Original Article

Early Warning Scores for COVID-19 Outcomes: Modified Early Warning Score and Rapid Emergency Medicine Score Performance in Mortality and Hospital Readmission Risk Stratification

Abstract

Background: The COVID-19 pandemic highlighted the need for rapid and reliable triage tools to predict patient outcomes and support resource allocation. This study aimed to compare the predictive performance of Modified Early Warning Score (MEWS) and Rapid Emergency Medicine Score (REMS) for predicting mortality and hospitalization among COVID-19 patients. **Materials and Methods:** This prospective cohort study included 900 outpatients and 280 inpatients with COVID-19 who presented to 22 Bahman Hospital in Neyshabur, Iran, between 2022 and 2024. Physiological parameters for both MEWS and REMS were recorded at admission and monitored for 30 days. The receiver operating characteristic curves were used to assess the prognostic accuracy of MEWS and REMS for mortality and hospitalization. **Results:** At 48 hours before death, MEWS showed slightly better discrimination than REMS (AUC = 74.00, 95% CI: 68.80, 79.20 vs. 73.20, 95% CI: 67.50, 78.90; both $p < 0.001$). REMS exhibited greater sensitivity (75.50 vs. 38.00), while MEWS showed higher specificity (84.60 vs. 75.80). At 24 hours before death, REMS marginally outperformed MEWS (AUC = 62.80, 95% CI: 55.50, 70.10 vs. 62.30, 95% CI: 54.90, 69.70; $p < 0.001$ and < 0.001 respectively), with higher sensitivity (48.90 vs. 42.80) and slightly lower specificity (75.00 vs. 83.60). **Conclusions:** REMS demonstrated better prognostic accuracy 24 hours before death, likely reflecting its inclusion of age and neurological status. MEWS showed stronger performance 48 hours before death and in predicting hospitalization.

Keywords: *COVID-19, hospitalization, modified early warning score, mortality, rapid emergency medicine score*

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Introduction

The outbreak of COVID-19 in late 2019 became a global health crisis, necessitating urgent attention and effective management strategies.[1] Early phases brought varied community responses, such as those in Razavi Khorasan province, Iran, illustrating both local mobilization and the need for efficient triage protocols to manage surges and optimize resource allocation.[2] Similar patterns of health system strain and public response were observed internationally, including in Afghanistan, underscoring the challenges of patient management and acute care during the pandemic.[3]

The high transmissibility of COVID-19—with one patient infecting up to 3.5 others—compounded these pressures, highlighting the need for precise triage and rapid risk assessment.[4] Heightened public anxiety and stress further complicated clinical evaluation, reinforcing the imperative for standardized and objective tools such as Modified Early Warning Score (MEWS) and Rapid Emergency Medicine Score (REMS) to guide decision-making, rather than relying solely on subjective or self-reported symptoms.[5] Traditional laboratory markers, while informative, often proved nonspecific and time-consuming. Effective triage required assessment methods that not only stratified risk rapidly but also addressed disparities in health literacy and self-care.[6-10]

Early Warning Scores (EWSs) have emerged as valuable tools for assessing patient prognosis and identifying COVID-19 patients requiring intensive care.[6,11] Recent studies highlight their

How to cite this article: Sahebkar M, Langari M, Saadati M, Assarroudi A, Mahdavifar N, Khalili H. Early warning scores for COVID-19 outcomes: Modified early warning score and rapid emergency medicine score performance in mortality and hospital readmission risk stratification. Iran J Nurs Midwifery Res 2026;31:336-42.

Submitted: 07-Aug-2025. **Revised:** 03-Dec-2025. **Accepted:** 06-Dec-2025. **Published:** 07-May-2026.

Access this article online

Website: https://journals.lww.com/jnmr

DOI: 10.4103/ijnmr.ijnmr_324_25

Quick Response Code:

predictive value. Evidence shows that the first prehospital REMS can predict Emergency Department (ED) and hospital outcomes, supporting its role in early risk stratification and resource planning.[12] Assessments of REMS on admission have also been shown to outperform other early warning systems, such as MEWS, in predicting in-hospital mortality.[13] Additionally, research indicates that the RISE-UP score demonstrates greater efficacy than both MEWS and REMS in predicting poor outcomes in patients with COVID-19.[14]

Although EWSs have been studied for predicting mortality and intensive care unit (ICU) admissions, limited research has directly compared the predictive abilities of MEWS and REMS in COVID-19 patients.[15] Given the heterogeneity of COVID-19 and the lack of a standardized risk classification tool, implementing a reliable rapid triage system is critical.[11] Therefore, this study aims to address this gap by comparing MEWS and REMS in predicting hospitalization and mortality and to provide evidence for improved clinical decision-making, resource allocation, and triage in emergency settings.

