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Influence of Language Skills on the Choice of Terms Used to Describe Lung Sounds in a Language Other Than English: A Survey of Staff Physicians, Residents and Medical Students

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Abstract

Introduction: The value of chest auscultation would be enhanced by the use of a standardised terminology. However, recommendations were made in English, and therefore, must be transferred to languages other than English (LOTE) without distortion.

Objective: To examine the influence of language skills on the transfer to Hebrew – taken as a model of LOTE - of the recommended terminology in English.

Design/Setting: Cross-sectional study; university-based hospital.

Participants: 143 caregivers including 31 staff physicians, 65 residents, and 47 medical students

Methods: Observers provided spontaneous, uninstructed descriptions in Hebrew, and English of audio-recordings of 5 sounds identified by computer analysis as: Normal breath sound (NBS); wheezes; crackles; stridor and pleural friction rub (PFR).

Outcomes: a) Rates of correct classification; b) Correspondence between correct Hebrew and recommended terms; c) Language and auscultation skills assessed by crossing the responses in the two languages with one another, and with the true classification.

Results: Range (%) of correct rating was as follows: NBS=11.3%-20%; Wheezes=79.7%-87.2%; crackles=58.6%-67.4%; stridor=67.4%-96.3%; and PFR=3.6%-28.6%. Of 60 Hebrew terms 10 were correct, but only 5 matched the recommended terms. Many Hebrew terms were adaptions or transliterations of ancient English terms, some of which are deemed inadequate. Observers were classified as having good language skills in 586 (83.5%) of 687 sessions of evaluation; of these, however, 265 (45.2%) lacked auscultation skills.

Conclusion: Poor auscultation skills largely surpassed poor language skills as a factor hampering the transfer to LOTE (Hebrew) of the recommended terminology. Improved education in auscultation is the most important measure to promote use of standardised lung sound terminology. Our results can help devise a strategy to encourage the use of standardised terminology in non-native English speaking countries.

Word count: 276

Key words: lung sound terminology; lung auscultation; observer variability; language other than English; LOTE

Strengths and Limitations of the Study

- To our knowledge, this is the first study to examine the transfer to LOTE of the recommended lung sound terminology in English.
- True sound classification was based on computer-based sound analysis.
- Participants were from the same hospital – which tends to limit the study generalizability – but had different clinical and educational background.
- Use of more complex sounds (e.g. rhonchus, squawk) might have further hampered the observers' ability to classify the sounds.

Introduction

Lung auscultation has been a traditional part of the chest examination since the invention of the stethoscope [**1**]. Whilst no other method equals auscultation in providing quick, cost-effective, and easily obtained, relevant information about the respiratory system, its value is limited by the confused terminology [**2**]. Even though recommendations on terminology have been developed [**3-5**] significant variation in the terms used to describe the sounds persists among health professionals [**6-11**].

To examine this variation, we invited staff physicians, residents, and medical students working in a university-based hospital in Israel, to spontaneously classify a set of common lung sounds presented to them in audio-recordings. They were asked to classify the sounds successively in English and Hebrew, taken as a model of a language other than English (LOTE). Different aspects of the survey were highlighted in two companion papers. The first paper, published recently, found that poor auscultation skills were the main factor influencing the choice of English terminology [**11**]. The second study, reported herein, examined the influence of language skills on the transfer, to LOTE (Hebrew), of the terminology recommended currently by scientific societies [3-5]. This aspect has practical importance. First, between-language differences hamper communication in teaching and in meaningful exchanges of auscultation findings between clinicians and researchers from different countries [**10**]. Moreover, they can cause divergent interpretations of the same sound even by caregivers from the same country. This study aimed to compare the Hebrew terms used by our observers, with (a) those recommended currently [3-5] and, additionally, with (b) the English terms they used to classify the same sounds previously [**11**].

Materials and Methods

These were described in detail previously [**11**]. Briefly, we recruited 143 caregivers, including 31 staff physicians (SP), 65 residents (R) and 47 medical students (MS) working at Shaare Zedek Medical Center, affiliated with the Hebrew University of Jerusalem. Participants were informed about the study through word-of-mouth. The study was submitted to the hospital's Ethics Committee, but no informed consent was deemed necessary.

Assessments

Upon arrival, participants received standardised instructions to fill in a questionnaire on background information including demographics, medical status, years of practice, and medical specialty.

Sound rating

Next, they were invited to listen through loudspeakers to the audio-files of 5 common lung sounds namely: 1. Normal breath sound; 2. Wheezes; 3. Crackles; 4. Stridor and 5. Pleural Friction Rub. The files, which were taken from a set of files published previously [**2**], were stored in a computer placed in a silent room. The observers classified the sounds in the order they were played (i.e. 1-5) and wrote "free-form" answers successively in English and Hebrew, describing the sounds with their own words in the appropriate columns. No sonograms or waveform analysis were provided to substantiate the nature of the sounds. However, each observer was informed about the site of sound recording and of the fact that all recordings started from an inspiration. The ability to correctly identify the sounds was determined by comparing the observers' response in Hebrew with the true classification obtained by computer-based waveform analysis of each sound,

taken as gold-standard [**2**]. The rating was considered correct if a recommended term or an accepted synonym was used to describe it (term use ascribed to preference). The use of any incorrect term was ascribed to lack of skills on chest auscultation.

Language and Auscultation Skills

The ability to correctly classify the sounds depends both on language and auscultation skills. To assess this relationship, we crossed the responses in the two languages with one another and with the true classification obtained by computer analysis. Four groups were identified, as follows.

1. Caregivers with both language and auscultation skills: Those using correct, *corresponding* terms in the two languages to *correctly* classify the sound (e.g. use of, say, the terms "wheeze" and "tziftzufim' to classify the wheezes of audio sound # 2)

2. Caregivers with language skills but no auscultation skills. Those using correct, *corresponding* terms in the two languages to *incorrectly* classify a sound (e.g. use of "bronchial sound" and "neshima bronchialit" to classify the normal breath sound of sample # 1)

3. Caregivers with single-language skills and auscultation skills. Those using a *correct* term in one language only, to *correctly* classify a sound (e.g. use of the correct term "wheeze" and of the incorrect term "crepitaziot" to classify the wheezes of sound sample # 2).

4. Caregivers with neither language nor auscultation skills. Those using *incorrect* terms in the two languages to *incorrectly* classify a sound (e.g. use of the term "rales" or, say, "crepitatziot" to classify the pleural friction rub of sample # 5).

Patient and Public Involvement

No patient involved

Data Analysis

Baseline characteristics are presented as mean (SD) and proportions. For each audio sample, the difference in the proportion of correct vs. incorrect rating was tested using the Fisher's exact test; a $p < 0.05$ was considered significant.

Results

Characteristics of participants

Participants' mean (SD) age was as follows: SP= 48.4 yrs. (10.4); R=32.5 yrs. (3.5), and MS=28.4 yrs. (4.5). Overall, 17 (54.8%) staff physicians declared more than 20-year experience with auscultation; in turn, 60 (92%) residents and 47 (100%) medical students declared < 5-year experience.

Auscultation Skills

For each sound, the rates of correct sound identification were as follows: Sample #1 (normal breath sound): n=20 (14.6%) (SP=20%; R=11.3%; MS=14.9% [p=0.527]); Sample #2 (wheeze): n=116 (82.3%) (SP=80%; R=79.7%; MS=87.2%. [p=0.551]); Sample #3 (crackle): n=85 (65.4%) (SP=58.6%; R=67,2%; MS=67.4%; [p=.685]); Sample #4 (stridor): n=110 (84%) (SP=96.3%; R=90.2%; MS=67.4%; [p=.001]); Sample #5 (pleural friction rub); n=11 (9.1%) (SP=28.6%; R=3.6%; MS=2.7%; [p=.000]). Altogether, the observers used 60 Hebrew terms to classify the sounds. Of these, 10 (16.7%) were correct, being therefore ascribed to preferences regarding terminology, while 50 (83.3%) were incorrect, being ascribed to lack of chest auscultation skills.

Hebrew Terms versus Recommended Terminology

Table 1 lists (i) the standard and phonetic forms of the *correct* Hebrew terms used by the three groups; (ii) their accepted meaning in English; and (iii) the recommended English terminology. The Hebrew terms describing the normal breath sound, wheezes, crackles, stridor, and pleural friction rub corresponded to

the recommended terminology in English. Although they were considered correct for the purpose of classifying the sounds, the Hebrew terms meaning “vesicular” and “alveolar”, “crepitation”, “rale” and “friction” were not in conformity with the recommendations. The Hebrew terms for “vesicular” (“vesiculari”) and “crepitation” (“crepitatziot”) were simple adaptations of English terms, while the term for “stridor” was the very English term, spelled with Hebrew letters. **e-Table 1** in the e-supplement lists the 50 *incorrect* Hebrew terms used by the observers. Of these, 10 were used to classify the normal breath sound, 11 to classify the wheezes, 11 to classify the crackles, 8 to classify the stridor, and 10 to classify the pleural friction rub.

Influence of Language and Auscultation Skills

Overall, 687 sessions of sound identification were carried out [**Table 2**]. In 598, for each sound, the observers provided terms in the two languages. In 89 they provided terms in one language only, and in 28 they provided no terms in either language. Percent rates of subjects in the 4 groups described above were as follows:

1. Caregivers with both language and auscultation skills: n=321 (46.7%)
2. Caregivers with language skills but no auscultation skills: n=265 (38.6%)
3. Caregivers with single-language skills and auscultation skills: n=43 (6.3%)
4. Caregivers with neither language nor auscultation skills: n=58 (8.4%)

Discussion

In his original work, Laennec used the terms rale and rhonchus interchangeably to denote all classes of adventitious sounds [**1**]. Successive translations — first into English, then into other languages — and redefinitions of the original terminology gave different meanings to these terms, starting a confusion that persists to this day. To overcome this drawback, recommendations for use of a standardised terminology in the English language were made by the *Ad Hoc* committees of scientific societies [**3-5**]. The terms — simple and precise — are based on the physics of the sounds, without assumptions about their mechanism of generation or site of production **[3-5].** In a population of caregivers working in Israel, we compared the Hebrew terms used to classify 5 common sounds with the (a) recommended terminology and (b) the English terms used by the same caregivers to classify the same sounds.

Overall, the observers' ability to classify the sounds in Hebrew was high for the wheezes and stridor, fair for the crackles, and low for the normal breath sounds and the pleural friction rub. The three groups of caregivers performed similarly in classifying all sounds but the stridor, for which staff physicians and residents performed better than the medical students. Additionally, staff physicians performed better than the other two groups in classifying the pleural friction rub; however, their absolute performance was too low to be considered clinically meaningful. As a whole, this evaluation was similar to that of the English terms reported in the first study **[11]**. This finding is interesting because in theory one

could expect the caregivers to perform better in their working language than in English.

Of 3 correct Hebrew terms used to classify the normal breath sound, just one, – "normal sound" — corresponded to the recommended term in English. The other two, "vesiculari" and "buyit" — meaning respectively "vesicular" and "alveolar" — are deemed inappropriate, as they convey the incorrect assumption that the normal sound originates from the *entrance of air into and out of the air-cells of the lungs* [**1**]. Incidentally, although the *exact* locale and mode of production of the normal breath sound has not been established, there is evidence to support the view that it has a double origin: the lobar and segmental airways for the inspiratory component and a more central source for the expiratory component [**12, 13**]

Consistent with our previous study [**11**] the observers used a single Hebrew term to classify the wheezes. This term, "tziftzufim," is the classic Hebrew term for this sound. This homogeneous description is interesting. Indeed, the term "wheezing" has been in use long before Laennec's invention of the stethoscope, while "wheeze", as used nowadays, corresponds to the "rale sibilant sec" described by Laennec [**14**]. We speculate that since this sound has been traditionally attributed to a single mechanism — airway obstruction — over the years, a single term was used to describe it. Consequently, the translation from the source language to other languages was kept relatively uniform, as found in the present study.

The term "stridor" — from the Latin ***stridere*** (harsh, shrill or creaking noise) — describes the high-pitched, musical sound produced by turbulent flow passing through a narrowed segment of the upper respiratory tract [**15**]. In similarity with

the classification of the wheezes, all correct raters used a single term. However, instead of the Hebrew term "שִׁרְנוּק" ("shirnuk") they used the term "stridor" itself, spelled in the Hebrew alphabet. This peculiar choice suggests that, rather than searching for a suitable terminology, the caregivers preferred a term familiar to them. This finding is similar to that reported in a recent survey of lung sound nomenclature carried out in 34 European countries, which showed that caregivers from *all* the countries - representing 29 languages, five of which had non-Latin alphabets – spelled the term "stridor" verbatim in all languages but Greek [**16**].

With two categories – "fine" and "coarse" – "crackles" can be defined as brief, non-musical, explosive, adventitious sounds [**17, 18**]. In this study, the Hebrew equivalent of "crackles" was used correctly just once, by a medical student. Of the other acceptable terms, "crepitatziot" is solely an adaptation of "crepitations", while "hirhurim" is the classical Hebrew term for "rales". It should be noted that both these terms are considered superfluous or inadequate: "crepitations" because it merely means high-pitched crackling and "rales" because as stated above, it was originally a generic term applied to every variety of adventitious pulmonary sound [1]. Incidentally, the accepted mechanism of production of fine crackles is not the presence of secretions in the airways, but the sudden opening of airways in deflated territories of the lung as observed, for instance, in restrictive lung disorders (e.g. Interstitial Lung Disease) [**17-19**].

Of the presented sounds, the pleural friction rub is probably the less well-studied. Purportedly, it is produced by the sudden release of tangential tension in a superficial portion of the lung momentarily arrested in its sliding movement by a frictional force between the two pleurae [**18**]. The tiny group of observers who

correctly classified this sound used 2 terms (vs. 4 terms in the English part of the survey [**11**]): pleural and friction, alone or in combination.

