Acta Med. Nagasaki 65: 89－94

The effectiveness of Modified Early Warning Score (MEWS) using individual-specific range in predicting pneumonia hospitalization among nursing home residents in Japan: Comparison with National Early Waring Score (NEWS)

Shunsuke Maeta[1,2,3,4,5], Satoshi Mizukami PhD[1], Yoshihito Tomita PhD[6], Yutaka Date MD, PhD[5], Kazuhiko Arima MD, PhD[1], Kiyoshi Aoyagi MD, PhD[1]

[1] Department of Public Health, Nagasaki University Graduate School of Biomedical Sciences, Nagasaki, Japan
[2] Fuyo Development Co., Ltd., Fukuoka, Japan
[3] Fuyo kaihatsu Co., Ltd., Fukuoka, Japan
[4] Maeda Shouji Co., Ltd., Fukuoka, Japan
[5] Medical Corporation Fuyokai Chikushi minamigaoka Hospital, Fukuoka, Japan
[6] School of Rehabilitation, Department of Physical Therapy, Tokyo Professional University of Health Sciences, Tokyo, Japan

Aim: The purpose of this study was to compare the usefulness between the National Early Warning Score (NEWS), which uses the absolute value range, and the Modified Early Warning Score (MEWS), which considers individual-specific ranges (evaluated by mean and standard deviation [SD], relative measures), in predicting pneumonia hospitalization among nursing home residents.
Methods: The current study was a retrospective, observational study. The subjects were 235 nursing home residents (75 men and 160 women; pneumonia group, n=62; non-pneumonia group, n=173). The mean and SD of each vital sign (systolic blood pressure, heart rate, body temperature, and oxygen saturation) of each subject recorded over 28 days was calculated. In the pneumonia group, the points at the date of hospitalization were aggregated to derive the NEWS and MEWS. In the non-pneumonia group, the point at the 35th day from the start of the nursing home stay was aggregated to derive the NEWS and MEWS.
Results: The area under the curve (AUC) for predicting pneumonia hospitalization was 0.80 (95% confidence interval [CI], 0.72-0.88) for NEWS and 0.92 (95%CI, 0.87-0.97) for MEWS using individual-specific ranges. The AUC of MEWS using individual-specific ranges was significantly greater than that of NEWS ($p<0.0001$). When 3 was used as a cutoff value in MEWS, the Youden Index was the best value (0.75). Sensitivity, specificity, positive predictive value, and negative predictive value were 0.77, 0.97, 0.91, and 0.92, respectively.
Conclusion: Our MEWS system using individual-specific ranges showed good performance in predicting hospitalization for pneumonia among nursing home residents.

ACTA MEDICA NAGASAKIENSIA 65: 89－94, 2022

Key words: Early Warning Score, individual-specific range, pneumonia, nursing home

Introduction

The Japanese society is aging rapidly and the number of elderly people requiring daily nursing care is on the rise[1]. The total population of Japan in 2019 was 126 million, out of which 36 million were individuals aged 65 and over (the elderly). Thus, the elderly made up 28.4% of the total population[2]. The number of elderly people living in nursing homes is approximately 900,000 in Japan[3].

Globally, pneumonia is a significant cause of mortality

Address correspondence: Satoshi Mizukami, PhD
Department of Public Health, Nagasaki University Graduate School of Biomedical Sciences, 1-12-4 Sakamoto Nagasaki, 852-8523, Japan
TEL: +81 95 819 7067, FAX: +81 95 819 7069, e-mail: s.mizukami@nagasaki-u.ac.jp

Received October 29, 2021; Accepted December 22, 2021

and morbidity among the elderly[4]. It is the most common reason for transfer to acute care hospitals in patients living in long-term care facilities[5]. Nursing home residents admitted with pneumonia were identified as the group having the greatest influence on mortality[6]. Therefore, it is important to detect signs of pneumonia early in nursing home residents.

Early warning scores (EWSs) are composite scales that consider patients' vital signs such as blood pressure and heart rate[7]. They are often used in the hospital setting to assess worsening or improvement in patients' clinical status[7]. Recently, EWS was also implemented in health management at a nursing home[8,9]. EWSs can be calculated by healthcare assistants or nursing staff, who can contact an appropriate medical team member depending on the patient's score with the view of treatment escalation as needed[10,11].