Materials and Methods

This prospective cohort study was conducted to compare the MEWS and REMS scores in predicting hospitalization and mortality among COVID-19 patients from 2022 to 2024. In this study, "hospitalization" refers to any admission from the ED, including both general ward and ICU admissions, whereas "ICU admission" denotes transfer for higher-acuity care.

The study population comprised all COVID-19 patients referred to 22 Bahman Hospital in Neyshabur, Iran, from 17 November 2022 to 6 December 2024. Patients who met the inclusion criteria, were over 18 years of age, and provided informed consent were included. In cases where patients were unable to provide consent due to their clinical condition, informed consent was obtained from their first-degree relatives as legal proxies. The exclusion criteria included patients connected to a shock device and undergoing cardiopulmonary resuscitation (CPR), those who were intubated before reaching the hospital, pregnant women, and individuals unwilling to participate in the study.

In this study, both MEWS and REMS tools were utilized. MEWS, proposed by Barnett WR *et al*.,[16] is a tool for evaluating patients requiring special care. This scoring system calculates scores based on pulse, breathing rate, fever, AVPU (Alert, Verbal, Pain, Unresponsive) scale, and systolic blood pressure.[16] REMS, proposed by Bulut *et al*.,[17] was designed to predict the mortality of nonsurgical patients in the emergency room, with its calculation involving Glasgow Coma Scale (GCS), respiration rate, oxygen saturation, mean arterial pressure (MAP), heart rate, and age. The MEWS score ranges from 0 to 13, with higher scores indicating greater deterioration in patient condition. The REMS score ranges from 0 to 26, with 0 representing the lowest and 26 the highest score.[18]

Both tools have been validated in Iranian clinical settings. MEWS has shown good predictive accuracy for identifying serious adverse events among hospitalized patients,[19] while REMS has demonstrated higher accuracy in predicting mortality, particularly in COVID-19 cohorts.[20] Building on this evidence, our study evaluated these scoring systems among Iranian patients with COVID-19 presenting to the emergency department between 2022 and 2024.

Clinically relevant thresholds were identified to support decision-making. MEWS scores above 1 were found useful for predicting hospitalization, whereas REMS scores above 6 indicated patients requiring closer monitoring. For mortality prediction, MEWS scores above 4 and REMS scores above 9 at 24 hours or 13 at 48 hours signaled increased risk. These findings support the application of MEWS for early detection of deterioration and REMS for identifying patients at higher risk of death.

A convenience sampling method was employed due to the urgent clinical context of the COVID-19 pandemic and the practical constraints of patient enrolment in the ED. This approach allowed the inclusion of consecutive patients presenting to the hospital during the study period, thereby capturing real-world variability in patient characteristics and clinical presentations. While convenience sampling may introduce potential selection bias, it was considered appropriate given the exploratory aim of comparing the predictive performances of MEWS and REMS under routine clinical conditions. To mitigate bias, all eligible patients who met the inclusion criteria were systematically evaluated, and standardized protocols were implemented for data collection. A skilled anesthesia nurse with 4 years of ED experience recorded the physiological parameters for both tools daily, from admission until discharge, hospitalization, or death, with a maximum follow-up period of 30 days. Vital signs were assessed using a manual arm sphygmomanometer (blood pressure, mmHg), tympanic thermometer (temperature, °C), and finger pulse oximeter (oxygen saturation, %), all manufactured by the German Richter® brand in compliance with the European Standard (CE). Data were collected from both inpatients and outpatients upon arrival at the ED. Inpatients were monitored daily until discharge or death. For outpatients, follow-up data over the 30-day period were obtained through structured telephone interviews conducted at three time points: Day 7, Day 14, and Day 30. Each interview lasted approximately 10–15 minutes and collected information on hospitalization status (defined as any admission to the hospital from the ED, including both general ward and ICU admissions), mortality, new or worsening symptoms, and any subsequent ED visits. In addition, hospital electronic medical records were reviewed to confirm outcomes and

ensure completeness of data. Prior to data collection, the sphygmomanometer was validated using a precision water bath at fixed reference temperatures, and the pulse oximeter was cross-checked with a clinical simulator following built-in self-calibration. These procedures ensured accuracy and consistency of measurements.