A novel information provided by this study is that poor skills in chest auscultation largely surpassed deficient language skills as a cause of incorrect lung sound classification. While almost 90% of participants were found to be skilled in the two languages, rather surprisingly, less than half were found to be equally skilled in auscultation. Consistent with our previous study [11] this finding further illustrates the fact that use of recommended terminology is meaningful only among observers with good auscultation skills. In fact, observer agreement on a wrong classification can be detrimental to the patients, as it may lead to unnecessary and expensive investigations as well as improper treatment [11].

To our knowledge, there is no research similar to this study that can provide data for comparison. Searching the literature, we found that the importance of the correct understanding of the original terminology by caregivers working in LOTE has been examined only peripherally. For instance, in a survey of seven European countries, lack of familiarity with the English nomenclature was invoked to explain the lower agreement of Russian and Dutch practitioners to classify crackles and wheezes from video-recordings [**20**]. Also, in the European terminology survey quoted above, the terms used across the countries were generally non-uniform, some countries having their own terminology, others simply adopting the English terminology [**16**].

This study has limitations. First, for the sake of feasibility, we recruited caregivers from the same hospital, which may limit the generalizability of the findings. However, compensation was provided by their heterogeneity in terms of clinical

and educational background. Second, we did not investigate all adventitious sounds. For simplicity, we stuck to the commonest ones, intentionally excluding others such as, for instance, the rhonchus or the squawk, whose inclusion might have further hampered the observers' ability to classify the sounds.

In summary, the Hebrew terms used to classify common lung sounds corresponded only partly to the recommended terminology. Many Hebrew terms were adaptations or transliterations of ancient, inappropriate English terms, such as "vesicular sound" and "crepitations". Of practical importance, a high proportion of matched Hebrew/English terms were incorrect. These data support the conclusion that poor auscultation skills surpassed poor language skills as a factor hampering the meaningful transfer of the recommended terminology to LOTE (Hebrew). By consequence, improved education in chest auscultation should be the main prerequisite for the successful dissemination of the recommended terminology. Based on our results, some suggestions can be made to encourage the widespread use of a standardised lung sound terminology in non-native English speaking countries. Countries with a high knowledge of English could simply adopt the recommended terminology verbatim. Alternatively, countries with a lower knowledge of English could opt for the translation of the recommended terms; however, this must be done properly, by professionals skilled in both the source (English) and the target (LOTE) language. Finally, if resources for translation are not available, transliteration of the recommended terms seems a viable option. Adopted spontaneously by many observers in this study, transliteration requires no special language skills and can be performed in any language, including those with non-Latin alphabets. For its simplicity, it should be given consideration by the medical societies of all concerned countries.

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Competing Interest

None declared

Author contribution

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Statistical analysis: A. Bohadana

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Responsibility for data: AB; AR; HA; AJ; GK and GI are guarantors for the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Critical revision of the manuscript: All authors

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Table 1. Comparison Between Hebrew Terms Used and Recommended English Terms

Audio sample	Recommended Terminology in the English Language	Hebrew Terms			Frequency of Use	
		Standard	Phonetic	English Meaning	n	By Group
# 1	Normal breath sound	נשימה נורמלית	Neshima normalit	*Normal breathing*	8	SP=1 R= 3; MS=4
		נשימה וסקולרית	Neshima vesicularit	Vesicular breathing	2	SP=2
		נשימה בועית	Neshima buit	"Alveolar" breathing	10	SP=3 R= 4; MS=3
# 2	Wheezes	צפצופים	Tziftzufim	*Wheezes*	116	SP=24 R=51 MS=41
# 3	Crackles	קריפיטציות	Crepitatziot	Crepitations	42	SP=12 R=17 MS=13
		פיצפוצים	Pitzputzim	*Crackles*	1	MS=1
		חרחורים	Hirhurim	Rales	42	SP=5 R=22 MS=15
# 4	Stridor[1]	סטרידור[2]	Stridor	*Stridor*	110	SP=26 R=55 MS=29
# 5	Pleural friction rub[1]	שפשוף פלאורלי	Shifshuf pleurali	*Pleural rubbing*	10	SP=8 R=1 MS=1
		פריקשן	Friction	Friction	1	R=1

1. Suggested [2]
2. The correct term - **שִׁרְנוּק** (shirnuk) - was not used by any rater.

Table 2: Language and Auscultation Skills Among Caregivers From the Three Groups

True classification	Observers providing classification in the two languages (n=598)				Observers providing classification in one language only (n=89)				No classification in either language (n=28)
	Identical terms in the two languages (n=586)		Different terms in the two languages, (n=12)		English (n=27)		Hebrew (n=62)		
	Both terms correct [1] (n=321)	Both terms Incorrect [2] (n=265)	English correct [3] (n=8)	Hebrew correct [3] (n=4)	Correct [3] (n=14)	Incorrect [4] (n=13)	Correct [3] (n=17)	Incorrect [4] (n=45)	
# 1 Normal	19 (5.9%)	106 (40.0%)	1	0	0	3	1	10	3
# 2 Wheeze	110 (34.3%)	19 (7.2%)	2	1	2	0	5	4	0
# 3 Crackle	76 (23.7%)	34 (12.8%)	3	3	4	2	6	8	7
# 4 Stridor	105 (32.7%)	17 (6.4%)	2	0	5	3	5	2	4
# 5 PFR	11 (3.4%)	89 (33.6%)	0	0	3	5	0	21	14

1. Caregivers with both language and auscultation skills: n=321 (46.7%)
2. Caregivers with language skills but no auscultation skills: n=265 (38.6%)
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4. Caregivers with neither language nor auscultation skills: n=58 (8.4%)

e-Supplement

e-Table 1. Incorrect Hebrew Terms Used by the Three Groups

Sound Sample	Standard Hebrew	Phonetic Hebrew	English Meaning	n	Repartition by group
#1	קריפיטציות	Crepitatziot	Crepitations	60	SP=10 R=37 MS=13
N=10	חרחורים	Hirhurim	Rales	32	SP=3 R=11 MS=18
	נשימה ברונכיאלית	Neshima bronchialit	Bronchial breathing	18	SP=8 R=6 MS=4
	אקספיריום מאורך	Expirium meorah	Prolonged expiration	1	MS=1
	ירידה עם חירחורים עדינים	Yerida im hirhurim adinim	Diminished with fine rales	1	MS=1
	שפשוף	Shifshuf	Friction	1	SP=1
	ציפצופים	Tziftzufim	Wheezes	1	MS=1
	שיפשוף פליאורלי	Shifshuf pleurali	Pleural friction	1	SP=1
	פיכפוך	Pichpuch	Bubbling	1	R=1
	רישרוש של פלוירה	Rishrush shel pleura	Pleural friction	1	SP=1
#2	סטרידור	Stridor	Stridor	4	SP=1 R=2 MS=1
N=11	חרחורים	Hirhurim	Rales	1	MS=1
	קרפיטציות	Crepitatziot	Crepitations	1	MS=1
	נשימה ברונכיאלית	Neshima bronchialit	Bronchial breathing	2	SP=1 R=1
	חיכוך פליאורלי	Chikuch pleurali	Pleural friction	1	SP=1
	אקספיריום מאורך	Expirium meorah	Prolonged expiration	8	SP=2 R=5 MS=1
	גניחות	Genihot	Groan	1	R=1
	אנחות	Anahot	Sigh	1	SP=1
	אוושה סיסטולית	Ivsha sistolit	Systolic murmur	4	R=3 MS=1
	מיוזיקלי	Musicali	Musical	1	R=1
	קולות ממקור עליון	Kolot mimakor elion	Sounds from upper source	1	MS=1
#3	נשימה ברונכיאלית/תקינה	Neshima bronchialit tekina	Normal bronchial br.	19	SP=7 R=10 MS=2
N=11	נורמלי	Normali	Normal	6	SP=1 R=2 MS=3
	נחירות	Nehirot	Snoring	1	SP=1
	כניסת אוויר מופחתת	Knissat avir mufhetet	Diminished air entry	1	MS=1
	כניסת אוויר מופחתת,רשרו אקספירטורי	Knissat avir mufhetet im rishrush expiratoy	Diminished air entry with expiratory rustle	1	MS=1
	נשימה ברונכיאלית	Neshima bronchialit	Bronchial breathing	2	R=1 MS=1
	ציפצופים	Tziftzufim	Wheezes	2	R=1 MS=1
	נשימה בועית	Neshima buyit	Vesicular breathing	9	SP=3 R=3 MS=3
	כניסת אוויר ירודה	Knisat avir yeruda	Decrease air entry	2	R=1 MS=1
	אקספיריום מאורך	Expirium meorah	Prolonged expiration	1	R=1
	פקעיים	Pkaim	Crepitations	1	MS=1
#4	ציפצופים	Tziftzufim	Wheezes	14	SP=1 R=5 MS=8
N=8	וויזינג	Wizing	Wheezing	1	MS=1
	השתנקות	Histankut	Gasping	1	MS=1
	שריקה	Shirika	Whistle/wheezing	1	MS=1
	דיבור	Dibur	Talk	1	MS=1
	ברונכוספאזם	Bronchospasm	Bronchospasm	1	MS=1
	מיוזיקל	Musical	Musical	1	R=1
	חריקה/שרנוק	Harika	Creak/Friction	1	MS=1
#5 PFR	ריילס	Rales	Rales	1	SP=1
N=10	קריפיטציות	Crepitatziot	Crepitations	13	SP=4 R=5 MS=4
	חרחורים	Hirhurim	Rales	78	SP=15 R=36 MS=27
	ירידה בכניסת אוויר	Yerida beknissat avir	Decrease air entry	1	MS=1
	ציפצופים	Tziftzufim	Wheezes	1	R=1
	נשימה ברונכיאלית	Neshima bronchialit	Bronchial breathing	12	R=9 MS=3
	שיפשוף פריקרדיאלי	Shifshuf pericardiali	Pericardial friction rub	1	MS=1
	פיכפוך	Pichpuch	Bubbling	1	R=1
	איוושה	Ivsha	Murmur	1	R=1
	גודש ריאתי	Godesh reiati	Pulmonary congestion	1	R=1

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"Influence of Language Skills on the Choice of Terms Used to Describe Lung Sounds in a Language Other Than English: A Cross-Sectional Survey of Staff Physicians, Residents and Medical Students."

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Influence of Language Skills on the Choice of Terms Used to Describe Lung Sounds in a Language Other Than English: A Cross-Sectional Survey of Staff Physicians, Residents and Medical Students

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Abstract

Introduction: The value of chest auscultation would be enhanced by the use of a standardised terminology. To that end, the recommended English terminology must be transferred to a language other than English (LOTE) without distortion.

Objective: To examine the transfer to Hebrew – taken as a model of LOTE - of the recommended terminology in English.

Design/Setting: Cross-sectional study; university-based hospital.

Participants: 143 caregivers, including 31 staff physicians, 65 residents, and 47 medical students

Methods: Observers provided uninstructed descriptions in Hebrew and English of audio-recordings of 5 common sounds, namely, normal breath sound (NBS); wheezes; crackles; stridor and pleural friction rub (PFR).

Outcomes: a) Rates of correct/incorrect classification; b) Correspondence between Hebrew and recommended English terms; c) Language and auscultation skills, assessed by crossing the responses in the two languages with each other and with the classification of the audio-recordings validated by computer analysis.

Results: Range (%) of correct rating was as follows: NBS=11.3%-20%; Wheezes=79.7-87.2%; Crackles=58.6-69.8%; Stridor=67.4-96.3%; and PFR=2.7-28.6%. Of 60 Hebrew terms, 11 were correct and 5 matched the recommended English terms. Many Hebrew terms were adaptations or transliterations of inadequate English terms. Of 687 evaluations, good dual- and single-language skills were found in 586 (85.3%) and 41 (6%), respectively. However, in 325 (47.3%) evaluations good language skills were associated with poor auscultation skills.

Conclusion: Poor auscultation skills surpassed poor language skills as a factor hampering the transfer to Hebrew (LOTE) of the recommended English terminology. Improved education in auscultation emerged as the main factor to promote the use of standardised lung sound terminology. Using our data, a strategy was devised to encourage the use of standardised terminology in non-native English speaking countries.

Word count: 273

Key words: lung sound terminology; lung auscultation; observer variability; language skills; language other than English; LOTE

Strengths and Limitations of this Study

- To our knowledge, this is the first study to examine the transfer to LOTE of the recommended lung sound terminology in English.
- True sound classification was validated by computer-based sound analysis.
- Participants were from the same hospital – which tends to limit the study generalisability – but had different clinical and educational background.
- Use of more complex sounds (e.g. rhonchus, squawk) might have further hampered the observers' ability to classify the sounds.

INTRODUCTION

Lung auscultation has been a traditional part of the chest examination since the invention of the stethoscope [**1**]. Whilst no other method equals auscultation in providing quick, cost-effective, and easily obtained, relevant information about the respiratory system, its value is limited by the confused terminology [**2**]. Even though recommendations on terminology have been developed [**3-5**] significant variation in the terms used to describe the sounds persists among health professionals [**6-11**].

To examine this variation, we invited staff physicians, residents, and medical students working in a university-based hospital in Israel, to spontaneously classify a set of common lung sounds presented to them in audio-recordings. They were asked to classify the sounds successively in English and Hebrew, taken as a model of a language other than English (LOTE). Different aspects of the survey were highlighted in two companion papers. The first, published recently, found that poor auscultation skills were the main factor influencing the choice of English terminology [**11**]. The second, reported herein, examined the influence of language skills on the transfer to a LOTE (i.e. Hebrew) of the terminology recommended currently by scientific societies [**3-5**]. This aspect has practical importance. First, between-language differences hamper communication in teaching and in meaningful exchanges of auscultation findings between clinicians and researchers from different countries [**10**]. Moreover, they can cause divergent interpretations of the same sound even by caregivers from the same country. This study aimed to compare the Hebrew terms used by our observers, with those recommended currently [**3-5**] and with the English terms they used to classify the same sounds previously [**11**].