National Early Warning Score (NEWS) is determined using the absolute value of each vital sign[10,12]. However, vital signs indicate different variations in each individual[13]. Vital signs such as body temperature, heart rate, and blood pressure may change with aging, depending on the health status[14]. Therefore, we propose the modified early warning score (MEWS) developed by us, which uses individual-specific ranges (evaluated by mean and standard deviation [SD], relative measures) instead of the absolute values.

The purpose of this study was to compare the usefulness between NEWS, which is based on absolute value range, and MEWS, which is based on individual-specific ranges, and evaluate the effectiveness of MEWS in predicting pneumonia hospitalization among nursing home residents.

Subjects and Methods

Subjects

The participants were 252 nursing home residents staying from May 1, 2016, to July 31, 2019. The exclusion criteria were those who stayed for 35 days or less and those who were absent in the vital sign data for 5 days or more; thus, 17 subjects were excluded. Among those who were hospitalized for pneumonia multiple times, the first hospitalization data were used for analysis. The study protocols were approved by the ethics committee of the Nagasaki University Graduate School of Biomedical Sciences (No 18050741-2), and it conforms to the provisions of the Declaration of Helsinki. Informed consent was obtained with an opt-out policy. We displayed our study protocol on the wall at the nursing home. Anonymized data from the nursing home residents were obtained and analyzed.

Study design

A retrospective observational study was conducted among nursing home residents.

Diagnosis of pneumonia

Diagnosis of pneumonia was based on the American Thoracic Society guidelines for hospital-acquired, ventilator-associated and healthcare-associated pneumonia (HAP, VAP and HCAP)[15].

Vital sign measurements

Nursing staff measured vital signs (systolic blood pressure, heart rate, body temperature, oxygen saturation, and level of consciousness) of subjects every morning. Systolic blood pressure was measured using an automatic blood pressure monitor; heart rate and oxygen saturation were measured using a pulse oximeter; and body temperature was measured using a thermometer. The vital signs were automatically transferred to in the ICT health management system (Anshin-net™: Fuyo kaihatsu Co., Ltd., Japan and Fuyo Development Co., Ltd., Japan) by FeliCa™ (Sony Group Corporation, Japan).

Calculations of NEWS and MEWS

Using the ICT health management system mentioned above, NEWS and MEWS were calculated according to Table 1[10]. Regarding MEWS, since systolic blood pressure, heart rate, and body temperature were normally distributed, we weighted 0 points for mean ± 2SD, 1 point for mean -3SD to -2SD or mean + 2SD to + 3SD, and 2 points for mean -3SD> or mean + 3SD <. In contrast, oxygen saturation was not normally distributed. According to NEWS[10], we weighted 0 points when the oxygen saturation was ≥ 96%, 1 point when 94-95, 2 points when 92-93, and 3 points when ≤91%. The level of consciousness was 0 points for normal and 3 points for abnormal consciousness. In the pneumonia group, the mean and SD of each vital sign of the individual were calculated for 28 days, from 35 days to 7 days before hospitalization (Figure 1A). As shown in Table 1, the point at the date of hospitalization was aggregated to derive the NEWS and MEWS. In the non-pneumonia group, the mean and SD of each vital sign of the individual were calculated for 28 days from the start of stay at the nursing home (Figure 1B). According to Table 1, the point on the 35th day from the start of stay at the nursing home was aggregated to derive the NEWS and MEWS.

Table 1. National Early Warning Score (NEWS) and Modified Early Warning Score (MEWS) using individual-specific range (SD) chart

NEWS	3	2	1	0	1	2	3
Oxygen Saturations (%)	≤ 91	92-93	94-95	≥ 96			
Temperature (℃)	≤ 35.0		35.1-36.0	36.1-38.0	38.1-39.0	≥ 39.1	
Systolic BP† (mmHg)	≤ 90	91-100	101-110	111-219			≥ 220
Heart Rate (bpm‡)	≤ 40		41-50	51-90	91-110	111-130	≥ 131
Level of Consciousness				A§			V§, P§, or U§
MEWS	**3**	**2**	**1**	**0**	**1**	**2**	**3**
Oxygen Saturations (%)	≤ 91	92-93	94-95	≥ 96			
Temperature (° C)		<-3SD	-3SD ≤ ,<-2SD	± 2SD	2SD<, ≤ 3SD	3SD<	
Systolic BP† (mmHg)		<-3SD	-3SD ≤ ,<-2SD	± 2SD	2SD<, ≤ 3SD	3SD<	
Heart Rate (bpm‡)		<-3SD	-3SD ≤ ,<-2SD	± 2SD	2SD<, ≤ 3SD	3SD<	
Level of Consciousness				A§			V§, P§, or U§

