Received: 1 June 2016 | Revised: 19 July 2016 | Accepted: 1 August 2016
DOI 10.1002/clc.22586

WILEY CLINICAL CARDIOLOGY

CLINICAL INVESTIGATIONS

Assessment of Respiratory Distress by the Roth Score

Ehud Chorin MD, PhD | Allison Padegimas MD | Ofer Havakuk MD | Edo Y. Birati MD | Yacov Shacham MD | Anat Milman MD | Guy Topaz MD | Nir Flint MD | Gad Keren MD | Ori Rogowski MD

Department of Cardiology (Chorin, Havakuk, Birati, Shacham, Milman, Topaz, Flint, Keren) and Department of Internal Medicine "C" (Rogowski), Tel Aviv Sourasky Medical Center and Sackler School of Medicine, Tel Aviv University, Tel Aviv, Israel; Department of Internal Medicine (Padegimas, Birati) and Division of Cardiovascular Medicine (Birati), Perelman School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania

Corresponding Author: Ehud Chorin, MD, PhD, Department of Cardiology, Tel Aviv Sourasky Medical Center, 6 Weizman Street, Tel Aviv 6423906, Israel (udichorin5@gmail.com)

Introduction: Health care demand is increasing due to greater longevity of patients with chronic comorbidities. This increasing demand is occurring in a setting of resource scarcity. To address these changes, high-value care initiatives, such as telemedicine, are valuable resource-preservation strategies. This study introduces the Roth score as a telemedicine tool that uses patient counting times to accurately risk-stratify dyspnea severity in terms of hypoxia.

Hypothesis: The Roth score has correlation with dyspnea severity.

Methods: This is a prospective, controlled-cohort study. Roth score index is measured by having the patient count from 1 to 30 in their native language, in a single breath, as rapidly as possible. The primary result of the Roth score is the duration of time and the highest number reached.

Results: There was a strongly positive correlation between pulse oximetry and both maximal count achieved in 1 breath ($r = 0.67$; $P < 0.001$) and counting time ($r = 0.59$; $P < 0.001$). For oxygen saturation <95%, the maximal count number area under the curve is 0.828 and counting time area under the curve is 0.764. Counting time >8 seconds had a sensitivity of 78% and specificity of 73% for pulse oximetry <95%.

Conclusions: The Roth score has strong correlation with dyspnea severity as determined by hypoxia. This tool is reproducible, low resource-utilization, and amenable to telemedicine. It is not intended to replace full clinical workup and diagnosis of respiratory distress, but it is useful in risk-stratifying severity of dyspnea that warrants further clinical evaluation.

KEYWORDS

Respiratory Distress, telemedicine, hypoxia

1 | INTRODUCTION

The current health care economy has become increasingly reliant on high-value care as a necessary strategy to deal with resource scarcity and increasing patient demand. In this health care landscape of cost containment, telemedicine is an optimal tool that is both cost-effective and resource-sparing. Telemedicine is defined as the use of electronic information and communication technologies to provide health care when the caregiver and patient are geographically distanced.[1] Successful telemedicine requires objective evaluation of disease symptomatology that is achievable via electronic communication in a discreet manner that is correlated with clinical status.[2,3]

This study focuses on the characterization of dyspnea. Dyspnea has been correlated with worsening clinical status in several cardiopulmonary diseases; however, its evaluation has remained multifaceted, with no single objective measurement to triage severity classification.[4,5] Recent systematic reviews[6,7] have concluded that even the data that physicians routinely depend on to assess dyspnea (respiratory rate, use of accessory muscles, arterial blood saturation) cannot be regarded as a gold standard for achieving accurate, comprehensive assessment of dyspnea. This study introduces an index called the Roth score as a tool that uses patient counting times to accurately risk-stratify dyspnea severity in terms of hypoxia.

E.Y.B. has received research support from HeartWare Ltd.

Furthermore, this tool is amenable to telemedicine application and may aid in high-value care management of patients with chronic cardiopulmonary comorbidities.

2 | METHODS

2.1 | Study Population

The study cohort consisted of patients admitted to the internal medicine service or the cardiac intensive care unit at the Tel Aviv Sourasky Medical Center (Tel Aviv, Israel) between January 2014 and April 2015. Inclusion criteria included pulse oximetry on room air requiring 2 L to 6 L nasal cannula oxygen to maintain oxygen saturation >92%. Exclusion criteria included hypoxia requiring advanced noninvasive or invasive oxygenation. The control group consisted of healthy volunteers; control-group exclusion criteria included any present chronic or acute illness. The control group was used to generate a normal range of the score in 5 common languages.