MATERIALS AND METHODS

Recruitment of the raters

From February 2017 through March 2018 we recruited 143 caregivers, including 31 staff physicians (SP), 65 residents (R) and 47 medical students (MS) working at Shaare Zedek Medical Center, affiliated with the Hebrew University of Jerusalem [11]. Participants were informed about the study by word-of-mouth. The study was submitted to the hospital's Ethics Committee and approved with advice that no informed consent was required.

Questionnaire

Upon arrival, participants were invited to complete an anonymous questionnaire on background information, including demographics, medical status, years of practice, and specialty. We avoided questions likely to facilitate participants' identification.

Presentation of the sounds

Next, the participants were invited to listen through loudspeakers to the audio-files of 5 common lung sounds stored in a computer placed in a silent room. The sound files were taken from a set of processed files in the **Movie.mp4** format, which were deemed to be clean and devoid of artifacts, as required for an article published previously [**2**]. The following sounds were presented, in that order: 1. Normal breath sound; 2. Wheezes; 3. Crackles; 4. Stridor and 5. Pleural Friction Rub.

Classification of the sound files

The observers were asked to classify the sounds successively in English and Hebrew in the order they were played (i.e. 1-5). No pre-established list of sound

nomenclature was given in either language, and the observers were asked to describe the sounds in a "free-form" format, with their own words. No sonograms, waveform analysis or clinical information were provided to substantiate the nature of the sounds. To attempt to compensate for the lack of clinical context, the observers were informed that all recordings started at the onset of inspiration. Additionally, the site of recording of each sound was indicated on a diagram, as follows: 1. Normal breath sound: posterior left basal lung region at a point situated in the scapular line, 3 cm below the angle of scapula; 2. Wheezes: anterior right upper lung zone at the intersection of the mid-clavicular line and the 2nd intercostal space; 3. Inspiratory crackles: right posterior basal region at the intersection of the scapular line and a point situated 3 cm below the angle of scapula; 4. Stridor: over the trachea, 2 cm above the supra-sternal notch; and 5. Pleural friction rub: left axillary region at the intersection of the mid-axillary line and the 5th intercostal space.

Correct versus Incorrect Sound Classification

The ability to correctly identify the sounds was determined for each sound file by comparing the observers' response with the true classification i.e. clinical classification validated by computer analysis [**2**]. A rating was considered correct if a recommended term or an accepted synonym was used to describe the sound (term use ascribed to preference). The use of any incorrect term was ascribed to lack of skills on chest auscultation.

Language and Auscultation Skills

The ability to correctly classify the sounds depends both on language skills and auscultation skills. For each observer, we crossed the sound classification in Hebrew with the corresponding classification English, performed previously by

the same observers [**11**]. Four classes of combined skills were identified, as follows: *1.* Dual-language skills *and* good auscultation skills*.* Use of *accepted* terms in the two languages *to correctly* classify a sound (e.g. use of the English term "wheeze" and the Hebrew term "tziftzufim" to classify the wheezes of sound sample # 2). *2.* Dual-language skills *and* poor auscultation skills. Use of *accepted*, corresponding terms in the two languages to *incorrectly* classify a sound (e.g. use of the English term "pleural friction rub" and its *corresponding* Hebrew equivalent "shifshuf pleurali" to wrongly classify the wheezes of sound sample # 2). *3. Single-language skills and* good auscultation skills*.* Use of a *correct* term in one language and an *incorrect* (or no) term in the other language to correctly classify a sound (e.g. use of the English term wheeze coupled with, say, the *incorrect* Hebrew term "hirhurim" to classify the wheezes of sound sample # 2}. *4.* Poor language skills *and* poor auscultation skills. Use of different, incorrect terms in the two languages to classify a sound (e.g. use of "crackle" and "shifshuf pleurali" to classify the wheezes of sound sample # 2).

Patient and Public Involvement

Due to the nature of this study, patients and the public were not involved in the study design and research analysis.

Data Analysis

Baseline characteristics are presented as mean (SD) and proportions. For each audio sample, the difference in the proportion of correct vs. incorrect rating was tested using the Chi square test; a $p < 0.05$ was considered significant.

RESULTS

Characteristics of participants

Participants' mean (SD) age was as follows: SP= 48.4 yrs. (10.4); R=32.5 yrs. (3.5), and MS=28.4 yrs. (4.5). Overall, 17 (54.8%) staff physicians declared more than 20-year experience with auscultation; in turn, 60 (92%) residents and 47 (100%) medical students declared < 5-year experience.

Language profile and specialty of staff physicians

The first language of 27 SPs who provided responses to this question were: Hebrew, n=16, English, n=4, Arabic, n=2, French, n=2, Russian, n=2, and Portuguese, n=1. All respondents reported the learning of unspecified versions of the lung sound terminology in English and Hebrew (n=23). The repartition by specialty was as follows: Pulmonology, n=7; Pediatrics, n=6; Internal Medicine, n=4; Cardiology, n=2; Oncology, n=2; Geriatrics, n=1; Hematology, n=1; Emergency medicine, n=1; Rheumatology, n=1; Palliative care, n=1 and Family medicine, n=1. Twenty four SPs practiced medicine in both English and Hebrew, while 3 practiced only in Hebrew.

Correct Hebrew Terms versus Recommended English Terminology

Table 1 lists (i) the standard and phonetic forms of the *correct* Hebrew terms used by the three groups; (ii) their meaning in English; and (iii) the corresponding recommended English terminology. Overall, the rates of correct identification were high for the wheeze (SP=80%; R=79.7%; MS=87.2%; [p=.944]) and the stridor (SP=96.3%; R=90.2%; MS=67.4%; [p=.544]), fair for the crackles (SP=58.6%; R=67.2%; MS=69.8%; [p=.899]) and low for the normal lung sound (SP=20%;

R=11.3%; MS=15.5%; [p=.624]) and the pleural friction rub (SP=28.6%; R=3.6%; MS=2.7% [p=.002]).

Preference versus Poor Auscultation Skill

Altogether, the observers used 60 Hebrew terms to classify the 5 sounds; of these 11 (18.3%) were correct, being therefore ascribed to preferences regarding terminology, while 49 (81.7%) were incorrect, being ascribed to lack of chest auscultation skills.

Correct terms by group

Sample sound #1 (*Normal breath sound*): Of **137** participants classifying this file, 20 correctly classified it as normal. Of 3 Hebrew terms used, only 1 corresponded to the recommended English term "normal breath sound".

Sample sound # 2 (*Wheezes*): Of **141** participants classifying this file, 116 (82.3%) used a single Hebrew term - "Tziftzufim" - corresponding to the recommended English term "Wheeze".

Sample sound # 3 (*Crackles*): Of **130** participants classifying this file, 86 (66.2%) used 4 Hebrew terms to correctly classify it as crackles. However, only 1 term – "Pitzputzim" - corresponded to the recommended English term crackle.

Sample sound # 4 (*Stridor*): Of **131** participants classifying this sound, 110 (84%) correctly classified it by means of a Hebrew transliteration of the recommended English term "stridor".

Sample sound # 5 (*Pleural friction rub*): Of **121** participants classifying this sample, 11 (9.1%) correctly classified it as pleural friction rub. They used 2 terms, of which "Shifshuf Pleurali", meaning "Pleural rubbing", was used on 10 occasions.

Incorrect Hebrew Terms

The 49 incorrect Hebrew terms are listed in the **e-Table 1**. Of these, 10 were used to classify the normal breath sound, 11 to classify the wheezes, 10 to classify the crackles, 8 to classify the stridor, and 10 to classify the pleural friction rub.

Transfer to Hebrew of the English Terminology

Identification of 5 sounds by 143 subjects would have resulted in 715 instances of identification. However, on 28 occasions the observers declined to classify a sound in either language, thus giving a total of 687 (96%) instances of sound identification. On 597 (87%) of these occasions, the observers provided terms in the two languages for all sounds, while on 90 (12.9%) they provided terms in one language only. The combination of language skills and auscultation skills, obtained by crossing the correct and incorrect responses in the 687 sessions, is given in detail in **Table 2**. The resulting combination of language skills and auscultation skills was a follows:

1. Dual-language skills *and* good auscultation skills. n=321 (46.7%)

2. Dual-language skills *and* poor auscultation skills n=265 (38.6%).

3. Single-language skills and good auscultation skills. n=41 (6.0%)

4. Poor language skills *and* poor auscultation skills. n=60 (8.7%)

DISCUSSION

In his original work, Laennec used the terms “rale” and “rhonchus” interchangeably, to denote all classes of adventitious sounds [**1**]. Successive translations — first into English, then into other languages — and redefinitions of the original terminology gave different meanings to these terms, starting a confusion that persists to this day. To overcome this drawback, recommendations for use of a standardised terminology in the English language were made by the *Ad Hoc* committees of scientific societies [**3-5**]. The recommended terms — simple and precise — are based on the physics of the sounds, without assumptions about their mechanism of generation or site of production **[3-5].** In a population of caregivers working in Israel, we compared the Hebrew terms used to classify 5 common sounds with: (a) the recommended terminology in English and; (b) the terms used by the same caregivers to classify the same sounds in the English language.

In similarity with our companion study [11] the observers’ ability to classify the sounds in Hebrew was high for the wheezes and the stridor, fair for the crackles, and low for the normal breath sounds and the pleural friction rub, with the three groups of caregivers performing similarly in classifying all sounds. Even though the staff physicians performed better than the other groups in classifying the pleural friction rub, the overall performance of the three groups was too low to be considered clinically meaningful. This similarity of performance regarding the two languages is interesting, because, in theory, one could expect the caregivers to perform better in their working language - Hebrew - than in English.

Of 3 correct Hebrew terms used to classify sound file # 1, just one corresponded to the recommended term “Normal breath sound” in English. The other two, “Vesiculari” and “Buyit” — meaning respectively “Vesicular” and “Alveolar” — are deemed inappropriate as they convey the incorrect assumption that the normal sound originates from the *entrance of air into and out of the air-cells of the lungs* [**1**]. As a quick aside, although the *exact* locale and mode of production of the normal breath sound has not been established, there is evidence to support the view that it has a double origin: the lobar and segmental airways for the inspiratory component, and a more central source for the expiratory component [**12, 13**]

Consistent with our previous study [**11**] all observers used the classic Hebrew term “Tziftzufim” to classify the wheezes. This homogeneous description is interesting. Indeed, the term “Wheezing” has been in use long before Laennec’s invention of the stethoscope, while “Wheeze”, as used nowadays, corresponds to the “Rale sibilant sec” described by Laennec [**14**]. We speculate that the traditional attribution of this sound to a single mechanism – airway obstruction – might have contributed for the use of a single term to describe it. Consequently, the translation from the source language (i.e. English) to other languages was kept relatively uniform, as found in the present study.

The term “Stridor” — from the Latin ***stridere*** (harsh, shrill or creaking noise) — describes the high-pitched, musical sound produced by turbulent flow passing through a narrowed segment of the upper respiratory tract [**15**]. In similarity with the classification of the wheezes, all correct raters used a single term. However, instead of the Hebrew term “שִׁרְנוּק” (“Shirnuk”) they used the term “Stridor” itself, spelled in the Hebrew alphabet. This peculiar choice suggests that, rather than

searching for a suitable terminology, the caregivers preferred a term familiar to them. This finding is similar to that reported in a recent survey of lung sound nomenclature carried out in 34 European countries, which showed that caregivers from *all* the countries - representing 29 languages of which 5 had non-Latin alphabets – spelled the term "Stridor" verbatim in all languages but Greek [**16**].

With two categories – "Fine" and "Coarse" – crackles can be defined as brief, non-musical, explosive, adventitious sounds [**17, 18**]. In this study, the Hebrew equivalent of "Crackles" was used just once, by a medical student. Of the other acceptable terms, "Crepitatziot" is solely an adaptation of "Crepitations", while "Hirhurim" is the classical Hebrew term for "Rales". It should be noted that both these terms are considered superfluous or inadequate: "Crepitations" because it merely means high-pitched crackling, and "Rales" because, as stated above, it was originally a generic term applied to every variety of adventitious pulmonary sound [1]. Incidentally, the accepted mechanism of production of fine crackles is not the presence of secretions in the airways, but the sudden opening of airways in deflated territories of the lung as observed in restrictive lung disorders (e.g. Interstitial Lung Disease) [**17-19**].

Of the presented sounds, the pleural friction rub is probably the less well-studied. Purportedly, it is produced by the sudden release of tangential tension in a superficial portion of the lung momentarily arrested in its sliding movement by a frictional force between the two pleurae [**18**]. The tiny group of observers who correctly classified this sound used 2 terms (vs. 4 terms in the English part of the survey [**11**]): pleural and friction, alone or in combination.

A novel information provided by this study is that poor skills in chest auscultation largely surpassed deficient language skills as a cause of incorrect lung sound classification. Of 90% of participants found to have good language skills, 50% had poor auscultation skills. Consistent with our previous study [11] this finding further illustrates the fact that the use of recommended terminology is meaningful only among observers with good auscultation skills. In fact, observer agreement on a wrong classification can be detrimental to the patients, as it may lead to unnecessary and expensive investigations as well as improper treatment [11].

Most of our staff physicians practiced medicine in both Hebrew and English. This aspect has clinical relevance. The ability of nonnative English-speaking doctors to communicate with patients in English is now considered a core-competency. Consistent with its status of global lingua franca, the English language is the universal means of communication between people with different native languages. In this context, ensuring the similarity of terminology between English and a LOTE is important, as language-concordant health care contributes to prevent expensive tests and poor patient follow-up.