† BP: blood pressure
‡ bpm: beats per minute
§ A, V, P & U: alert, verbal, pain & unresponsive

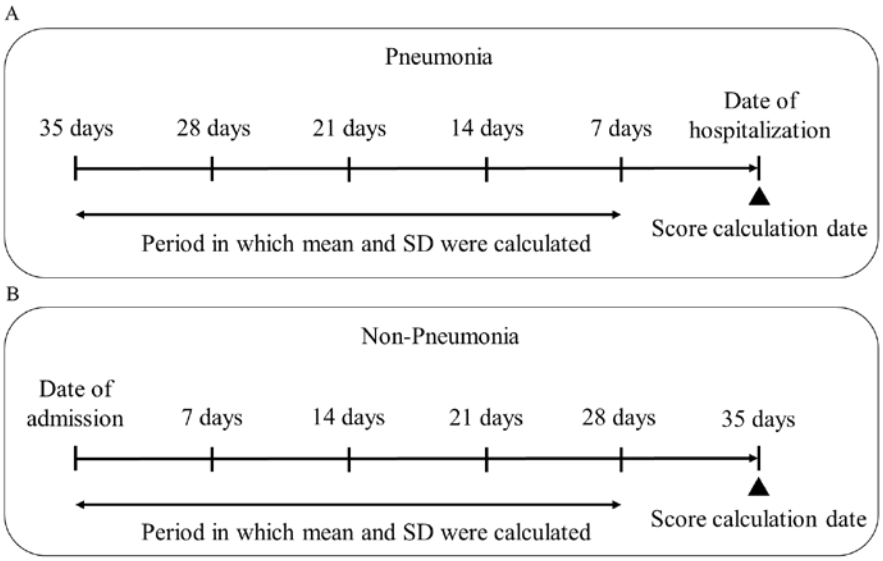

Figure 1. In the pneumonia group, the mean and standard deviation (SD) of each vital sign of the individual were calculated for 28 days, from 35 days to 7 days before hospitalization (A). According to Table 1, the point at the date of hospitalization was aggregated to derive the National Early Warning Score (NEWS) and Modified Early Warning Score (MEWS). In the non-pneumonia group, the mean and SD of each vital sign of the individual were calculated for 28 days from the start of stay at the nursing home (B).

Statistical analysis

Continuous variables were described as mean (SD) or median (interquartile range [IQR]) and were compared using the t-test or Mann-Whitney U-test. Receiver operating characteristic analysis and the area under the curve (AUC) were used to evaluate the predictive value of NEWS and MEWS using individual-specific ranges for pneumonia hospitalization. The cutoff value for MEWS using individual-specific ranges was determined using the Youden index (sensitivity + specificity – 1). Statistical significance was set at $p < 0.05$. Data were analyzed using SAS software (version 9.4; SAS Institute, Cary, NC, USA).

Results

Table 2 summarizes the basic characteristics of the study participants. Of the 235 subjects analyzed (mean age, 85.8 ± 8.2 years; 75 men and 160 women), those who were

Table 2. Characteristics of study participants (n=235)

	Total (n=235)	Pneumonia (n=62)	Non-Pneumonia (n=173)	p-value
Age	Mean ± SD† 85.8 ± 8.2	Mean ± SD† 85.8 ± 7.4	Mean ± SD† 85.8 ± 8.5	0.999
Men/Women	n (%) 75 (31.9)/160(68.1)	n (%) 27(43.5)/35(56.5)	n (%) 48 (27.7)/125(72.3)	0.022
NEWS§	Median (IQR‡) 2 (1-3)	Median (IQR‡) 4 (2-6)	Median (IQR‡) 1 (1-2)	<0.001
MEWS¶	0 (0-2)	5 (3-8)	0 (0-1)	<0.001

† SD: standard deviation
‡ IQR: interquartile range
§ NEWS: National Early Warning Score
¶ MEWS: Modified Early Warning Score

hospitalized for pneumonia were defined as the pneumonia group (n=62), and the others were defined as the non-pneumonia group (n=173). The mean age was not significantly different between the pneumonia and non-pneumonia groups. The median (interquartile range [IQR]) of MEWS using individual-specific ranges in the pneumonia group was 5 (3-8), which was greater than that in the non-pneumonia group.