2.2 | The Roth Score

Dr. Arie Roth, to whom this study is dedicated, was the director of the cardiac intensive care unit at the Tel Aviv Sourasky Medical Center and a professor of cardiology in the Sackler Faculty of Medicine, University of Tel Aviv. Dr. Roth mentored generations of cardiologists in Israel. This score is measured by requesting that the patients take a deep breath followed by counting out loud from 1 to 30 in their native language, in a single breath, as rapidly as possible. The time duration was measured on a stopwatch in seconds from number 1 until the highest number reached. The test was repeated after the subject had taken 3 deep breaths. The result of the Roth score includes 2 measurements: (1) the duration of time elapsed between counting from 1 to 30 in 1 breath, or until the patient took another breath; and (2) the highest number reached in 1 breath. The subjects' respiratory rate and pulse oximetry on room air were recorded as markers of respiratory distress to evaluate for correlation with their Roth scores.

2.3 | Statistical Analysis

All data are summarized and displayed as mean ± SD for continuous variables and as number (percentage) of patients in each group for categorical variables. All categorical variables were analyzed by χ^2 and Fisher exact tests. Continuous variables were compared using independent sample *t* test. Score index specificity and sensitivity were analyzed using receiver operating characteristic (ROC) curve.

3 | RESULTS

3.1 | Baseline Patient Characteristics

Demographic data, clinical characteristics, and comorbidities of the study population are shown in Table 1. The patient group consists of 93 individuals (53 males and 40 females) with mean age of 76 ± 13 years. Themost common admission diagnoses were congestive heart failure exacerbation (25%), pneumonia (17%), and acute coronary syndrome (15%); other diagnoses included pulmonary embolism, asthma, upper respiratory infection, and chronic obstructive pulmonary disease (Table 1).

TABLE 1 Baseline Patient Characteristics (N = 93)

Variable	Value
Mean age, y	76 ± 13
Female sex	40 (43)
Comorbidities	
HTN	78 (85)
Dyslipidemia	72 (77)
DM	39 (42)
Current smoker	13 (14)
Past smoker	33 (36)
AF	26 (28)
Previous PCI	48 (52)
Prior CABG	15 (16)
COPD	18 (19)
Hospitalization etiology	
CHF exacerbation	23 (25)
Pneumonia	16 (17)
ACS	14 (15)
COPD exacerbation	6 (6)
Upper respiratory infection	6 (6)
Others	28 (30)

Abbreviations: ACS, acute coronary syndrome; AF, atrial fibrillation; CABG, coronary artery bypass graft surgery; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; DM, diabetes mellitus; HTN, hypertension; PCI, percutaneous coronary intervention; SD, standard deviation.

Data are presented as n (%) or mean ± SD.

The study control group was used to generate a normal range of the score in Hebrew, Arabic, Russian, French, and English. The study control group included 103 healthy volunteers (64 males and 39 females) with mean age of 56 ± 18 years.

3.2 | Correlation Between the Room-Air Pulse Oximetry and Roth Score

There is a positive strong correlation between the pulse oximetry measurement on room air and both the maximal count achieved in 1 breath ($r = 0.67$; $P < 0.001$) and the counting time ($r = 0.59$; $P < 0.001$; Figure 1). All individuals in the control group counted to at least 15 in 1 breath, and 97 (94%) counted to at least 20 (not shown).

3.3 | Sensitivity and Specificity for Maximal Count and Count Time

To evaluate the predictive value of the counting time and the maximal number reached on dyspnea (as characterized by room-air pulse oximetry), we constructed an ROC curve with room-air saturation as the primary variable (Table 2 and Figure 2). For identifying oxygen