To our knowledge, there is no research similar to this study that can provide data for comparison. Searching the literature, we found that the importance of the correct understanding of the original English terminology by caregivers working in a LOTE has been examined only peripherally. For instance, in a survey of seven European countries, lack of familiarity with the English nomenclature was invoked to explain the lower agreement of Russian and Dutch practitioners to classify crackles and wheezes from video-recordings [**20**]. Also, in the European terminology survey quoted above, the terms used across the countries were

generally non-uniform, some countries having their own terminology, others simply adopting the English terminology [**16**].

This study has limitations. First, for the sake of feasibility, we recruited caregivers from the same hospital, which may limit the generalisability of the findings. However, compensation was provided by their heterogeneity in terms of clinical and educational background. Second, we did not investigate all adventitious sounds. For simplicity, we stuck to the commonest ones, intentionally excluding more complex sounds such as, for instance, the rhonchus or the squawk, whose inclusion might have further hampered the observers' ability to classify the sounds. Finally, the experimental conditions were not representative of those in clinical practice. The study design prevented the participants to auscultate all over the chest, at will, or to command the respiratory maneuvers, which may have altered outcomes compared with real-life. However, to avoid more detrimental biases we were forced to standardize the study conditions across participants.

CONCLUSION

In this study, the Hebrew terms used to classify common lung sounds corresponded only partly to the recommended terminology. Many Hebrew terms were adaptations or transliterations of inappropriate English terms (e.g. "Vesicular sound", "Crepitations"). Noticeably, a high proportion of matched Hebrew/English terms was incorrect. These data support the conclusion that poor auscultation skills surpassed poor language skills as a factor hampering the meaningful transfer of the recommended terminology to a LOTE (Hebrew). In this context, improved education in chest auscultation should be the main prerequisite for the successful dissemination of the recommended terminology.

Based on our results, some suggestions can be made to encourage the widespread use of a standardised lung sound terminology in non-native English speaking countries. Countries with a high knowledge of English could simply adopt the recommended English terminology verbatim. Alternatively, countries with a lower knowledge of English could opt for the translation of the recommended terms by professionals skilled in both the source (English) and the target (LOTE) language. Finally, if resources for translation are not available, transliteration of the recommended terms seems a viable option. Adopted spontaneously by many observers in this study, transliteration requires no special language skills and can be performed in any language, including those with non-Latin alphabets. For its simplicity, it should be given consideration by the medical societies of all concerned countries.

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Table 1. Comparison Of Hebrew Terms With Recommended English Terms Used By Three Groups of Caregivers to Classify Five Lung Sounds

Audio sample	Recommended Terminology in the English Language	Hebrew Terms			Frequency of Use	
		Standard	Phonetic	English Meaning	n	By Group
# 1	Normal breath sound	נשימה נורמלית	Neshima normalit	Normal breathing	8	SP=1 R= 3; MS=4
		נשימה וסקולרית	Neshima vesicularit	*Vesicular breathing*[3]	2	SP=2
		נשימה בועית	Neshima buit	*"Alveolar" breathing*[3]	10	SP=3 R= 4; MS=3
# 2	Wheezes	צפצופים	Tziftzufim	Wheezes	116	SP=24 R=51 MS=41
# 3	Crackles	קריפיטציות	Crepitatziot	*Crepitations*[3]	42	SP=12 R=17 MS=13
		פיצפוצים	Pitzputzim	Crackles	1	MS=1
		פקעיים	Pkaim	*Fine Crepitations*[3]	1	MS=1
		חרחורים	Hirhurim	*Rales*	42	SP=5 R=22 MS=15
# 4	Stridor[1]	סטרידור[2]	Stridor	Stridor	110	SP=26 R=55 MS=29
# 5	Pleural friction rub[1]	שפשוף פלאורלי	Shifshuf pleurali	*Pleural rubbing*[3]	10	SP=8 R=1 MS=1
		פריקשן	Friction	Friction	1	R=1

1. Term suggested [ref # 2]
2. The correct term - **שִׁרְנוּק** (shirnuk) - was not used by any rater.
3. Term considered correct but nor recommended

SP= Staff physicians; R= Residents; MS= Medical students

Table 2: Language and Auscultation Skills Among Staff Physicians, Residents and Medical Students: English versus Terminology in LOTE

Sound Classification	Possible Number of Sessions of Sound Identification for All Observers (n=75)								
	Observers providing classification in the two languages (n=597)				Observers providing classification in one language only (n=90)				No classification in either language (n=28)
	Similar terms in the two languages (n=586)		Different terms in the two languages (n=11)		English (n=27)		Hebrew (n=63)		
	Both terms correct [1] (n=321)	Both terms Incorrect [2] (n=265)	English correct[3] (n=7)	Hebrew correct[3] (n=4)	Correct[3] (n=14)	Incorrect[4] (n=13)	Correct[3] (n=16)	Incorrect[4] (n=47)	
# 1 Normal	19 (5.9%)	106 (40.0%)	1	0	0	3	1	10	3
# 2 Wheeze	110 (34.3%)	19 (7.2%)	2	1	2	0	5	4	0
# 3 Crackle	77 (24.0%)	34 (12.8%)	2	3	4	2	6	8	7
# 4 Stridor	104 (32.4%)	17 (6.4%)	2	0	5	3	4	4	4
# 5 PFR	11 (3.4%)	89 (33.6%)	0	0	3	5	0	21	14

1. Dual-language skills *and* good auscultation skills. n=321 (46.7%)
2. Dual-language skills *and* poor auscultation skills n=265 (38.6%).
3. Single-language skills and good auscultation skills. n=41 (6.0%)
4. Poor language skills *and* poor auscultation skills. n=60 (8.7%)

e-Supplement

e-Table 1. Incorrect Hebrew Terms Used by the Three Groups

Sound Sample	Standard Hebrew	Phonetic Hebrew	English Meaning	n	Repartition by group
#1 NBS	קריפיטציות	Crepitatziot	Crepitations	60	SP=10 R=37 MS=13
N=10	חרחורים	Hirhurim	Rales	32	SP=3 R=11 MS=18
	נשימה ברונכיאלית	Neshima bronchialit	Bronchial breathing	18	SP=8 R=6 MS=4
	אקספיריום מאורך	Expirium meorah	Prolonged expiration	1	MS=1
	ירידה עם חירחורים עדינים	Yerida im hirhurim adinim	Diminished with fine rales	1	MS=1
	שפשוף	Shifshuf	Friction	1	SP=1
	ציפצופים	Tziftzufim	Wheezes	1	MS=1
	שיפשוף פליאורלי	Shifshuf pleurali	Pleural friction	1	SP=1
	פיכפוך	Pichpuch	Bubbling	1	R=1
	רישרוש של פלוירה	Rishrush shel pleura	Pleural friction	1	SP=1
#2 Wheeze	סטרידור	Stridor	Stridor	4	SP=1 R=2 MS=1
N=11	חרחורים	Hirhurim	Rales	1	MS=1
	קרפיטציות	Crepitatziot	Crepitations	1	MS=1
	נשימה ברונכיאלית	Neshima bronchialit	Bronchial breathing	2	SP=1 R=1
	חיכוך פליאורלי	Chikuch pleurali	Pleural friction	1	SP=1
	אקספיריום מאורך	Expirium meorah	Prolonged expiration	8	SP=2 R=5 MS=1
	גניחות	Genihot	Groan	1	R=1
	אנחות	Anahot	Sigh	1	SP=1
	אוושה סיסטולית	Ivsha sistolit	Systolic murmur	4	R=3 MS=1
	מיוזיקלי	Musicali	Musical	1	R=1
	קולות ממקור עליון	Kolot mimakor elion	Sounds from upper source	1	MS=1
#3 Crackle	נשימה ברונכיאלית/תקינה	Neshima bronchialit tekina	Normal bronchial br.	19	SP=7 R=10 MS=2
N=10	נורמלי	Normali	Normal	6	SP=1 R=2 MS=3
	נחירות	Nehirot	Snoring	1	SP=1
	כניסת אוויר מופחתת	Knissat avir mufhetet	Diminished air entry	1	MS=1
	כניסת אוויר מופחתת,רשרו אקספירטורי	Knissat avir mufhetet im rishrush expiratoy	Diminished air entry with expiratory rustle	1	MS=1
	נשימה ברונכיאלית	Neshima bronchialit	Bronchial breathing	2	R=1 MS=1
	ציפצופים	Tziftzufim	Wheezes	2	R=1 MS=1
	נשימה בועית	Neshima buyit	Vesicular breathing	9	SP=3 R=3 MS=3
	כניסת אוויר ירודה	Knisat avir yeruda	Decrease air entry	2	R=1 MS=1
	אקספיריום מאורך	Expirium meorah	Prolonged expiration	1	R=1
#4 Stridor	ציפצופים	Tziftzufim	Wheezes	14	SP=1 R=5 MS=8
N=8	ווזינג	Wizing	Wheezing	1	MS=1
	השתנקות	Histankut	Gasping	1	MS=1
	שריקה	Shirika	Whistle/wheezing	1	MS=1
	דיבור	Dibur	Talk	1	MS=1
	ברונכוספאזם	Bronchospasm	Bronchospasm	1	MS=1
	מיוזיקל	Musical	Musical	1	R=1
	חריקה/שרנוק	Harika	Creak/Friction	1	MS=1
#5 PFR	ריילס	Rales	Rales	1	SP=1
N=10	קריפיטציות	Crepitatziot	Crepitations	13	SP=4 R=5 MS=4
	חרחורים	Hirhurim	Rales	78	SP=15 R=36 MS=27
	ירידה בכניסת אוויר	Yerida beknissat avir	Decrease air entry	1	MS=1
	ציפצופים	Tziftzufim	Wheezes	1	R=1
	נשימה ברונכיאלית	Neshima bronchialit	Bronchial breathing	12	R=9 MS=3
	שיפשוף פריקרדיאלי	Shifshuf pericardiali	Pericardial friction rub	1	MS=1
	פיכפוך	Pichpuch	Bubbling	1	R=1
	איוושה	Ivsha	Murmur	1	R=1
	גודש ריאתי	Godesh reiati	Pulmonary congestion	1	R=1

NBS: Normal breath sound; PFR: Pleural friction rub SP= Staff physicians; R= Residents; MS= Medical students

Influence of Language Skills on the Choice of Terms Used to Describe Lung Sounds in a Language Other Than English: A Cross-Sectional Survey of Staff Physicians, Residents and Medical Students

A. Bohadana et al.

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract **page 1**
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **page 2**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **page 4**
Objectives	3	State specific objectives, including any prespecified hypotheses **page 4**
Methods		
Study design	4	Present key elements of study design early in the paper **page 5**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **page 5**
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants **NA**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **NA**
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **NA**
Bias	9	Describe any efforts to address potential sources of bias **NA**
Study size	10	Explain how the study size was arrived at **NA**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **NA**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding **page 7**
		(*b*) Describe any methods used to examine subgroups and interactions **NA**
		(*c*) Explain how missing data were addressed **NA**
		(*d*) If applicable, describe analytical methods taking account of sampling strategy **NA**
		(*e*) Describe any sensitivity analyses **NA**
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed **NA**
		(b) Give reasons for non-participation at each stage **NA**
		(c) Consider use of a flow diagram **NA**
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders **NA**

		(b) Indicate number of participants with missing data for each variable of interest **NA**
Outcome data	15*	Report numbers of outcome events or summary measures **NA**
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included **NA**
		(*b*) Report category boundaries when continuous variables were categorized **NA**
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period **NA**
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses **NA**
Discussion		
Key results	18	Summarise key results with reference to study objectives **page 12**
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias **page 16**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence **page 15**
Generalisability	21	Discuss the generalisability (external validity) of the study results **page 15**
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based **page 18**

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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CLEAN COPY Revision # 2

Influence of Language Skills on the Choice of Terms Used to Describe Lung Sounds in a Language Other Than English: A Cross-Sectional Survey of Staff Physicians, Residents and Medical Students

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Abstract

Introduction: The value of chest auscultation would be enhanced by the use of a standardised terminology. To that end, the recommended English terminology must be transferred to a language other than English (LOTE) without distortion.

Objective: To examine the transfer to Hebrew – taken as a model of LOTE - of the recommended terminology in English.

Design/Setting: Cross-sectional study; university-based hospital.

Participants: 143 caregivers, including 31 staff physicians, 65 residents, and 47 medical students

Methods: Observers provided uninstructed descriptions in Hebrew and English of audio-recordings of 5 common sounds, namely, normal breath sound (NBS); wheezes; crackles; stridor and pleural friction rub (PFR).

Outcomes: a) Rates of correct/incorrect classification; b) Correspondence between Hebrew and recommended English terms; c) Language and auscultation skills, assessed by crossing the responses in the two languages with each other and with the classification of the audio-recordings validated by computer analysis.

Results: Range (%) of correct rating was as follows: NBS=11.3%-20%; Wheezes=79.7-87.2%; Crackles=58.6-69.8%; Stridor=67.4-96.3%; and PFR=2.7-28.6%. Of 60 Hebrew terms, 11 were correct and 5 matched the recommended English terms. Many Hebrew terms were adaptations or transliterations of inadequate English terms. Of 687 evaluations, good dual- and single-language skills were found in 586 (85.3%) and 41 (6%), respectively. However, in 325 (47.3%) evaluations good language skills were associated with poor auscultation skills.

Conclusion: Poor auscultation skills surpassed poor language skills as a factor hampering the transfer to Hebrew (LOTE) of the recommended English terminology. Improved education in auscultation emerged as the main factor to promote the use of standardised lung sound terminology. Using our data, a strategy was devised to encourage the use of standardised terminology in non-native English speaking countries.

