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【 ORIGINAL ARTICLE 】

A Convenient Risk Prediction Score for COVID-19 for Determining Whether or Not Hospitalization Is Recommended: Kanagawa Admission Priority Assessment Score

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Abstract:

Objective Coronavirus disease 2019 (COVID-19) has caused a collapse of the medical care system, with effective triage proving vital. The Kanagawa admission priority assessment score, version-1 (KAPAS-1) and version-2 (KAPAS-2), was developed to determine the need for hospitalization. Patients with a high KAPAS (≥5) are recommended for hospitalization. We retrospectively investigated the correlation between the KAPAS and oxygen requirement during hospitalization.

Methods We collected the clinical data of COVID-19 patients admitted between February 5 and December 6, 2020. Patients were divided into two groups: those who required oxygen therapy during hospitalization (OXY) and those who did not (NOXY). We assessed the correlations between the groups and KAPAS-1 and KAPAS-2.

Results Overall, 117 COVID-19 patients were analyzed, including 20 OXY and 97 NOXY and 54 high KAPAS-1 and 63 high KAPAS-2. The median KAPAS-1 and KAPAS-2 were significantly higher in OXY than in NOXY (6.5 vs. 3, and 9 vs. 4, respectively). The areas under the receiver operating characteristic curves of KAPAS-1 and KAPAS-2 for oxygen requirement were 0.777 and 0.825, respectively, and the maximum values of Youden's index were 4 and 6, respectively. The proportions of high KAPAS-1 and high KAPAS-2 were significantly higher in OXY than in NOXY (90.0% vs. 37.1%, and 90.0% vs. 46.4%, respectively).

Conclusion The KAPAS was significantly correlated with oxygen requirement. Furthermore, the KAPAS may be useful for deciding which patients are most likely to require hospitalization and for selecting non-hospitalized patients who should be carefully monitored.

Key words: COVID-19, predictive score, severity, worsening

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Introduction

Coronavirus disease 2019 (COVID-19), caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has spread rapidly around the world since the outbreak first started in Wuhan, China, in December 2019. In many countries, large numbers of patients have been infected, ranging from mild cases with few symptoms to severe cases with critical respiratory failure. As of November 15, 2021, there have been 253,163,330 confirmed cases of COVID-19 around the world, including 5,098,174 deaths, reported to the WHO (1). As a result, a collapse of the medical care system has occurred in many countries. In Japan, we had experienced five explosive increases in the number of COVID-19 patients as of September 2021, threatening the

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Table 1. Kanagawa Admission Priority Assessment Score. A: Version-1, B: Version-2.

A

Factor	Score	Factor	Score
Age ≥75 years	3	Diabetes	2
65-74 years	2	Chronic respiratory disease	2
Hemodialysis	6	Cardiovascular disease	2
Pregnancy after 37 weeks	6	Poorly controlled hypertension	1
Pneumonia less than half of one side	3	Chronic kidney disease (GFR <30)	1
more than half of one side	6	Obesity (BMI ≥30)	1
both sides	6	Use of steroids or immunosuppressive drugs	2
Oxygen requirement	5	Malignant tumor	2
Serious impression*	1	Blood transplant, bone marrow transplant, immunodeficiency, or HIV infection	2
No symptoms	-1		
		Organ transplant	1

Patients with a score of five or higher are recommended for hospitalization.

B

Factor	Score	Factor	Score
Male	1	Diabetes	2
Age ≥75 years	3	Chronic respiratory disease	2
65-74 years	2	Cardiovascular disease	2
Hemodialysis	6	Chronic kidney disease (GFR <30)	2
Pregnancy after 37 weeks	6	Obesity BMI ≥30	2
Pneumonia less than 25%	3	30>BMI≥25	1
more than or equal to 25%	6	Malignant tumor	2
Fever of 38°C or higher lasting more than 3 days	2	Immunosuppressive condition (use of steroids or immunosuppressive drugs, organ transplant, blood transplant, bone marrow transplant, immunodeficiency, or HIV infection)	2
Desaturation 94 or 95%	2		
≤93%	6		
Serious impression*	2		
No symptoms	-1	Liver cirrhosis	1

Patients with a score of five or higher are recommended for hospitalization.

GFR: glomerular filtration rate, BMI: body mass index. * Difficulty lying down due to respiratory symptoms or unable to eat or drink.

Japanese medical care system.

It is vital for public health centers to triage which patients should be admitted because there are not enough beds available for admission when rapid increases in infections occur. However, in practice, without a score to help determine the need for hospitalization, many patients with mild illnesses or no symptoms were admitted to hospitals in Kanagawa Prefecture, Japan.

Some risk factors associated with severe COVID-19 have been previously reported, including an older patient age (2), cancer (3), chronic obstructive pulmonary disease (4), chronic kidney disease (5), diabetes (6), hypertension (7), dyslipidemia (2), obesity (8), smoking (7), immunodeficiency after organ transplantation (9), use of steroids or biological agents (10, 11), HIV infection (12), and pregnancy (13). Several risk assessment tools, such as the COVID-GRAM (14) and 4C mortality score (15), have been developed to predict whether or not a patient will become critically ill with COVID-19 and require intensive care or whether or not a patient is at high risk of death due to illness; however, there are few tools to help determine the risk of a patient requiring hospitalization.