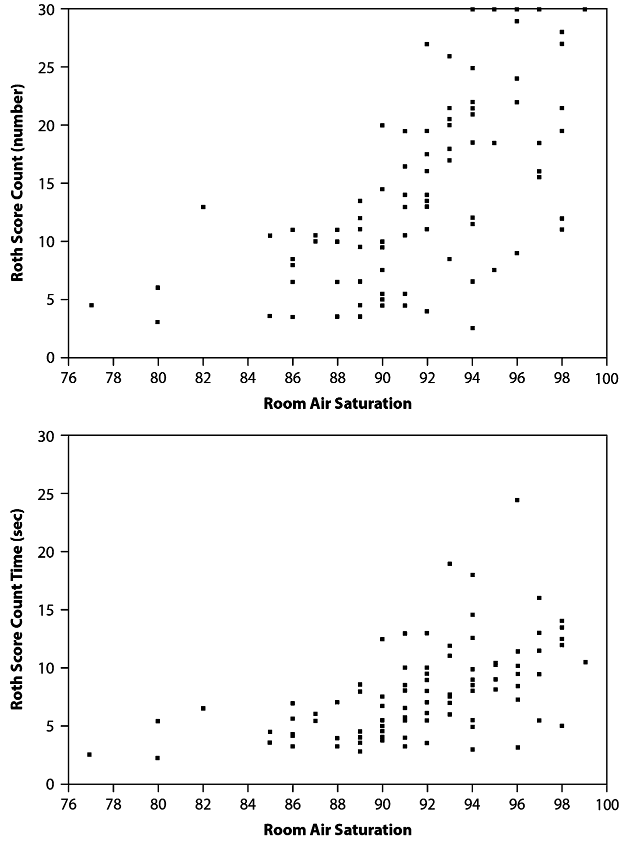

FIGURE 1 The correlation between the pulse oximetry measurement on room air and both the maximal count achieved in 1 breath and the counting time. Abbreviations: sec, seconds.

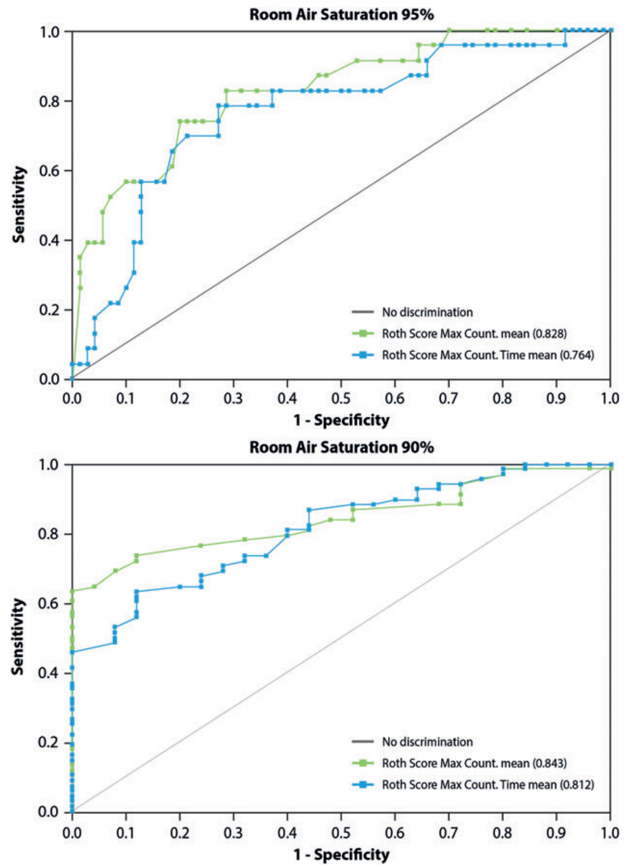

FIGURE 2 The ROC curve with room-air saturation as the primary variable to evaluate the predictive value of the counting time and the maximal number reached on dyspnea (as characterized by room-air pulse oximetry). Abbreviations: max, maximum; ROC, receiver operating characteristic.

TABLE 2 Sensitivity and Specificity for Maximal Count and Count Time

	Room Air <95%		Room Air <90%	
	Sensitivity, %	Specificity, %	Sensitivity, %	Specificity, %
Max count				
7	100	30	87	48
10	91	43	78	68
15	83	71	57	100
20	57	87	32	100
Count time, sec				
5	91	34	82	56
6	83	49	71	72
7	83	63	63	88
8	78	71	53	92
9	65	81	41	100
10	57	87		
11	39	89		
12	26	90		
13	17	96		

Abbreviations: max, maximum; sec, seconds.

saturation <95%, the maximal count number's area under the curve (AUC) is 0.828 and the counting time's AUC is 0.764. Counting time >8 seconds had a sensitivity of 78% and specificity of 71% for identifying a room-air pulse oximetry <95%. For identifying oxygen saturation <90%, the AUC for maximal count number is 0.843 and for count time is 0.812 (Table 2).