The inpatient sample size was calculated using the sensitivity and specificity estimates reported by Marcello Covino *et al*.[21] A two-sided α of 0.05, an expected prevalence of 17%, and a precision of 0.15 were applied. Using these parameters, the sensitivity-based calculations yielded required sample sizes of approximately 210 participants for MEWS (based on sensitivity = 0.70) and 226 participants for NEWS (based on sensitivity = 0.66). Similarly, the specificity-based calculations produced sample size requirements of approximately 232 participants for MEWS (specificity = 0.64) and 135 participants for NEWS (specificity = 0.84). Considering the highest requirement across these estimates and accounting for a 10% anticipated dropout rate, the final minimum inpatient sample size was set at 280 participants. To strengthen the study's external validity and capture a broader spectrum of disease severity, all outpatients with confirmed COVID-19 who presented to the ED during the study period were included, resulting in a total of 900 outpatient participants. While the inpatient sample followed a calculated estimation, there was the inclusion of all eligible outpatients' comprehensive representation of patients seeking emergency care during the data collection period.

Descriptive statistics were utilized to characterize the quantitative variables, which were presented as means (standard deviations). The qualitative variables were described in terms of frequency (percentage). Prior to conducting comparative analyses, normality assumptions were assessed using the Kolmogorov–Smirnov test. The patients' baseline characteristics were compared using appropriate statistical tests, including independent t-tests for continuous variables and Chi-square tests for categorical variables. Furthermore, the prognostic value of the MEWS and REMS tools in predicting hospitalization and mortality was evaluated using receiver operating characteristic (ROC) curves and the corresponding area under the curve (AUC). The optimal cutoff points were determined using Youden's index. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were also calculated. To formally compare the discriminative performances of MEWS and REMS, AUCs were compared using the DeLong test. Data analysis was performed using SPSS version 22.0 (IBM Corp., 2013) and MEDCALC version 20.0.13 (MedCalc Software, 2020). A p value less than 0.05 was considered statistically significant.

Ethical considerations

This study obtained ethical approval from Sabzevar University of Medical Sciences, with license no. IR.MEDSAB.REC.1400.110. Written informed consent was obtained from all eligible participants at the start of the study. The questionnaire did not include any personal names or identification, and each patient was allocated a unique identification code to ensure confidentiality and anonymity of the collected data. This study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

Results

In this study, a total of 1197 patients were initially assessed for eligibility. Of these, 1180 were included, while 8 were excluded due to negative polymerase chain reaction (PCR) results and 9 due to lack of consent. Among them, 280 were classified as inpatients, while 900 were identified as outpatients [Figure 1]. The distribution of sex differed significantly between the two groups (χ^2 = 8.85, p = 0.003), with outpatients consisting of 46% (n = 411) men and 54% (n = 489) women and inpatients comprising 56% (n = 157) men and 44% (n = 123) women. The mean age of all participants was 56.90 (18.60) years. The mean age of outpatients was 54.30 (18.60) years, whereas that of inpatients was 65.40 (17.90) years. Notably, hospitalized patients were older than nonhospitalized patients. The mortality rate among hospitalized patients was 19%.

Prognostic value of MEWS and REMS in predicting mortality for COVID-19 patients

The diagnostic performance of MEWS and REMS was evaluated for predicting mortality at 24 and 48 hours before death. At 48 hours, MEWS demonstrated slightly higher discriminative performance (AUC = 74.00, 95% CI: 68.80, 79.20; $p < 0.001$) compared to REMS (AUC = 73.20, 95% CI: 67.50, 78.90; $p < 0.001$). At this time point, REMS