Word count: 273

Key words: lung sound terminology; lung auscultation; observer variability; language skills; language other than English; LOTE

Strengths and Limitations of this Study

- To our knowledge, this is the first study to examine the transfer to LOTE of the recommended lung sound terminology in English.
- True sound classification was validated by computer-based sound analysis.
- Participants were from the same hospital – which tends to limit the study generalisability – but had different clinical and educational background.
- Use of more complex sounds (e.g. rhonchus, squawk) might have further hampered the observers' ability to classify the sounds.

INTRODUCTION

Lung auscultation has been a traditional part of the chest examination since the invention of the stethoscope [**1**]. Whilst no other method equals auscultation in providing quick, cost-effective, and easily obtained, relevant information about the respiratory system, its value is limited by the confused terminology [**2**]. Even though recommendations on terminology have been developed [**3-5**] significant variation in the terms used to describe the sounds persists among health professionals [**6-11**].

To examine this variation, we invited staff physicians, residents, and medical students working in a university-based hospital in Israel, to spontaneously classify a set of common lung sounds presented to them in audio-recordings. They were asked to classify the sounds successively in English and Hebrew, taken as a model of a language other than English (LOTE). Different aspects of the survey were highlighted in two companion papers. The first, published recently, found that poor auscultation skills were the main factor influencing the choice of English terminology [**11**]. The second, reported herein, examined the influence of language skills on the transfer to a LOTE (i.e. Hebrew) of the terminology recommended currently by scientific societies [**3-5**]. This aspect has practical importance. First, between-language differences hamper communication in teaching and in meaningful exchanges of auscultation findings between clinicians and researchers from different countries [**10**]. Moreover, they can cause divergent interpretations of the same sound even by caregivers from the same country. This study aimed to compare the Hebrew terms used by our observers, with those recommended currently [**3-5**] and with the English terms they used to classify the same sounds previously [**11**].

MATERIALS AND METHODS

Recruitment of the raters

From February 2017 through March 2018 we recruited 143 caregivers, including 31 staff physicians (SP), 65 residents (R) and 47 medical students (MS) working at Shaare Zedek Medical Center, affiliated with the Hebrew University of Jerusalem [11]. Participants were informed about the study by word-of-mouth. The study was submitted to the hospital's Ethics Committee and approved with advice that no informed consent was required.

Questionnaire

Upon arrival, participants were invited to complete an anonymous questionnaire on background information, including demographics, medical status, years of practice, and specialty. We avoided questions likely to facilitate participants' identification.

Presentation of the sounds

Next, the participants were invited to listen through loudspeakers to the audio-files of 5 common lung sounds stored in a computer placed in a silent room. The sound files were taken from a set of processed files in the **Movie.mp4** format, which were deemed to be clean and devoid of artifacts, as required for an article published previously [**2**]. The following sounds were presented, in that order: 1. Normal breath sound; 2. Wheezes; 3. Crackles; 4. Stridor and 5. Pleural Friction Rub.

Classification of the sound files

The observers were asked to classify the sounds successively in English and Hebrew in the order they were played (i.e. 1-5). No pre-established list of sound

nomenclature was given in either language, and the observers were asked to describe the sounds in a "free-form" format, with their own words. No sonograms, waveform analysis or clinical information were provided to substantiate the nature of the sounds. To attempt to compensate for the lack of clinical context, the observers were informed that all recordings started at the onset of inspiration. Additionally, the site of recording of each sound was indicated on a diagram, as follows: 1. Normal breath sound: posterior left basal lung region at a point situated in the scapular line, 3 cm below the angle of scapula; 2. Wheezes: anterior right upper lung zone at the intersection of the mid-clavicular line and the 2nd intercostal space; 3. Inspiratory crackles: right posterior basal region at the intersection of the scapular line and a point situated 3 cm below the angle of scapula; 4. Stridor: over the trachea, 2 cm above the supra-sternal notch; and 5. Pleural friction rub: left axillary region at the intersection of the mid-axillary line and the 5th intercostal space.

Correct versus Incorrect Sound Classification

The ability to correctly identify the sounds was determined for each sound file by comparing the observers' response with the true classification i.e. clinical classification validated by computer analysis [**2**]. In this process, an expert selected a segment of the recorded normal sounds that was free of artifacts. A rating was considered correct if a recommended term or an accepted synonym was used to describe the sound (term use ascribed to preference). The use of any incorrect term was ascribed to lack of skills on chest auscultation.

Language and Auscultation Skills

The ability to correctly classify the sounds depends both on language skills and auscultation skills. For each observer, we crossed the sound classification in

Hebrew with the corresponding classification English, performed previously by the same observers [**11**]. Four classes of combined skills were identified, as follows: *1.* Dual-language skills *and* good auscultation skills*.* Use of *accepted* terms in the two languages *to correctly* classify a sound (e.g. use of the English term "wheeze" and the Hebrew term "tziftzufim" to classify the wheezes of sound sample # 2). *2.* Dual-language skills *and* poor auscultation skills. Use of *accepted*, corresponding terms in the two languages to *incorrectly* classify a sound (e.g. use of the English term "pleural friction rub" and its *corresponding* Hebrew equivalent "shifshuf pleurali" to wrongly classify the wheezes of sound sample # 2). *3. Single-language skills and* good auscultation skills*.* Use of a *correct* term in one language and an *incorrect* (or no) term in the other language to correctly classify a sound (e.g. use of the English term wheeze coupled with, say, the *incorrect* Hebrew term "hirhurim" to classify the wheezes of sound sample # 2}. *4.* Poor language skills *and* poor auscultation skills. Use of different, incorrect terms in the two languages to classify a sound (e.g. use of "crackle" and "shifshuf pleurali" to classify the wheezes of sound sample # 2).

Patient and Public Involvement

Patients or the public were not involved in the design, conduct, reporting or dissemination of this study.

Data Analysis

Baseline characteristics are presented as mean (SD) and proportions. For each audio sample, the difference in the proportion of correct vs. incorrect rating was tested using the Chi square test; a $p < 0.05$ was considered significant.

RESULTS

Characteristics of participants

Participants' mean (SD) age was as follows: SP= 48.4 yrs. (10.4); R=32.5 yrs. (3.5), and MS=28.4 yrs. (4.5). Overall, 17 (54.8%) staff physicians declared more than 20-year experience with auscultation; in turn, 60 (92%) residents and 47 (100%) medical students declared < 5-year experience.

Language profile and specialty of staff physicians

The first language of 27 SPs who provided responses to this question were: Hebrew, n=16, English, n=4, Arabic, n=2, French, n=2, Russian, n=2, and Portuguese, n=1. All respondents reported the learning of unspecified versions of the lung sound terminology in English and Hebrew (n=23). The repartition by specialty was as follows: Pulmonology, n=7; Pediatrics, n=6; Internal Medicine, n=4; Cardiology, n=2; Oncology, n=2; Geriatrics, n=1; Hematology, n=1; Emergency medicine, n=1; Rheumatology, n=1; Palliative care, n=1 and Family medicine, n=1. Twenty four SPs practiced medicine in both English and Hebrew, while 3 practiced only in Hebrew.

Correct Hebrew Terms versus Recommended English Terminology

Table 1 lists (i) the standard and phonetic forms of the *correct* Hebrew terms used by the three groups; (ii) their meaning in English; and (iii) the corresponding recommended English terminology. Overall, the rates of correct identification were high for the wheeze (SP=80%; R=79.7%; MS=87.2%; [p=.944]) and the stridor (SP=96.3%; R=90.2%; MS=67.4%; [p=.544]), fair for the crackles (SP=58.6%; R=67.2%; MS=69.8%; [p=.899]) and low for the normal lung sound (SP=20%;

R=11.3%; MS=15.5%; [p=.624]) and the pleural friction rub (SP=28.6%; R=3.6%; MS=2.7% [p=.002]).

Preference versus Poor Auscultation Skill

Altogether, the observers used 60 Hebrew terms to classify the 5 sounds; of these 11 (18.3%) were correct, being therefore ascribed to preferences regarding terminology, while 49 (81.7%) were incorrect, being ascribed to lack of chest auscultation skills.

Correct terms by group

Sample sound #1 (*Normal breath sound*): Of **137** participants classifying this file, 20 correctly classified it as normal. Of 3 Hebrew terms used, only 1 corresponded to the recommended English term "normal breath sound".

Sample sound # 2 (*Wheezes*): Of **141** participants classifying this file, 116 (82.3%) used a single Hebrew term - "Tziftzufim" - corresponding to the recommended English term "Wheeze".

Sample sound # 3 (*Crackles*): Of **130** participants classifying this file, 86 (66.2%) used 4 Hebrew terms to correctly classify it as crackles. However, only 1 term – "Pitzputzim" - corresponded to the recommended English term crackle.

Sample sound # 4 (*Stridor*): Of **131** participants classifying this sound, 110 (84%) correctly classified it by means of a Hebrew transliteration of the recommended English term "stridor".

Sample sound # 5 (*Pleural friction rub*): Of **121** participants classifying this sample, 11 (9.1%) correctly classified it as pleural friction rub. They used 2 terms, of which "Shifshuf Pleurali", meaning "Pleural rubbing", was used on 10 occasions.

Incorrect Hebrew Terms

The 49 incorrect Hebrew terms are listed in the **e-Table 1**. Of these, 10 were used to classify the normal breath sound, 11 to classify the wheezes, 10 to classify the crackles, 8 to classify the stridor, and 10 to classify the pleural friction rub.

Transfer to Hebrew of the English Terminology

Identification of 5 sounds by 143 subjects would have resulted in 715 instances of identification. However, on 28 occasions the observers declined to classify a sound in either language, thus giving a total of 687 (96%) instances of sound identification. On 597 (87%) of these occasions, the observers provided terms in the two languages for all sounds, while on 90 (12.9%) they provided terms in one language only. The combination of language skills and auscultation skills, obtained by crossing the correct and incorrect responses in the 687 sessions, is given in detail in **Table 2**. The resulting combination of language skills and auscultation skills was a follows:

1. Dual-language skills *and* good auscultation skills. n=321 (46.7%)

2. Dual-language skills *and* poor auscultation skills n=265 (38.6%).

3. Single-language skills and good auscultation skills. n=41 (6.0%)

4. Poor language skills *and* poor auscultation skills. n=60 (8.7%)

DISCUSSION

In his original work, Laennec used the terms “rale” and “rhonchus” interchangeably, to denote all classes of adventitious sounds [**1**]. Successive translations — first into English, then into other languages — and redefinitions of the original terminology gave different meanings to these terms, starting a confusion that persists to this day. To overcome this drawback, recommendations for use of a standardised terminology in the English language were made by the *Ad Hoc* committees of scientific societies [**3-5**]. The recommended terms — simple and precise — are based on the physics of the sounds, without assumptions about their mechanism of generation or site of production **[3-5].** In a population of caregivers working in Israel, we compared the Hebrew terms used to classify 5 common sounds with: (a) the recommended terminology in English and; (b) the terms used by the same caregivers to classify the same sounds in the English language.

In similarity with our companion study [11] the observers’ ability to classify the sounds in Hebrew was high for the wheezes and the stridor, fair for the crackles, and low for the normal breath sounds and the pleural friction rub, with the three groups of caregivers performing similarly in classifying all sounds. Even though the staff physicians performed better than the other groups in classifying the pleural friction rub, the overall performance of the three groups was too low to be considered clinically meaningful. This similarity of performance regarding the two languages is interesting, because, in theory, one could expect the caregivers to perform better in their working language - Hebrew - than in English.

Of 3 correct Hebrew terms used to classify sound file # 1, just one corresponded to the recommended term “Normal breath sound” in English. The other two, “Vesiculari” and “Buyit” — meaning respectively “Vesicular” and “Alveolar” — are deemed inappropriate as they convey the incorrect assumption that the normal sound originates from the *entrance of air into and out of the air-cells of the lungs* [**1**]. As a quick aside, although the *exact* locale and mode of production of the normal breath sound has not been established, there is evidence to support the view that it has a double origin: the lobar and segmental airways for the inspiratory component, and a more central source for the expiratory component [**12, 13**]

Consistent with our previous study [**11**] all observers used the classic Hebrew term “Tziftzufim” to classify the wheezes. This homogeneous description is interesting. Indeed, the term “Wheezing” has been in use long before Laennec’s invention of the stethoscope, while “Wheeze”, as used nowadays, corresponds to the “Rale sibilant sec” described by Laennec [**14**]. We speculate that the traditional attribution of this sound to a single mechanism – airway obstruction – might have contributed for the use of a single term to describe it. Consequently, the translation from the source language (i.e. English) to other languages was kept relatively uniform, as found in the present study.

The term “Stridor” — from the Latin ***stridere*** (harsh, shrill or creaking noise) — describes the high-pitched, musical sound produced by turbulent flow passing through a narrowed segment of the upper respiratory tract [**15**]. In similarity with the classification of the wheezes, all correct raters used a single term. However, instead of the Hebrew term “שִׁרְנוּק” (“Shirnuk”) they used the term “Stridor” itself, spelled in the Hebrew alphabet. This peculiar choice suggests that, rather than

searching for a suitable terminology, the caregivers preferred a term familiar to them. This finding is similar to that reported in a recent survey of lung sound nomenclature carried out in 34 European countries, which showed that caregivers from *all* the countries - representing 29 languages of which 5 had non-Latin alphabets – spelled the term "Stridor" verbatim in all languages but Greek [**16**].