4 | DISCUSSION

The 2012 American Thoracic Society Consensus Statement on Dyspnea states that dyspnea, a condition they found present in 50% of patients admitted to tertiary-care hospitals, "is a potent predictor of mortality, often surpassing common physiological measurements in predicting the clinical course of a patient."[9] Historically, the evaluation of dyspnea has remained multifaceted, but this study introduces a tool that can be used for initial risk stratification of dyspnea severity using a single test measurement that is achievable in a patient's hospital room or by telemedicine. Both the Roth score maximum count number in 1 breath and the time measurement of time to count to 30 (or duration of a single breath) show ROC curves that have clinically useful discrimination for pulse oximetry at different cutoffs (<95%, <90%). The Roth score is based on both counting time and counting number, because counting rate may change depending on patient age, culture, sex, emotional state, fluency, and profession. The results of the current study support the use of the Roth score in identifying patients at risk of having higher-severity dyspnea and needing further evaluation. Maximal counting number <10 or counting time

<7 seconds identified patients with a room-air pulse oximetry <95% with sensitivity of 91% and 83%, respectively. Maximal counting number <7 or counting time <5 seconds identified patients with a room-air pulse oximetry <90% with sensitivity of 87% and 82%, respectively.

This quick and accurate surrogate for discerning the presence of hypoxia in a dyspneic patient is novel in that, unlike other clinical characterizations of dyspnea, the Roth score is easily accomplishable by a non–health care professional in the residential setting. This index makes it possible to use telemedicine to evaluate dyspnea, which was not feasible with other characterizations of dyspnea such as pulse oximetry, presence of accessory muscle use, or arterial blood gas measurement. This resource-sparing evaluation of a symptom that is common among several cardiopulmonary disease states that affect many patients may increase out-of-hospital triaging of initial patient management.

4.1 | Study Limitations

The test is patient effort–dependent, hypoxia is only one element of dyspnea, and we do not have information on other defining elements of disease-state severity to further validate this tool. Future studies might research specific comorbidities more extensively to correlate the Roth score with overall disease severity as measured by several variables in addition to hypoxia. This method is not intended to replace more advanced testing in diagnosing respiratory distress or etiology of dyspnea; rather, its use is most applicable in identifying patients at risk of having higher-severity dyspnea and needing further evaluation.

5 | CONCLUSION

In this era of increasing health care costs, the use of a low-resource accurate triaging tool like the Roth score represents optimal high-value care.

6 | CONFLICTS OF INTEREST

The authors have no other funding, financial relationships, or conflicts of interest to disclose.

REFERENCES

1. Field MJ, Grigsby J. Telemedicine and remote patient monitoring. *JAMA*. 2002;288:423–425.
2. Bui AL, Fonarow GC. Home monitoring for heart failure management. *J Am Coll Cardiol*. 2012;59:97–104.
3. Bruderman I, Abboud S. Telespirometry: novel system for home monitoring of asthmatic patients. *Telemed J*. 1997;3:127–133.
4. Finkelstein J, O'Connor G, Friedmann RH. Development and implementation of the home asthma telemonitoring (HAT) system to facilitate asthma self-care. *Stud Health Technol Inform*. 2001;84(part 1):810–814.
5. Finkelstein J, Hripcsak G, Cabrera M. Telematic system for monitoring of asthma severity in patients' homes. *Stud Health Technol Inform*. 1998;52 (part 1):272–276.
6. Bausewein C, Farquhar M, Booth S, et al. Measurement of breathlessness in advanced disease: a systematic review. *Respir Med*. 2007;101:399–410.
7. Dorman S, Byrne A, Edwards A. Which measurement scales should we use to measure breathlessness in palliative care? A systematic review. *Palliat Med*. 2007;21:177–191.
8. Rector TS, Cohn JN; Pimobendan Multicenter Research Group. Assessment of patient outcome with the Minnesota Living with Heart Failure questionnaire: reliability and validity during a randomized, double-blind, placebo-controlled trial of pimobendan. *Am Heart J*. 1992;124:1017–1025.
9. Parshall MB, Schwartzstein RM, Adams L, et al; American Thoracic Society Committee on Dyspnea. An official American Thoracic Society statement: update on the mechanisms, assessment, and management of dyspnea. *Am J Respir Crit Care Med*. 2012;185:435–452.

How to cite this article: Chorin E, Padegimas A, Havakuk O, Birati EY, Shacham Y, Milman A, Topaz G, Flint N, Keren G and Rogowski O. Assessment of Respiratory Distress by the Roth Score, *Clinical Cardiology*, 2016;39(11):636–639.