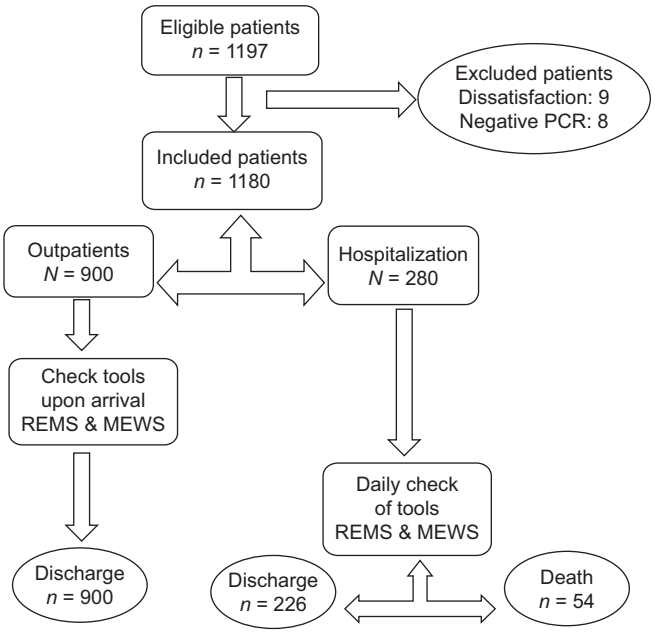

Figure 1: STARD diagram of the study

achieved higher sensitivity (75.50) than MEWS (38.00), whereas MEWS showed higher specificity (84.60 vs. 75.80). At 24 hours before death, both tools showed modest discrimination, with REMS (AUC = 62.80, 95% CI: 55.50, 70.10; $p < 0.001$) performing slightly better than MEWS (AUC = 62.30, 95% CI: 54.90, 69.70; $p < 0.001$). REMS demonstrated higher sensitivity (48.90) compared to MEWS (42.80), whereas MEWS retained higher specificity (83.60 vs. 75.00) [Figure 2 and Table 1].

Prognostic value of MEWS and REMS in predicting hospitalization for COVID-19 patients

The predictive performance of MEWS and REMS was also assessed for hospitalization upon admission. MEWS demonstrated superior discriminative performance (AUC = 84.00, 95% CI: 80.90, 87.10; $p < 0.001$) compared to REMS (AUC = 70.00, 95% CI: 63.90, 76.10; $p < 0.001$). MEWS also achieved a higher sensitivity (88.60) and NPV (94.90), whereas REMS demonstrated a higher specificity (90.40) and PPV (53.50) [Figure 2 and Table 2].

Discussion

This study evaluated the prognostic value of MEWS and REMS for predicting hospitalization and mortality among COVID-19 patients, with specific focus on their accuracy at different intervals before death. Findings indicated that MEWS had stronger predictive power 48 hours before death, while REMS performed more effectively at the 24-hour interval. These differences likely reflect the distinct physiological domains emphasized by each scoring tool.

Beyond mortality prediction, both MEWS and REMS serve roles in acute patient management, triage prioritization, and identification of patients requiring ICU or hospital admission.[11,22,23] In our study, the results demonstrate that MEWS achieved a high NPV, indicating strong ability to identify patients unlikely to require hospital admission. This aligns with its design, which emphasizes easily obtained physiological parameters that help identify low-risk patients, thereby supporting safe discharge decisions and efficient allocation of hospital resources. In contrast, REMS demonstrated a comparatively higher PPV, reflecting stronger identification of patients who ultimately required admission. This may be due to the inclusion of oxygen saturation and neurological status, variables that more directly reflect imminent clinical deterioration.[13,24] Thus, the observed differences in predictive values between MEWS and REMS can be understood as a function of their underlying design and clinical focus: MEWS enhances confidence in ruling out the need for admission, whereas REMS improves precision in identifying patients at higher risk who warrant rapid escalation of care.