With two categories – "Fine" and "Coarse" – crackles can be defined as brief, non-musical, explosive, adventitious sounds [**17, 18**]. In this study, the Hebrew equivalent of "Crackles" was used just once, by a medical student. Of the other acceptable terms, "Crepitatziot" is solely an adaptation of "Crepitations", while "Hirhurim" is the classical Hebrew term for "Rales". It should be noted that both these terms are considered superfluous or inadequate: "Crepitations" because it merely means high-pitched crackling, and "Rales" because, as stated above, it was originally a generic term applied to every variety of adventitious pulmonary sound [1]. Incidentally, the accepted mechanism of production of fine crackles is not the presence of secretions in the airways, but the sudden opening of airways in deflated territories of the lung as observed in restrictive lung disorders (e.g. Interstitial Lung Disease) [**17-19**].

Of the presented sounds, the pleural friction rub is probably the less well-studied. Purportedly, it is produced by the sudden release of tangential tension in a superficial portion of the lung momentarily arrested in its sliding movement by a frictional force between the two pleurae [**18**]. The tiny group of observers who correctly classified this sound used 2 terms (vs. 4 terms in the English part of the survey [**11**]): pleural and friction, alone or in combination.

A novel information provided by this study is that poor skills in chest auscultation largely surpassed deficient language skills as a cause of incorrect lung sound classification. Of 90% of participants found to have good language skills, 50% had poor auscultation skills. Consistent with our previous study [11] this finding further illustrates the fact that the use of recommended terminology is meaningful only among observers with good auscultation skills. In fact, observer agreement on a wrong classification can be detrimental to the patients, as it may lead to unnecessary and expensive investigations as well as improper treatment [11].

Most of our staff physicians practiced medicine in both Hebrew and English. This aspect has clinical relevance. The ability of nonnative English-speaking doctors to communicate with patients in English is now considered a core-competency. Consistent with its status of global lingua franca, the English language is the universal means of communication between people with different native languages. In this context, ensuring the similarity of terminology between English and a LOTE is important, as language-concordant health care contributes to prevent expensive tests and poor patient follow-up.

To our knowledge, there is no research similar to this study that can provide data for comparison. Searching the literature, we found that the importance of the correct understanding of the original English terminology by caregivers working in a LOTE has been examined only peripherally. For instance, in a survey of seven European countries, lack of familiarity with the English nomenclature was invoked to explain the lower agreement of Russian and Dutch practitioners to classify crackles and wheezes from video-recordings [**20**]. Also, in the European terminology survey quoted above, the terms used across the countries were

generally non-uniform, some countries having their own terminology, others simply adopting the English terminology [**16**].

This study has limitations. First, for the sake of feasibility, we recruited caregivers from the same hospital, which may limit the generalisability of the findings. However, compensation was provided by their heterogeneity in terms of clinical and educational background. Second, we did not investigate all adventitious sounds. For simplicity, we stuck to the commonest ones, intentionally excluding more complex sounds such as, for instance, the rhonchus or the squawk, whose inclusion might have further hampered the observers' ability to classify the sounds. Finally, the experimental conditions were not representative of those in clinical practice. The study design prevented the participants to auscultate all over the chest, at will, or to command the respiratory maneuvers, which may have altered outcomes compared with real-life. However, to avoid more detrimental biases we were forced to standardize the study conditions across participants.

CONCLUSION

In this study, the Hebrew terms used to classify common lung sounds corresponded only partly to the recommended terminology. Many Hebrew terms were adaptations or transliterations of inappropriate English terms (e.g. "Vesicular sound", "Crepitations"). Noticeably, a high proportion of matched Hebrew/English terms was incorrect. These data support the conclusion that poor auscultation skills surpassed poor language skills as a factor hampering the meaningful transfer of the recommended terminology to a LOTE (Hebrew). In this context, improved education in chest auscultation should be the main prerequisite for the successful dissemination of the recommended terminology.

Based on our results, some suggestions can be made to encourage the widespread use of a standardised lung sound terminology in non-native English speaking countries. Countries with a high knowledge of English could simply adopt the recommended English terminology verbatim. Alternatively, countries with a lower knowledge of English could opt for the translation of the recommended terms by professionals skilled in both the source (English) and the target (LOTE) language. Finally, if resources for translation are not available, transliteration of the recommended terms seems a viable option. Adopted spontaneously by many observers in this study, transliteration requires no special language skills and can be performed in any language, including those with non-Latin alphabets. For its simplicity, it should be given consideration by the medical societies of all concerned countries.

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Table 1. Comparison Of Hebrew Terms With Recommended English Terms Used By Three Groups of Caregivers to Classify Five Lung Sounds

Audio sample	Recommended Terminology in the English Language	Hebrew Terms			Frequency of Use	
		Standard	Phonetic	English Meaning	n	By Group
# 1	Normal breath sound	נשימה נורמלית	Neshima normalit	Normal breathing	8	SP=1 R= 3; MS=4
		נשימה וסקולרית	Neshima vesicularit	*Vesicular breathing*[3]	2	SP=2
		נשימה בועית	Neshima buit	*"Alveolar" breathing*[3]	10	SP=3 R= 4; MS=3
# 2	Wheezes	צפצופים	Tziftzufim	Wheezes	116	SP=24 R=51 MS=41
# 3	Crackles	קריפיטציות	Crepitatziot	*Crepitations*[3]	42	SP=12 R=17 MS=13
		פיצפוצים	Pitzputzim	Crackles	1	MS=1
		פקעיים	Pkaim	*Fine Crepitations*[3]	1	MS=1
		חרחורים	Hirhurim	*Rales*	42	SP=5 R=22 MS=15
# 4	Stridor[1]	סטרידור[2]	Stridor	Stridor	110	SP=26 R=55 MS=29
# 5	Pleural friction rub[1]	שפשוף פלאורלי	Shifshuf pleurali	*Pleural rubbing*[3]	10	SP=8 R=1 MS=1
		פריקשן	Friction	Friction	1	R=1

1. Term suggested [ref # 2]
2. The correct term - **שִׁרְנוּק** (shirnuk) - was not used by any rater.
3. Term considered correct but nor recommended

SP= Staff physicians; R= Residents; MS= Medical students

Table 2: Language and Auscultation Skills Among Staff Physicians, Residents and Medical Students: English versus Terminology in LOTE

Sound Classification	Possible Number of Sessions of Sound Identification for All Observers (n=715)								
	Observers providing classification in the two languages (n=597)				Observers providing classification in one language only (n=90)				No classification in either language (n=28)
	Similar terms in the two languages (n=586)		Different terms in the two languages (n=11)		English (n=27)		Hebrew (n=63)		
	Both terms correct [1] (n=321)	Both terms Incorrect [2] (n=265)	English correct[3] (n=7)	Hebrew correct[3] (n=4)	Correct[3] (n=14)	Incorrect[4] (n=13)	Correct[3] (n=16)	Incorrect[4] (n=47)	
# 1 Normal	19 (5.9%)	106 (40.0%)	1	0	0	3	1	10	3
# 2 Wheeze	110 (34.3%)	19 (7.2%)	2	1	2	0	5	4	0
# 3 Crackle	77 (24.0%)	34 (12.8%)	2	3	4	2	6	8	7
# 4 Stridor	104 (32.4%)	17 (6.4%)	2	0	5	3	4	4	4
# 5 PFR	11 (3.4%)	89 (33.6%)	0	0	3	5	0	21	14

1. Dual-language skills *and* good auscultation skills. n=321 (46.7%)
2. Dual-language skills *and* poor auscultation skills n=265 (38.6%).
3. Single-language skills and good auscultation skills. n=41 (6.0%)
4. Poor language skills *and* poor auscultation skills. n=60 (8.7%)

e-Table 1. Incorrect Hebrew Terms Used by the Three Groups

Sound Sample	Standard Hebrew	Phonetic Hebrew	English Meaning	n	Repartition by group
#1 NBS	קריפיטציות	Crepitatziot	Crepitations	60	SP=10 R=37 MS=13
N=10	חרחורים	Hirhurim	Rales	32	SP=3 R=11 MS=18
	נשימה ברונכיאלית	Neshima bronchialit	Bronchial breathing	18	SP=8 R=6 MS=4
	אקספיריום מאורך	Expirium meorah	Prolonged expiration	1	MS=1
	ירידה עם חירחורים עדינים	Yerida im hirhurim adinim	Diminished with fine rales	1	MS=1
	שפשוף	Shifshuf	Friction	1	SP=1
	ציפצופים	Tziftzufim	Wheezes	1	MS=1
	שיפשוף פליאורלי	Shifshuf pleurali	Pleural friction	1	SP=1
	פיכפוך	Pichpuch	Bubbling	1	R=1
	רישרוש של פלוירה	Rishrush shel pleura	Pleural friction	1	SP=1
#2 Wheeze	סטרידור	Stridor	Stridor	4	SP=1 R=2 MS=1
N=11	חרחורים	Hirhurim	Rales	1	MS=1
	קרפיטציות	Crepitatziot	Crepitations	1	MS=1
	נשימה ברונכיאלית	Neshima bronchialit	Bronchial breathing	2	SP=1 R=1
	חיכוך פליאורלי	Chikuch pleurali	Pleural friction	1	SP=1
	אקספיריום מאורך	Expirium meorah	Prolonged expiration	8	SP=2 R=5 MS=1
	גניחות	Genihot	Groan	1	R=1
	אנחות	Anahot	Sigh	1	SP=1
	אוושה סיסטולית	Ivsha sistolit	Systolic murmur	4	R=3 MS=1
	מיוזיקלי	Musicali	Musical	1	R=1
	קולות ממקור עליון	Kolot mimakor elion	Sounds from upper source	1	MS=1
#3 Crackle	נשימה ברונכיאלית/תקינה	Neshima bronchialit tekina	Normal bronchial br.	19	SP=7 R=10 MS=2
N=10	נורמלי	Normali	Normal	6	SP=1 R=2 MS=3
	נחירות	Nehirot	Snoring	1	SP=1
	כניסת אוויר מופחתת	Knissat avir mufhetet	Diminished air entry	1	MS=1
	כניסת אוויר מופחתת,רשרו אקספירטורי	Knissat avir mufhetet im rishrush expiratoy	Diminished air entry with expiratory rustle	1	MS=1
	נשימה ברונכיאלית	Neshima bronchialit	Bronchial breathing	2	R=1 MS=1
	ציפצופים	Tziftzufim	Wheezes	2	R=1 MS=1
	נשימה בועית	Neshima buyit	Vesicular breathing	9	SP=3 R=3 MS=3
	כניסת אוויר ירודה	Knisat avir yeruda	Decrease air entry	2	R=1 MS=1
	אקספיריום מאורך	Expirium meorah	Prolonged expiration	1	R=1
#4 Stridor	ציפצופים	Tziftzufim	Wheezes	14	SP=1 R=5 MS=8
N=8	וויזינג	Wizing	Wheezing	1	MS=1
	השתנקות	Histankut	Gasping	1	MS=1
	שריקה	Shirika	Whistle/wheezing	1	MS=1
	דיבור	Dibur	Talk	1	MS=1
	ברונכוספאזם	Bronchospasm	Bronchospasm	1	MS=1
	מיוזיקל	Musical	Musical	1	R=1
	חריקה/שרנוק	Harika	Creak/Friction	1	MS=1
#5 PFR	ריילס	Rales	Rales	1	SP=1
N=10	קריפיטציות	Crepitatziot	Crepitations	13	SP=4 R=5 MS=4
	חרחורים	Hirhurim	Rales	78	SP=15 R=36 MS=27
	ירידה בכניסת אוויר	Yerida beknissat avir	Decrease air entry	1	MS=1
	ציפצופים	Tziftzufim	Wheezes	1	R=1
	נשימה ברונכיאלית	Neshima bronchialit	Bronchial breathing	12	R=9 MS=3
	שיפשוף פריקרדיאלי	Shifshuf pericardiali	Pericardial friction rub	1	MS=1
	פיכפוך	Pichpuch	Bubbling	1	R=1
	איוושה	Ivsha	Murmur	1	R=1
	גודש ריאתי	Godesh reiati	Pulmonary congestion	1	R=1

NBS: Normal breath sound; PFR: Pleural friction rub SP= Staff physicians; R= Residents; MS= Medical students

Influence of Language Skills on the Choice of Terms Used to Describe Lung Sounds in a Language Other Than English: A Cross-Sectional Survey of Staff Physicians, Residents and Medical Students

A. Bohadana et al.

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract **page 1**
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **page 2**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **page 4**
Objectives	3	State specific objectives, including any prespecified hypotheses **page 4**
Methods		
Study design	4	Present key elements of study design early in the paper **page 5**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **page 5**
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants **NA**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **NA**
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **NA**
Bias	9	Describe any efforts to address potential sources of bias **NA**
Study size	10	Explain how the study size was arrived at **NA**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **NA**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding **page 7**
		(*b*) Describe any methods used to examine subgroups and interactions **NA**
		(*c*) Explain how missing data were addressed **NA**
		(*d*) If applicable, describe analytical methods taking account of sampling strategy **NA**
		(*e*) Describe any sensitivity analyses **NA**
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed **NA**
		(b) Give reasons for non-participation at each stage **NA**
		(c) Consider use of a flow diagram **NA**
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders **NA**

		(b) Indicate number of participants with missing data for each variable of interest **NA**
Outcome data	15*	Report numbers of outcome events or summary measures **NA**
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included **NA**
		(*b*) Report category boundaries when continuous variables were categorized **NA**
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period **NA**
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses **NA**
Discussion		
Key results	18	Summarise key results with reference to study objectives **page 12**
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias **page 16**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence **page 15**
Generalisability	21	Discuss the generalisability (external validity) of the study results **page 15**
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based **page 18**

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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"Influence of Language Skills on the Choice of Terms Used to Describe Lung Sounds in a Language Other Than English: A Cross-Sectional Survey of Staff Physicians, Residents and Medical Students."

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Influence of Language Skills on the Choice of Terms Used to Describe Lung Sounds in a Language Other Than English: A Cross-Sectional Survey of Staff Physicians, Residents and Medical Students

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Abstract

Introduction: The value of chest auscultation would be enhanced by the use of a standardised terminology. To that end, the recommended English terminology must be transferred to a language other than English (LOTE) without distortion.