The AUC for predicting pneumonia hospitalization was 0.80 (95% confidence interval [CI], 0.72-0.88) for NEWS and 0.92 (95%CI, 0.87-0.97) for MEWS using individual-specific ranges (Figure 2). The AUC of MEWS using individual-specific ranges was significantly greater than that of NEWS (p<0.0001).

Sensitivity, specificity, positive predictive value, and negative

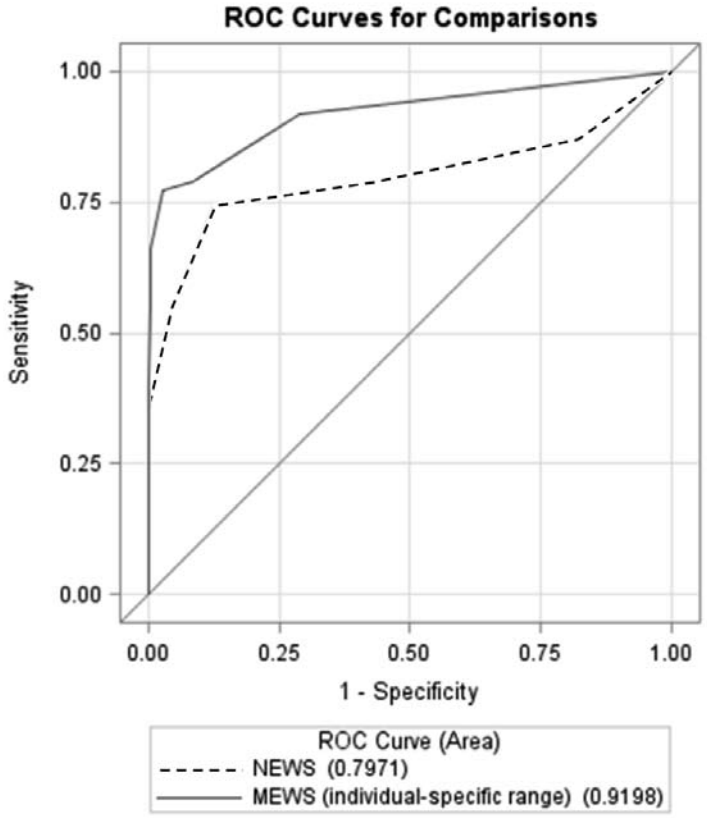

Figure 2. The area under curve (AUC) for predicting for pneumonia hospitalization was 0.80 (95% confidence interval [CI], 0.72-0.88) for National Early Warning Score (NEWS) and 0.92 (95%CI, 0.87-0.97) for Modified Early Warning Score (MEWS) using individual-specific ranges. The AUC of MEWS using individual-specific ranges was significantly greater than that of NEWS (p<0.0001).

predictive value among selected cutoffs (2-6) in MEWS for pneumonia hospitalization are shown in Table 3. When the cutoff values were set to 2, 3, 4, 5, and 6 in MEWS, the Youden Index was 0.70, 0.75, 0.66, 0.54, and 0.40, respectively. When 3 was used as a cutoff value in MEWS, the Youden Index was the best value; the sensitivity, specificity, positive predictive value, and negative predictive value were 0.77, 0.97, 0.91, and 0.92, respectively.

Discussion

This is the first study to evaluate the usefulness of MEWS using individual-specific ranges for pneumonia hospitalization among nursing home residents. We showed that the AUC of MEWS using individual-specific ranges was significantly greater than that of NEWS, indicating that it is a good tool. The sensitivity was 0.77 and the specificity was 0.97 at three or more MEWS, indicating good performance. Our MEWS system using individual-specific ranges may be able to identify nursing home residents requiring treatment for pneumonia significantly earlier.