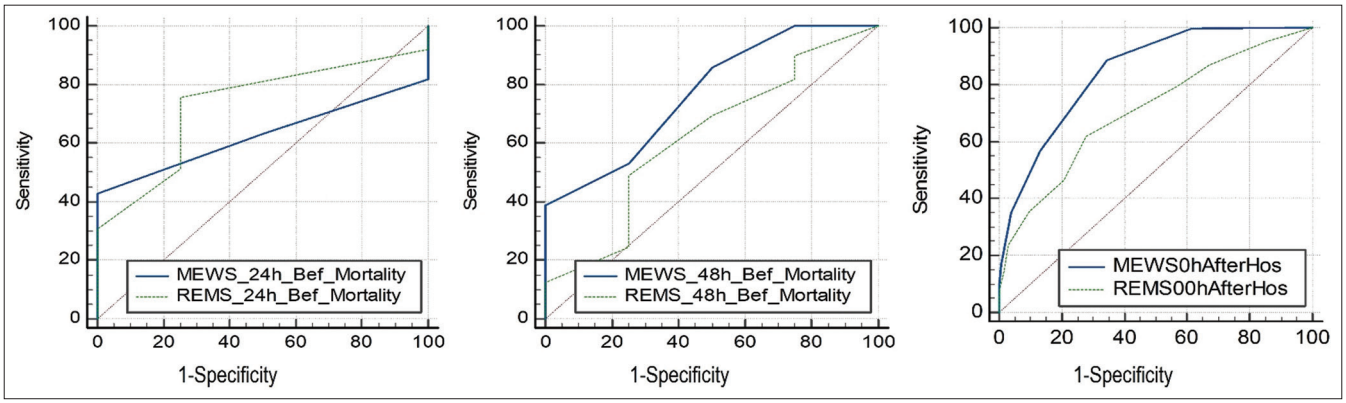

Figure 2: Receiver operating characteristic (ROC) curves and corresponding area under the curve (AUC) values for the Modified Early Warning Score (MEWS) and Rapid Emergency Medicine Score (REMS) tools assessed at 24 hours and 48 hours before mortality, as well as at the time of hospital admission, among patients with COVID-19

Table 1: Diagnostic performance of MEWS and REMS in predicting mortality at 24 and 48 hours before death

Tools	Time	AUC*** (95% CI)	CUT OFF	Sensitivity (95% CI)	Specificity (95% CI)	PPV**** (95% CI)	NPV$ (95% CI)	*p*
MEWS*	24 hours before death	62.30 (54.90, 69.70)	≥4	42.80 (34.70, 50.90)	83.60 (75.40, 90.00)	37.60 (34.50, 40.70)	76.50 (67.10, 85.90)	<0.001
	48 hours before death	74.00 (68.80, 79.20)	>4	38.00 (30.40, 45.60)	84.60 (76.60, 90.80)	42.70 (37.30, 48.20)	72.50 (65.60, 79.40)	<0.001
REMS**	24 hours before death	62.80 (55.50, 70.10)	>9	48.90 (40.20, 57.60)	75.00 (68.70, 81.30)	67.10 (58.40, 75.80)	96.00 (92.70, 99.30)	<0.001
	48 hours before death	73.20 (67.50, 78.90)	≥13	75.50 (67.00, 84.00)	75.80 (68.70, 82.90)	80.10 (71.90, 88.30)	97.40 (95.90, 98.90)	<0.001

*Modified Early Warning Score (MEWS). **Rapid Emergency Medicine Score (REMS). ***The Area Under the Curve (AUC). ****Positive Predictive Value (PPV). $Negative Predictive Value (NPV)

Table 2: Diagnostic performance of MEWS and REMS in predicting hospitalization upon entering the hospital

Tools	Time	AUC*** (95% CI)	CUT OFF	Sensitivity (95% CI)	Specificity (95% CI)	PPV**** (95% CI)	NPV$ (95% CI)	*p*
MEWS*	Upon entering the hospital	84.00 (80.90, 87.10)	>1	88.50 (84.40, 92.60)	65.60 (62.10, 69.20)	44.50 (39.80, 49.20)	94.90 (92.70, 97.10)	<0.001
REMS**	Upon entering the hospital	70.00 (63.90, 76.10)	>6	35.30 (33.10, 37.50)	90.40 (87.20, 93.60)	53.50 (48.40, 58.60)	81.80 (77.60, 86.00)	<0.001

*Modified Early Warning Score (MEWS). **Rapid Emergency Medicine Score (REMS). ***The Area Under the Curve (AUC). ****Positive Predictive Value (PPV). $Negative Predictive Value (NPV)