Objective: To examine the transfer to Hebrew – taken as a model of LOTE - of the recommended terminology in English.

Design/Setting: Cross-sectional study; university-based hospital.

Participants: 143 caregivers, including 31 staff physicians, 65 residents, and 47 medical students

Methods: Observers provided uninstructed descriptions in Hebrew and English of audio-recordings of 5 common sounds, namely, normal breath sound (NBS); wheezes; crackles; stridor and pleural friction rub (PFR).

Outcomes: a) Rates of correct/incorrect classification; b) Correspondence between Hebrew and recommended English terms; c) Language and auscultation skills, assessed by crossing the responses in the two languages with each other and with the classification of the audio-recordings validated by computer analysis.

Results: Range (%) of correct rating was as follows: NBS=11.3%-20%; Wheezes=79.7-87.2%; Crackles=58.6-69.8%; Stridor=67.4-96.3%; and PFR=2.7-28.6%. Of 60 Hebrew terms, 11 were correct and 5 matched the recommended English terms. Many Hebrew terms were adaptations or transliterations of inadequate English terms. Of 687 evaluations, good dual- and single-language skills were found in 586 (85.3%) and 41 (6%), respectively. However, in 325 (47.3%) evaluations good language skills were associated with poor auscultation skills.

Conclusion: Poor auscultation skills surpassed poor language skills as a factor hampering the transfer to Hebrew (LOTE) of the recommended English terminology. Improved education in auscultation emerged as the main factor to promote the use of standardised lung sound terminology. Using our data, a strategy was devised to encourage the use of standardised terminology in non-native English speaking countries.

Word count: 273

Key words: lung sound terminology; lung auscultation; observer variability; language skills; language other than English; LOTE

Strengths and Limitations of this Study

- To our knowledge, this is the first study to examine the transfer to LOTE of the recommended lung sound terminology in English.
- True sound classification was validated by computer-based sound analysis.
- Participants were from the same hospital – which tends to limit the study generalisability – but had different clinical and educational background.
- Use of more complex sounds (e.g. rhonchus, squawk) might have further hampered the observers' ability to classify the sounds.

INTRODUCTION

Lung auscultation has been a traditional part of the chest examination since the invention of the stethoscope [**1**]. Whilst no other method equals auscultation in providing quick, cost-effective, and easily obtained, relevant information about the respiratory system, its value is limited by the confused terminology [**2**]. Even though recommendations on terminology have been developed [**3-5**] significant variation in the terms used to describe the sounds persists among health professionals [**6-11**].

To examine this variation, we invited staff physicians, residents, and medical students working in a university-based hospital in Israel, to spontaneously classify a set of common lung sounds presented to them in audio-recordings. They were asked to classify the sounds successively in English and Hebrew, taken as a model of a language other than English (LOTE). Different aspects of the survey were highlighted in two companion papers. The first, published recently, found that poor auscultation skills were the main factor influencing the choice of English terminology [**11**]. The second, reported herein, examined the influence of language skills on the transfer to a LOTE (i.e. Hebrew) of the terminology recommended currently by scientific societies [**3-5**]. This aspect has practical importance. First, between-language differences hamper communication in teaching and in meaningful exchanges of auscultation findings between clinicians and researchers from different countries [**10**]. Moreover, they can cause divergent interpretations of the same sound even by caregivers from the same country. This study aimed to compare the Hebrew terms used by our observers, with those recommended currently [**3-5**] and with the English terms they used to classify the same sounds previously [**11**].

MATERIALS AND METHODS

Recruitment of the raters

From February 2017 through March 2018 we recruited 143 caregivers, including 31 staff physicians (SP), 65 residents (R) and 47 medical students (MS) working at Shaare Zedek Medical Center, affiliated with the Hebrew University of Jerusalem [11]. Participants were informed about the study by word-of-mouth. The "Helsinki Committee" at Shaare Zedek Medical Center approved this study with a waiver of informed consent.

Questionnaire

Upon arrival, participants were invited to complete an anonymous questionnaire on background information, including demographics, medical status, years of practice, and specialty. We avoided questions likely to facilitate participants' identification.

Presentation of the sounds

Next, the participants were invited to listen through loudspeakers to the audio-files of 5 common lung sounds stored in a computer placed in a silent room. The sound files were taken from a set of processed files in the **Movie.mp4** format, which were deemed to be clean and devoid of artifacts, as required for an article published previously [**2**]. The following sounds were presented, in that order: 1. Normal breath sound; 2. Wheezes; 3. Crackles; 4. Stridor and 5. Pleural Friction Rub.

Classification of the sound files

The observers were asked to classify the sounds successively in English and Hebrew in the order they were played (i.e. 1-5). No pre-established list of sound

nomenclature was given in either language, and the observers were asked to describe the sounds in a "free-form" format, with their own words. No sonograms, waveform analysis or clinical information were provided to substantiate the nature of the sounds. To attempt to compensate for the lack of clinical context, the observers were informed that all recordings started at the onset of inspiration. Additionally, the site of recording of each sound was indicated on a diagram, as follows: 1. Normal breath sound: posterior left basal lung region at a point situated in the scapular line, 3 cm below the angle of scapula; 2. Wheezes: anterior right upper lung zone at the intersection of the mid-clavicular line and the 2nd intercostal space; 3. Inspiratory crackles: right posterior basal region at the intersection of the scapular line and a point situated 3 cm below the angle of scapula; 4. Stridor: over the trachea, 2 cm above the supra-sternal notch; and 5. Pleural friction rub: left axillary region at the intersection of the mid-axillary line and the 5th intercostal space.

Correct versus Incorrect Sound Classification

The ability to correctly identify the sounds was determined for each sound file by comparing the observers' response with the true classification i.e. clinical classification validated by computer analysis [**2**]. In this process, an expert selected a segment of the recorded normal sounds that was free of artifacts. A rating was considered correct if a recommended term or an accepted synonym was used to describe the sound (term use ascribed to preference). The use of any incorrect term was ascribed to lack of skills on chest auscultation.

Language and Auscultation Skills

The ability to correctly classify the sounds depends both on language skills and auscultation skills. For each observer, we crossed the sound classification in

Hebrew with the corresponding classification English, performed previously by the same observers [**11**]. Four classes of combined skills were identified, as follows: *1.* Dual-language skills *and* good auscultation skills. Use of *accepted* terms in the two languages *to correctly* classify a sound (e.g. use of the English term "wheeze" and the Hebrew term "tziftzufim" to classify the wheezes of sound sample # 2). *2.* Dual-language skills *and* poor auscultation skills. Use of *accepted*, corresponding terms in the two languages to *incorrectly* classify a sound (e.g. use of the English term "pleural friction rub" and its *corresponding* Hebrew equivalent "shifshuf pleurali" to wrongly classify the wheezes of sound sample # 2). *3. Single-language skills and* good auscultation skills. Use of a *correct* term in one language and an *incorrect* (or no) term in the other language to correctly classify a sound (e.g. use of the English term wheeze coupled with, say, the *incorrect* Hebrew term "hirhurim" to classify the wheezes of sound sample # 2}. *4.* Poor language skills *and* poor auscultation skills. Use of different, incorrect terms in the two languages to classify a sound (e.g. use of "crackle" and "shifshuf pleurali" to classify the wheezes of sound sample # 2).

Patient and Public Involvement

Patients or the public were not involved in the design, conduct, reporting or dissemination of this study.

Data Analysis

Baseline characteristics are presented as mean (SD) and proportions. For each audio sample, the difference in the proportion of correct vs. incorrect rating was tested using the Chi square test; a $p < 0.05$ was considered significant.

RESULTS

Characteristics of participants

Participants' mean (SD) age was as follows: SP= 48.4 yrs. (10.4); R=32.5 yrs. (3.5), and MS=28.4 yrs. (4.5). Overall, 17 (54.8%) staff physicians declared more than 20-year experience with auscultation; in turn, 60 (92%) residents and 47 (100%) medical students declared < 5-year experience.

Language profile and specialty of staff physicians

The first language of 27 SPs who provided responses to this question were: Hebrew, n=16, English, n=4, Arabic, n=2, French, n=2, Russian, n=2, and Portuguese, n=1. All respondents reported the learning of unspecified versions of the lung sound terminology in English and Hebrew (n=23). The repartition by specialty was as follows: Pulmonology, n=7; Pediatrics, n=6; Internal Medicine, n=4; Cardiology, n=2; Oncology, n=2; Geriatrics, n=1; Hematology, n=1; Emergency medicine, n=1; Rheumatology, n=1; Palliative care, n=1 and Family medicine, n=1. Twenty four SPs practiced medicine in both English and Hebrew, while 3 practiced only in Hebrew.

Correct Hebrew Terms versus Recommended English Terminology

Table 1 lists (i) the standard and phonetic forms of the *correct* Hebrew terms used by the three groups; (ii) their meaning in English; and (iii) the corresponding recommended English terminology. Overall, the rates of correct identification were high for the wheeze (SP=80%; R=79.7%; MS=87.2%; [p=.944]) and the stridor (SP=96.3%; R=90.2%; MS=67.4%; [p=.544]), fair for the crackles (SP=58.6%; R=67.2%; MS=69.8%; [p=.899]) and low for the normal lung sound (SP=20%;

R=11.3%; MS=15.5%; [p=.624]) and the pleural friction rub (SP=28.6%; R=3.6%; MS=2.7% [p=.002]).

Preference versus Poor Auscultation Skill

Altogether, the observers used 60 Hebrew terms to classify the 5 sounds; of these 11 (18.3%) were correct, being therefore ascribed to preferences regarding terminology, while 49 (81.7%) were incorrect, being ascribed to lack of chest auscultation skills.

Correct terms by group

Sample sound #1 (*Normal breath sound*): Of **137** participants classifying this file, 20 correctly classified it as normal. Of 3 Hebrew terms used, only 1 corresponded to the recommended English term "normal breath sound".

Sample sound # 2 (*Wheezes*): Of **141** participants classifying this file, 116 (82.3%) used a single Hebrew term - "Tziftzufim" - corresponding to the recommended English term "Wheeze".

Sample sound # 3 (*Crackles*): Of **130** participants classifying this file, 86 (66.2%) used 4 Hebrew terms to correctly classify it as crackles. However, only 1 term – "Pitzputzim" - corresponded to the recommended English term crackle.

Sample sound # 4 (*Stridor*): Of **131** participants classifying this sound, 110 (84%) correctly classified it by means of a Hebrew transliteration of the recommended English term "stridor".

Sample sound # 5 (*Pleural friction rub*): Of **121** participants classifying this sample, 11 (9.1%) correctly classified it as pleural friction rub. They used 2 terms, of which "Shifshuf Pleurali", meaning "Pleural rubbing", was used on 10 occasions.

Incorrect Hebrew Terms

The 49 incorrect Hebrew terms are listed in the **e-Table 1**. Of these, 10 were used to classify the normal breath sound, 11 to classify the wheezes, 10 to classify the crackles, 8 to classify the stridor, and 10 to classify the pleural friction rub.

Transfer to Hebrew of the English Terminology

Identification of 5 sounds by 143 subjects would have resulted in 715 instances of identification. However, on 28 occasions the observers declined to classify a sound in either language, thus giving a total of 687 (96%) instances of sound identification. On 597 (87%) of these occasions, the observers provided terms in the two languages for all sounds, while on 90 (12.9%) they provided terms in one language only. The combination of language skills and auscultation skills, obtained by crossing the correct and incorrect responses in the 687 sessions, is given in detail in **Table 2**. The resulting combination of language skills and auscultation skills was a follows:

1. Dual-language skills *and* good auscultation skills. n=321 (46.7%)

2. Dual-language skills *and* poor auscultation skills n=265 (38.6%).

3. Single-language skills and good auscultation skills. n=41 (6.0%)

4. Poor language skills *and* poor auscultation skills. n=60 (8.7%)

DISCUSSION

In his original work, Laennec used the terms “rale” and “rhonchus” interchangeably, to denote all classes of adventitious sounds [**1**]. Successive translations — first into English, then into other languages — and redefinitions of the original terminology gave different meanings to these terms, starting a confusion that persists to this day. To overcome this drawback, recommendations for use of a standardised terminology in the English language were made by the *Ad Hoc* committees of scientific societies [**3-5**]. The recommended terms — simple and precise — are based on the physics of the sounds, without assumptions about their mechanism of generation or site of production **[3-5].** In a population of caregivers working in Israel, we compared the Hebrew terms used to classify 5 common sounds with: (a) the recommended terminology in English and; (b) the terms used by the same caregivers to classify the same sounds in the English language.

In similarity with our companion study [11] the observers’ ability to classify the sounds in Hebrew was high for the wheezes and the stridor, fair for the crackles, and low for the normal breath sounds and the pleural friction rub, with the three groups of caregivers performing similarly in classifying all sounds. Even though the staff physicians performed better than the other groups in classifying the pleural friction rub, the overall performance of the three groups was too low to be considered clinically meaningful. This similarity of performance regarding the two languages is interesting, because, in theory, one could expect the caregivers to perform better in their working language - Hebrew - than in English.

Of 3 correct Hebrew terms used to classify sound file # 1, just one corresponded to the recommended term “Normal breath sound” in English. The other two, “Vesiculari” and “Buyit” — meaning respectively “Vesicular” and “Alveolar” — are deemed inappropriate as they convey the incorrect assumption that the normal sound originates from the *entrance of air into and out of the air-cells of the lungs* [**1**]. As a quick aside, although the *exact* locale and mode of production of the normal breath sound has not been established, there is evidence to support the view that it has a double origin: the lobar and segmental airways for the inspiratory component, and a more central source for the expiratory component [**12, 13**]

Consistent with our previous study [**11**] all observers used the classic Hebrew term “Tziftzufim” to classify the wheezes. This homogeneous description is interesting. Indeed, the term “Wheezing” has been in use long before Laennec’s invention of the stethoscope, while “Wheeze”, as used nowadays, corresponds to the “Rale sibilant sec” described by Laennec [**14**]. We speculate that the traditional attribution of this sound to a single mechanism – airway obstruction – might have contributed for the use of a single term to describe it. Consequently, the translation from the source language (i.e. English) to other languages was kept relatively uniform, as found in the present study.