The elderly often do not have subjective symptoms, and it is possible that health care professionals find it difficult to communicate with the elderly. On the other hand, vital signs are objective measures. The clinical deterioration of patients hospitalized in general wards is often preceded by worsening vital signs[16]. If identified early and acted upon quickly, it is conjectured that further deterioration can be prevented. The EWS system may be useful for early detection of deteriorating health conditions among nursing home residents.

NEWS was developed and validated in hospital wards to detect patients with increased risk of ICU admission, cardiac arrest, and in-hospital death within 24h and used worldwide[17,18]. Recently, Barker et al.[8] reported that the use of NEWS in care homes appears to be feasible, and that care home staff's concerns about residents were associated with a higher NEWS (worsening condition). Identifying acute illness among older adults in care homes can be difficult, and opportunities to initiate appropriate care may be missed if the illness is not promptly recognized[8]. Therefore, the use of an EWS system in nursing homes is highly recommended.

The individual-specific (reference) range for calculating MEWS may change depending on the measurement period of vital sign. For example, age, air temperature, antihypertensive or medications that affect the autonomic nerves may change blood pressure and/or heart rate. MEWS changes as the reference range changes. Care must be taken when setting the calculation period for the reference range.

This study has several limitations. First, this was a retro-

Table 3. Validity results for selected cutoff values with regard to pneumonia

		Pneumonia (n=62)	Non-Pneumonia (n=173)
Cutoff value: score 2			
	positive	49 (79.0)	15 (8.7)
	negative	13 (21.0)	158 (91.3)
sensitivity: 0.79	specificity: 0.91	positive predictive value: 0.77	negative predictive value: 0.92
Cutoff value: score 3			
	positive	48 (77.4)	5 (2.9)
	negative	14 (22.6)	168 (97.1)
sensitivity: 0.77	specificity: 0.97	positive predictive value: 0.91	negative predictive value: 0.92
Cutoff value: score 4			
	positive	41 (66.1)	1 (0.6)
	negative	21 (33.9)	172 (99.4)
sensitivity: 0.66	specificity: 0.99	positive predictive value: 0.98	negative predictive value: 0.89
Cutoff value: score 5			
	positive	34 (54.8)	1 (0.6)
	negative	28 (45.2)	172 (99.4)
sensitivity: 0.55	specificity: 0.99	positive predictive value: 0.97	negative predictive value: 0.86
Cutoff value: score 6			
	positive	25 (40.3)	0 (0)
	negative	37 (59.7)	173 (100)
sensitivity: 0.40	specificity: 1.00	positive predictive value: 1.00	negative predictive value: 0.82

spective observational study on hospitalization for pneumonia in only one target nursing home. Therefore, our results cannot be extrapolated to other nursing home residents. Further prospective studies to evaluate the validity of our MEWS system (using individual-specific ranges) in the context of several different diseases apart from pneumonia are needed in large-scale nursing homes. Second, the respiratory rate was included in a previously published EWS system[17-19], but it was not available in this study.

Conclusion

The MEWS system using individual-specific ranges showed good performance in predicting hospitalization for pneumonia among nursing home residents. We propose that our MEWS system should be applied as a standard practice in an acute setting, since it can serve as a simple but effective means of alerting less experienced staff to illness severity[20].

Acknowledgements

This work was in part funded by the Health Labour Sciences Research Grant (H29-ICT-Ippan-008) from the Ministry of Health, Labour and Welfare.

Disclosure statement

S. Maeta is the CEO of Fuyo Development Co., Ltd., the CEO of Maeda Shouji Co., Ltd., and the Director of Medical Corporation Fuyokai. S. Maeta owns shares of Fuyo Development Co., Ltd., Fuyo kaihatsu Co., Ltd. and Maeda Shouji Co., Ltd.

Y. Date is the Chairman of Medical Corporation Fuyokai.

The other authors declare no conflict of interest.

Patent

Maeda Shouji Co., Ltd. has the patents "HEALTH CONDITION DETERMINATION DEVICE" and "SOFTWARE, HEALTH CONDITION DETERMINATION DEVICE, AND HEALTH CONDITION DETERMINATION METHOD." Fuyo kaihatsu Co., Ltd. has the patent "SOFTWARE, HEALTH CONDITION DETERMINATION DEVICE, AND HEALTH CONDITION DETERMINATION METHOD."

