29 languages, while the term "vesicular sounds" was used in 19 out of 29. "Murmur" was mentioned in six out of 29 languages to describe normal (basic) sounds. "Crepitations" to describe crackles was reported in 16 out of 29 languages. "Rhonchus" was used in the same or very similar form in 15 out of 29 languages, while four out of 29 used "rales" and two out of 29 used "crackles". One report from France mentioned the interchangeable use of "rale" and "rhonchus". Only 15 out of 29 responses mentioned a term corresponding to "squawk" (details of all responses can be viewed in the supplementary data).

Table 2 summarises current lung sound nomenclature in the six most widely spoken European languages, using the format of the 1987 presentation of nomenclature on adventitious lung sounds in different languages [23]. Russian as a European language replaces Japanese in this table.

"Respiratory sounds" was introduced as a Medical Subject Heading in 1980 and defined as "noises, normal and abnormal, heard on auscultation over any part of the respiratory tract". The ERS Task Force on Computerized Respiratory Sound Analysis presented a schematic of the relationship between the terms respiratory sounds, breath sounds and lung sounds [4]. We suggest a modification, using "normal (basic) sounds" instead of "breath sounds", because "breathing sounds" is a recognised entry term for "respiratory sounds" in PubMed (figure 4).

Recommendations

The current nomenclature on lung sounds in European countries shows similarities that nevertheless do not conform to the recommended terminology in the English language [7]. Respiratory sounds heard normally on the chest of healthy subjects, *i.e.* normal or basic lung sounds, are still characterised as "vesicular" in many languages. While Laënnec considered normal lung sounds to originate from the flow of air in and out of alveoli, later investigations of the origin of respiratory sounds have not shown lung "vesicles" to participate in sound generation [24]. The term "vesicular lung sounds" should therefore be replaced by "normal" or "basic" lung sounds.

The term "crepitations" to describe crackling sounds is widely used across the European languages. Both "crepitations" and "crackles" refer to brief, non-musical, "discontinuous" sounds. Potential confusion may arise when the qualifier "coarse" is added, since "crepitations", at least in the English language, more typically refers to fine crackles, *e.g.* bone crepitus in fractures. The interchangeable use of "fine crackles" and "crepitations" may be considered, but "coarse crackles" should be kept, considering that there are different mechanisms of sound origin, *i.e.* sudden opening of airways in restrictive lung diseases implicated in "fine crackles" (*e.g.* "Velcro"-like crackles as an early sign of pulmonary fibrosis [25]) *versus* secretion-related sounds and rupture of fluid menisci in "coarse crackles" [26].

"Rhonchus" appears to be a most difficult term. Nevertheless, it is widely used across European languages, perhaps because in the past both "rales" and "rhonchi" have been used to describe, with qualifiers, any adventitious lung sound. The recommendation to apply it only to low-pitched "continuous" sounds [7] does not take into account differences in sound waveforms, *i.e.* the pure sinusoidal wave of a low-pitched wheeze *versus* complex repetitive waves of similar tonal pitch but rougher, snoring character. The generation of these two types of low-pitched musical or quasi-musical sounds can be quite different, *e.g.* airway wall flutter *versus* movement of air through secretions with successive rupture of fluid menisci [27]. Not surprisingly, most of the lung sound recordings with poor observer agreement in our collection were in this category. Since a low-pitched wheeze may signify different pathology from a snore-like sound, "rhonchus" should probably be placed in its own category, *i.e.* somewhere between a musical and non-musical sound.

A "squawk", *i.e.* a brief, almost exclusively inspiratory wheeze, was first described in relation to extrinsic allergic alveolitis and other pulmonary fibroses [28]. Since then it has also been observed in patients with pneumonia [29]. Laënnec appreciated wheeze ("râle sibilant") of widely different character: "sometimes it resembles a little prolonged whistle, low or high, or it is rather dull sound, but at other times this noise is quite short and sounds like the cry of small birds" [30]. Recognising that short inspiratory wheezes may signify pathology different from the longer, predominantly expiratory wheezes in asthma may justify the use of a separate term. However, the lack of a corresponding term in most of the European languages highlights a need for further education in this regard.