Once high-risk and low-risk patients are identified, risk stratification should inform post-triage management. Low-risk patients who are discharged require tailored self-care and educational instructions based on their clinical status and health literacy, which is crucial for improving outcomes during a pandemic.[25] Evidence also suggests that self-efficacy plays a significant role in shaping self-care behaviors, particularly under the heightened anxiety caused by COVID-19, underscoring the importance of incorporating psychological support into discharge planning.[26] Their ease of use and rapid implementation make these tools practical for frontline clinicians, particularly during pandemic surges when timely and reproducible risk stratification is critical for maintaining system capacity.[27] Moreover, using rapid and efficient tools like MEWS and REMS can help reduce the burden on healthcare workers. By simplifying decision-making and optimizing resource allocation, these scoring systems can decrease workload and help mitigate the burnout syndrome among medical staff during a crisis.[28]

The performance differences between MEWS and REMS are explained by their respective components. MEWS focuses on basic parameters that change early in deterioration, whereas REMS incorporates variables such as age and oxygen saturation, which are more sensitive to late-stage clinical decline.[11,12] This likely accounts for its stronger predictive ability at 48 hours prior to death.[29] In contrast, REMS incorporates additional variables such as age, oxygen saturation, and the Glasgow Coma Scale, which are more sensitive to late-stage critical manifestations, such as hypoxemia and altered mental status, explaining its superior accuracy closer to death.[15,30] Thus, MEWS enables early alert and monitoring, and REMS supports urgent escalation decisions; together, they offer complementary insights along the trajectory of patient deterioration.[11,29]

Comparison with previous studies helps contextualize these findings. Özdemir *et al*.[31] (2022) reported lower AUC values for MEWS (51.00) and REMS (67.00) at 30 days before death, suggesting predictive accuracy declines when assessed too early. Hu *et al*.[11] (2020) observed that REMS outperformed MEWS in patients under 65, whereas MEWS showed moderate predictive ability in older populations, highlighting the influence of patient age and symptom severity on scoring performance. In the present study, the hospitalized cohort had a mean age of 65.4 years and included patients with mild to severe symptoms, supporting the clinical applicability of both tools in real-world COVID-19 care. MEWS (AUC 84.00) effectively identified low-risk patients who did not require hospital admission, aligning with Bas *et al*.[32] (2021), who reported high predictive performance for both tools, although trends differed slightly between ICU and general admission. In contrast, Wei *et al*.[33] (2019) observed lower AUCs for both scores in a general emergency population, indicating that predictive accuracy is context-dependent and enhanced in COVID-19 settings, particularly because REMS incorporates key variables such as oxygenation and neurological status. Together, MEWS and REMS should be viewed as complementary: MEWS enabling earlier alerts and REMS guiding urgent escalation. Using both scores may improve risk stratification, support timely decision-making, and strengthen resource management during pandemic surges.

This study's single-center design may restrict generalizability. The focus on emergency department COVID-19 presentations limits applicability to other patient populations. Data collection during the pandemic introduced challenges due to increased patient load and adherence to infection control protocols. Utilization of a single anesthesia nurse reduces interobserver variability but may introduce systematic bias in physiological measurements. Despite these challenges, data integrity was maintained through standardized procedures and experienced personnel.

MEWS assists in early identification of moderate-risk patients, enabling timely intervention and efficient bed allocation, while REMS supports rapid ICU transfer for those at imminent risk.[12] Using these tools within standardized protocols improves patient flow, supports timely decision-making during surges, and optimizes healthcare resources.[12] Widespread deployment alleviates staff workload, decreases burnout, and enables patient-centered post-triage care tailored to health literacy and self-care requirements.[25]

Conclusion

The findings of this study suggest that MEWS and REMS are rapid and potentially useful scoring methods for supporting healthcare providers in predicting mortality

and hospitalization among COVID-19 patients. In the context of a dynamic pandemic, these tools may assist in patient triage and resource allocation. MEWS appears particularly helpful in identifying patients who may require hospitalization. However, given the study's limitations—including single-center design, convenience sampling, and pandemic-related data collection challenges—these findings should be interpreted with caution. Further research across multiple centers and diverse patient populations is needed to confirm and expand upon these preliminary results before widespread clinical implementation.

Acknowledgements

The authors would like to express their appreciation to the management and staff of 22 Bahman Hospital in Neyshabur city, who supported the implementation of this study.

Financial support and sponsorship

Nil.

Conflicts of interest

Nothing to declare.

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