References

1) Cabinet Office, Government of Japan. Annual Report on the Ageing Society 2014. https://www8.cao.go.jp/kourei/whitepaper/w-2014/zenbun/s1_2_3.html/ (final accessed: 2021.5.7.)
2) Cabinet Office, Government of Japan. Annual Report on the Ageing Society [summary] fy2020. https://www8.cao.go.jp/kourei/whitepaper/index-w.html/ (final accessed: 2021.5.7.)
3) Health and Welfare Bureau for the Elderly, Ministry of Health, Labour and Welfare, Government of Japan. Long-term care insurance system of Japan. 2016. https://www.mhlw.go.jp/english/policy/care-welfare/care-welfare-elderly/dl/ltcisj_e.pdf/ (final accessed: 2021.5.7.)
4) Stupka JE, Mortensen EM, Anzueto A, and Restrepo MI. Community-acquired pneumonia in elderly patients. Aging Health 5:763-774, 2009
5) Muder RR. Pneumonia in residents of long-term care facilities: Epidemiology, etiology, management, and prevention. Am J Med 105:319-330, 1998
6) Dempsey CL. Nursing home-acquired pneumonia: Outcomes from a clinical process improvement program. Pharmacotherapy 15:33s-38s, 1995
7) Jayasundera R, Neilly M, Smith TO, and Myint PK. Are early warning scores useful predictors for mortality and morbidity in hospitalised acutely unwell older patients? A systematic review. J Clin Med 7:309, 2018
8) Barker RO, Stocker R, Russell S, et al. Distribution of the national early warning score (news) in care home residents. Age Ageing 49:141-145, 2019
9) Russell S, Stocker R, Barker RO, Liddle J, Adamson J, and Hanratty B. Implementation of the national early warning score in uk care homes: A qualitative evaluation. Br J Gen Pract 70:e793-e800, 2020:
10) Royal College of Physicians. National Early Warning Score (NEWS) Standardising the assessment of acute-illness severity in the NHS. Report of a working party London 2012. https://www.rcplondon.ac.uk/file/32/download?token=5NwjEyTq/ (final accessed: 5.7.2021.)
11) Chen YC, Yu WK, Ko HK, et al. Post-intensive care unit respiratory failure in older patients liberated from intensive care unit and ventilator: The predictive value of the national early warning score on intensive care unit discharge. Geriatr Gerontol Int 19:317-322, 2019
12) Mitsunaga T, Hasegawa I, Uzura M, et al. Comparison of the national early warning score (news) and the modified early warning score (mews) for predicting admission and in-hospital mortality in elderly patients in the pre-hospital setting and in the emergency department. PeerJ 7:e6947, 2019
13) Forkan ARM, and Khalil I. A clinical decision-making mechanism for context-aware and patient-specific remote monitoring systems using the correlations of multiple vital signs. Comput Methods Programs Biomed 139:1-16, 2017
14) MedlinePlus. Aging changes in vital signs. https://www.medicalnewstoday.com/mnt/releases/253318#1/ (final accessed: 2021.6.28.)
15) Guidelines for the management of adults with hospital-acquired, ventilator-associated, and healthcare-associated pneumonia. Am J Respir Crit Care Med 4:388-416, 2005
16) Petersen JA. Early warning score challenges and opportunities in the care of deteriorating patients. Dan Med J 65:B5439, 2018
17) Bilben B, Grandal L, and Søvik S. National early warning score (news) as an emergency department predictor of disease severity and 90-day survival in the acutely dyspneic patient - a prospective observational study. Scand J Trauma Resusc Emerg Med 24:80, 2016:
18) Myrstad M, Ihle-Hansen H, Tveita AA, et al. National early warning score 2 (news2) on admission predicts severe disease and in-hospital mortality from covid-19 - a prospective cohort study. Scand J Trauma Resusc Emerg Med 28:66, 2020
19) Ehara J, Hiraoka E, Hsu HC, Yamada T, Homma Y, and Fujitani S. The effectiveness of a national early warning score as a triage tool for activating a rapid response system in an outpatient setting: A retrospective cohort study. Medicine (Baltimore) 98:e18475, 2019
20) Paterson R, MacLeod DC, Thetford D, et al. Prediction of in-hospital mortality and length of stay using an early warning scoring system: Clinical audit. Clin Med (Lond) 6:281-284, 2006