Future direction

The reference collection in its current scope invites further expansion, particularly with regard to sounds of contentious classification, *e.g.* rhonchi and low-pitched wheezes, also normal respiratory sounds at different ages, and sounds of extrathoracic origin, *e.g.* stridor and grunting. Several centres that

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TABLE 2 Lung sound nomenclature in the six most widely spoken European languages

	Report	English	French	German	Portuguese	Russian	Spanish
Discontinuous							
Fine (high pitched, low amplitude, short duration)	1987 nomenclature [23]	Fine crackles	Râles crepitants	Feines Rasseln	Estertores finos		Estertores finos
	This study	Fine crackles	Crépitants fins	Feinblasige Rasselgeräusche	Fervores finos or Crepitações finas	мелкопузырчатые влажные хрипы (melkopuzyrchatyye vlazhnyye khripy)	Crepitantes finos or Estertores finos
Coarse (low pitched, high amplitude, long duration)	1987 nomenclature [23]	Coarse crackles	Râles bulleux or sous-crepitants	Grobes Rasseln	Estertores grossos		Estertores grossos
	This study	Coarse crackles	Gros crépitants	Grobblasige Rasselgeräusche	Fervores grosseiros or Crepitações grossas	влажные хрипы (vlazhnyye khripy)	Crepitantes gruesos or Estertores gruesos
Continuous							
High pitched	1987 nomenclature [23]	Wheezes	Râles sibilants	Pfeifen	Sibilos		Sibilancias
	This study	Wheezes	Sifflement or Sibilants	Giemen, Pfeifen or Juchzen	Sibilos	Свистящие хрипы (svistyashchiye khripy)	Sibilancias
Low pitched	1987 nomenclature [23]	Rhonchus	Râles ronflants	Brummen	Roncos		Roncus
	This study	Rhonchus	Râles bronchique or ronchi	Brummen	Roncos	Хрипы (khripy)	Roncus

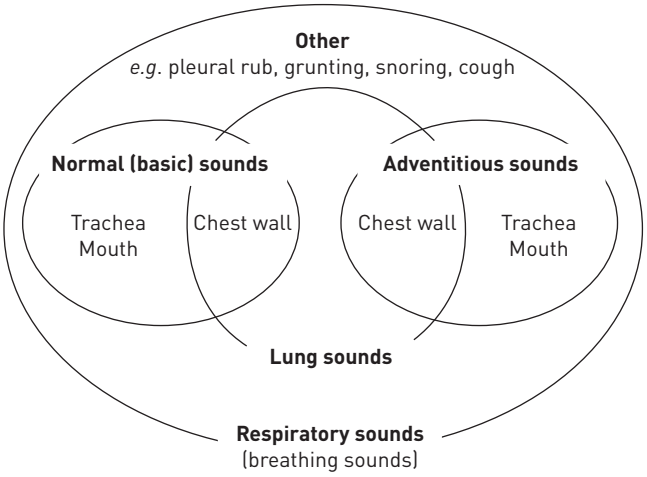

FIGURE 4 Suggested classification of sounds. Reproduced and modified from [4] with permission from the publisher.

participated in the initial recordings have committed to continue data acquisition. Directions and guidance with regard to further recordings and their presentation will also be based on commentaries and suggestions that users can leave at the e-learning pages.

Linguistic considerations when interpreting international questionnaires may be especially relevant with regard to estimating the prevalence of asthma [31]. As envisioned, the ERS reference collection should be of value to standardising lung sound nomenclature internationally and also at national levels. Our survey on current terminology provides a starting point, and past efforts in the Netherlands [32] and in France [33] may offer some guidance to national working groups.

Expectations that computerised lung sound analysis would influence terminology in clinical practice based on objective characterisation have been high [34]. To validate and expand the acoustical analyses of the recordings in the ERS reference collection, researchers in acoustics and computer engineering may be given access. A consensus on the objective characteristics of respiratory sounds, particularly those where observer agreement is poor, could then help in determining appropriate terminology.

As the reference collection grows, future uses may include the assessment of skills and examination of students and practitioners in the healthcare professions. Furthermore, the materials may be prepared for presentation to lay audiences to improve their understanding and reporting of respiratory symptoms. Finally, audiovisual recordings could be presented in the context of corresponding structural and functional imaging studies, leading to a better appreciation of the strengths and limitations of lung auscultation.

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