The term “Stridor” — from the Latin ***stridere*** (harsh, shrill or creaking noise) — describes the high-pitched, musical sound produced by turbulent flow passing through a narrowed segment of the upper respiratory tract [**15**]. In similarity with the classification of the wheezes, all correct raters used a single term. However, instead of the Hebrew term “שִׁרְנוּק” (“Shirnuk”) they used the term “Stridor” itself, spelled in the Hebrew alphabet. This peculiar choice suggests that, rather than

searching for a suitable terminology, the caregivers preferred a term familiar to them. This finding is similar to that reported in a recent survey of lung sound nomenclature carried out in 34 European countries, which showed that caregivers from *all* the countries - representing 29 languages of which 5 had non-Latin alphabets – spelled the term "Stridor" verbatim in all languages but Greek [**16**].

With two categories – "Fine" and "Coarse" – crackles can be defined as brief, non-musical, explosive, adventitious sounds [**17, 18**]. In this study, the Hebrew equivalent of "Crackles" was used just once, by a medical student. Of the other acceptable terms, "Crepitatziot" is solely an adaptation of "Crepitations", while "Hirhurim" is the classical Hebrew term for "Rales". It should be noted that both these terms are considered superfluous or inadequate: "Crepitations" because it merely means high-pitched crackling, and "Rales" because, as stated above, it was originally a generic term applied to every variety of adventitious pulmonary sound [1]. Incidentally, the accepted mechanism of production of fine crackles is not the presence of secretions in the airways, but the sudden opening of airways in deflated territories of the lung as observed in restrictive lung disorders (e.g. Interstitial Lung Disease) [**17-19**].

Of the presented sounds, the pleural friction rub is probably the less well-studied. Purportedly, it is produced by the sudden release of tangential tension in a superficial portion of the lung momentarily arrested in its sliding movement by a frictional force between the two pleurae [**18**]. The tiny group of observers who correctly classified this sound used 2 terms (vs. 4 terms in the English part of the survey [**11**]): pleural and friction, alone or in combination.

A novel information provided by this study is that poor skills in chest auscultation largely surpassed deficient language skills as a cause of incorrect lung sound classification. Of 90% of participants found to have good language skills, 50% had poor auscultation skills. Consistent with our previous study [11] this finding further illustrates the fact that the use of recommended terminology is meaningful only among observers with good auscultation skills. In fact, observer agreement on a wrong classification can be detrimental to the patients, as it may lead to unnecessary and expensive investigations as well as improper treatment [11].

Most of our staff physicians practiced medicine in both Hebrew and English. This aspect has clinical relevance. The ability of nonnative English-speaking doctors to communicate with patients in English is now considered a core-competency. Consistent with its status of global lingua franca, the English language is the universal means of communication between people with different native languages. In this context, ensuring the similarity of terminology between English and a LOTE is important, as language-concordant health care contributes to prevent expensive tests and poor patient follow-up.

To our knowledge, there is no research similar to this study that can provide data for comparison. Searching the literature, we found that the importance of the correct understanding of the original English terminology by caregivers working in a LOTE has been examined only peripherally. For instance, in a survey of seven European countries, lack of familiarity with the English nomenclature was invoked to explain the lower agreement of Russian and Dutch practitioners to classify crackles and wheezes from video-recordings [**20**]. Also, in the European terminology survey quoted above, the terms used across the countries were

generally non-uniform, some countries having their own terminology, others simply adopting the English terminology [**16**].

This study has limitations. First, for the sake of feasibility, we recruited caregivers from the same hospital, which may limit the generalisability of the findings. However, compensation was provided by their heterogeneity in terms of clinical and educational background. Second, we did not investigate all adventitious sounds. For simplicity, we stuck to the commonest ones, intentionally excluding more complex sounds such as, for instance, the rhonchus or the squawk, whose inclusion might have further hampered the observers' ability to classify the sounds. Finally, the experimental conditions were not representative of those in clinical practice. The study design prevented the participants to auscultate all over the chest, at will, or to command the respiratory maneuvers, which may have altered outcomes compared with real-life. However, to avoid more detrimental biases we were forced to standardize the study conditions across participants.

CONCLUSION

In this study, the Hebrew terms used to classify common lung sounds corresponded only partly to the recommended terminology. Many Hebrew terms were adaptations or transliterations of inappropriate English terms (e.g. "Vesicular sound", "Crepitations"). Noticeably, a high proportion of matched Hebrew/English terms was incorrect. These data support the conclusion that poor auscultation skills surpassed poor language skills as a factor hampering the meaningful transfer of the recommended terminology to a LOTE (Hebrew). In this context, improved education in chest auscultation should be the main prerequisite for the successful dissemination of the recommended terminology.

Based on our results, some suggestions can be made to encourage the widespread use of a standardised lung sound terminology in non-native English speaking countries. Countries with a high knowledge of English could simply adopt the recommended English terminology verbatim. Alternatively, countries with a lower knowledge of English could opt for the translation of the recommended terms by professionals skilled in both the source (English) and the target (LOTE) language. Finally, if resources for translation are not available, transliteration of the recommended terms seems a viable option. Adopted spontaneously by many observers in this study, transliteration requires no special language skills and can be performed in any language, including those with non-Latin alphabets. For its simplicity, it should be given consideration by the medical societies of all concerned countries.

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Data availability statement: All participant-level data relevant to the study are included in the article or uploaded as supplementary information. The study data are available from the corresponding author upon reasonable request, after removal of all personal identifiers.

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Table 1. Comparison Of Hebrew Terms With Recommended English Terms Used By Three Groups of Caregivers to Classify Five Lung Sounds

Audio sample	Recommended Terminology in the English Language	Hebrew Terms			Frequency of Use	
		Standard	Phonetic	English Meaning	n	By Group
# 1	Normal breath sound	נשימה נורמלית	Neshima normalit	Normal breathing	8	SP=1 R= 3; MS=4
		נשימה וסקולרית	Neshima vesicularit	*Vesicular breathing*[3]	2	SP=2
		נשימה בועית	Neshima buit	*"Alveolar" breathing*[3]	10	SP=3 R= 4; MS=3
# 2	Wheezes	צפצופים	Tziftzufim	Wheezes	116	SP=24 R=51 MS=41
# 3	Crackles	קריפיטציות	Crepitatziot	*Crepitations*[3]	42	SP=12 R=17 MS=13
		פיצפוצים	Pitzputzim	Crackles	1	MS=1
		פקעיים	Pkaim	*Fine Crepitations*[3]	1	MS=1
		חרחורים	Hirhurim	*Rales*	42	SP=5 R=22 MS=15
# 4	Stridor[1]	סטרידור[2]	Stridor	Stridor	110	SP=26 R=55 MS=29
# 5	Pleural friction rub[1]	שפשוף פלאורלי	Shifshuf pleurali	*Pleural rubbing*[3]	10	SP=8 R=1 MS=1
		פריקשן	Friction	Friction	1	R=1

1. Term suggested [ref # 2]
2. The correct term - **שִׁרְנוּק** (shirnuk) - was not used by any rater.
3. Term considered correct but nor recommended

SP= Staff physicians; R= Residents; MS= Medical students

Table 2: Language and Auscultation Skills Among Staff Physicians, Residents and Medical Students: English versus Terminology in LOTE

Sound Classification	Possible Number of Sessions of Sound Identification for All Observers (n=745)								
	Observers providing classification in the two languages (n=597)				Observers providing classification in one language only (n=90)				No classification in either language (n=28)
	Similar terms in the two languages (n=586)		Different terms in the two languages (n=11)		English (n=27)		Hebrew (n=63)		
	Both terms correct [1] (n=321)	Both terms Incorrect [2] (n=265)	English correct[3] (n=7)	Hebrew correct[3] (n=4)	Correct[3] (n=14)	Incorrect[4] (n=13)	Correct[3] (n=16)	Incorrect[4] (n=47)	
# 1 Normal	19 (5.9%)	106 (40.0%)	1	0	0	3	1	10	3
# 2 Wheeze	110 (34.3%)	19 (7.2%)	2	1	2	0	5	4	0
# 3 Crackle	77 (24.0%)	34 (12.8%)	2	3	4	2	6	8	7
# 4 Stridor	104 (32.4%)	17 (6.4%)	2	0	5	3	4	4	4
# 5 PFR	11 (3.4%)	89 (33.6%)	0	0	3	5	0	21	14

1. Dual-language skills *and* good auscultation skills. n=321 (46.7%)
2. Dual-language skills *and* poor auscultation skills n=265 (38.6%).
3. Single-language skills and good auscultation skills. n=41 (6.0%)
4. Poor language skills *and* poor auscultation skills. n=60 (8.7%)

e-Table 1. Incorrect Hebrew Terms Used by the Three Groups

Sound Sample	Standard Hebrew	Phonetic Hebrew	English Meaning	n	Repartition by group
#1 NBS	קריפיטציות	Crepitatziot	Crepitations	60	SP=10 R=37 MS=13
N=10	חרחורים	Hirhurim	Rales	32	SP=3 R=11 MS=18
	נשימה ברונכיאלית	Neshima bron**ch**ialit	Bronchial breathing	18	SP=8 R=6 MS=4
	אקספיריום מאורך	Expirium meorah	Prolonged expiration	1	MS=1
	ירידה עם חירחורים עדינים	Yerida im hirhurim adinim	Diminished with fine rales	1	MS=1
	שפשוף	Shifshuf	Friction	1	SP=1
	ציפצופים	Tziftzufim	Wheezes	1	MS=1
	שיפשוף פליאורלי	Shifshuf pleurali	Pleural friction	1	SP=1
	פיכפוך	Pichpuch	Bubbling	1	R=1
	רישרוש של פלוירה	Rishrush shel pleura	Pleural friction	1	SP=1
#2 Wheeze	סטרידור	Stridor	Stridor	4	SP=1 R=2 MS=1
N=11	חרחורים	Hirhurim	Rales	1	MS=1
	קרפיטציות	Crepitatziot	Crepitations	1	MS=1
	נשימה ברונכיאלית	Neshima bronchialit	Bronchial breathing	2	SP=1 R=1
	חיכוך פליאורלי	Chikuch pleurali	Pleural friction	1	SP=1
	אקספיריום מאורך	Expirium meorah	Prolonged expiration	8	SP=2 R=5 MS=1
	גניחות	Genihot	Groan	1	R=1
	אנחות	Anahot	Sigh	1	SP=1
	אוושה סיסטולית	Ivsha sistolit	Systolic murmur	4	R=3 MS=1
	מיוזיקלי	Musicali	Musical	1	R=1
	קולות ממקור עליון	Kolot mimakor elion	Sounds from upper source	1	MS=1
#3 Crackle	נשימה ברונכיאלית/תקינה	Neshima bronchialit tekina	Normal bronchial br.	19	SP=7 R=10 MS=2
N=10	נורמלי	Normali	Normal	6	SP=1 R=2 MS=3
	נחירות	Nehirot	Snoring	1	SP=1
	כניסת אוויר מופחתת	Knissat avir mufhetet	Diminished air entry	1	MS=1
	כניסת אוויר מופחתת,רשרו אקספירטורי	Knissat avir mufhetet im rishrush expiratoy	Diminished air entry with expiratory rustle	1	MS=1
	נשימה ברונכיאלית	Neshima bronchialit	Bronchial breathing	2	R=1 MS=1
	ציפצופים	Tziftzufim	Wheezes	2	R=1 MS=1
	נשימה בועית	Neshima buyit	Vesicular breathing	9	SP=3 R=3 MS=3
	כניסת אוויר ירודה	Knisat avir yeruda	Decrease air entry	2	R=1 MS=1
	אקספיריום מאורך	Expirium meorah	Prolonged expiration	1	R=1
#4 Stridor	ציפצופים	Tziftzufim	Wheezes	14	SP=1 R=5 MS=8
N=8	וויזינג	Wizing	Wheezing	1	MS=1
	השתנקות	Histankut	Gasping	1	MS=1
	שריקה	Shirika	Whistle/wheezing	1	MS=1
	דיבור	Dibur	Talk	1	MS=1
	ברונכוספאזם	Bronchospasm	Bronchospasm	1	MS=1
	מיוזיקל	Musical	Musical	1	R=1
	חריקה/שרנוק	Harika	Creak/Friction	1	MS=1
#5 PFR	ריילס	Rales	Rales	1	SP=1
N=10	קריפיטציות	Crepitatziot	Crepitations	13	SP=4 R=5 MS=4
	חרחורים	Hirhurim	Rales	78	SP=15 R=36 MS=27
	ירידה בכניסת אוויר	Yerida beknissat avir	Decrease air entry	1	MS=1
	ציפצופים	Tziftzufim	Wheezes	1	R=1
	נשימה ברונכיאלית	Neshima bronchialit	Bronchial breathing	12	R=9 MS=3
	שיפשוף פריקרדיאלי	Shifshuf pericardiali	Pericardial friction rub	1	MS=1
	פיכפוך	Pichpuch	Bubbling	1	R=1
	איוושה	Ivsha	Murmur	1	R=1
	גודש ריאתי	Godesh reiati	Pulmonary congestion	1	R=1

NBS: Normal breath sound; PFR: Pleural friction rub SP= Staff physicians; R= Residents; MS= Medical students