The Kanagawa admission priority assessment score, version 1 (KAPAS-1) was developed in Kanagawa Prefecture to determine patients' need for hospitalization (Table 1A) (16). This score is based on previously reported factors for severe illness. Public health centers in Kanagawa Prefecture introduced the KAPAS-1 to determine hospitalization priority on December 7, 2020. Patients with a score of ≥5 were recommended for hospitalization. A multivariate analysis of factors associated with the KAPAS-1 was then performed to determine whether or not patients who received care at home or at a facility for COVID-19 between December 2020 and March 2021 were subsequently hospitalized during their care (17). As a result of this analysis, the KAPAS, version 2 (KAPAS-2) was developed (Table 1B). However, there are no reports assessing whether or not patients with a high KAPAS had conditions that required inpatient care.

An analysis of the validation cohort is important for evaluating the usefulness of the KAPAS in determining the need for hospitalization and the appropriateness of the cut-off value. Furthermore, oxygen requirement is a significant factor associated with the need for hospitalization. We therefore retrospectively investigated the correlations between the KAPAS and oxygen requirement during hospitalization in patients admitted to Atsugi City Hospital to assess whether

or not the KAPAS was suitable for determining the need for hospitalization.

Materials and Methods

Patients

We collected the clinical data of COVID-19 patients admitted to Atsugi City Hospital between February 5, 2020, and December 6, 2020, before the KAPAS was introduced, from their medical records. All patients with a confirmed COVID-19 diagnosis by SARS-CoV-2 polymerase chain reaction (PCR), loop-mediated isothermal amplification (LAMP), or quantitative antigen test were included. Patients with oxygen requirement or oxygen saturation ≤93% on admission were excluded. Clinical data collected included the patient age, sex, smoking history, complications, symptoms, examination findings, outcome, interval between the onset of COVID-19 illness and hospitalization, and survival. Patients were divided into two groups: those who required oxygen therapy during hospitalization (OXY) and those who did not (NOXY). The decision on the need for oxygen therapy was left to the discretion of individual physicians. The data cut-off date was April 30, 2021.

This study was conducted with the approval of the institutional review board of Atsugi City Hospital (R2-07) in accordance with the Declaration of Helsinki.

The KAPAS

The factors included in the KAPAS-1 and KAPAS-2 are listed in Table 1. Scores were based on the condition and examination findings at the time of admission. Because many patients did not undergo computed tomography at admission, pneumonia was assessed by chest X-ray. A high KAPAS was defined as a score of ≥5, which meant the patient was recommended for hospitalization by Kanagawa Prefecture (16, 17).

Statistical analyses

Categorical variables were assessed using Pearson's chi-squared test. Continuous variables were assessed using the Mann-Whitney or Kruskal-Wallis tests. The values of the receiver operating characteristic (ROC) curve and area under the curve (AUC) were used. An AUC higher than 0.7 was considered acceptable. The maximum values of Youden's index were calculated. To assess the agreement between predictions and observations, calibration plots were created with a logistic regression model. Regarding the interval from the onset to hospitalization, for asymptomatic patients diagnosed with COVID-19 by screening, the number of days from the date of screening to hospitalization was used. Differences were statistically significant when p values were <0.05.

All statistical analyses were performed using EZR, version 1.54 (Saitama Medical Center, Jichi Medical University, Saitama, Japan), a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria). More precisely, it is a modified version of R Commander designed to add statistical functions frequently used in biostatistics (18).

Results

Characteristics

Overall, 135 patients definitively diagnosed with COVID-19 were admitted to Atsugi City Hospital between February 5 and December 6, 2020. Their clinical data was consecutively reviewed. Excluding 18 patients with oxygen requirement or oxygen saturation ≤93% on admission, 117 patients were included in the analysis. Twenty patients were in the OXY group, and 97 were in the NOXY group.

The patient characteristics at the time of admission are shown in Table 2. There were 48 women (41.0%) and 69 men (59.0%), with a median age of 56 (range, 0-100) years old. Twenty-three patients were current or past smokers. Three patients were undergoing hemodialysis. No pregnant women after 37 weeks' gestation were included. The extent of pneumonia was as follows: 25, less than half of one side; 3, half or more of one side; 23, both sides; 43, <25%; and 8, ≥25%. Twenty-five patients had fevers of ≥38°C lasting longer than 3 days. Twenty-three patients had an oxygen saturation of 94-95%. One patient had serious impressions (difficulty lying down due to cough), and 14 were asymptomatic. The complications were as follows: 27, diabetes; 9, chronic respiratory disease; 10, cardiovascular disease; 1, poorly controlled hypertension; 5, chronic kidney disease [glomerular filtration rate (GFR) <30]; 30, obesity [10, body mass index (BMI) ≥30; and 20, 30>BMI≥25]; 9, malignant tumor; 3, use of steroids or immunosuppressive drugs; and 1, immunodeficiency. There were no complications due to blood transplant, bone marrow transplant, HIV infection, organ transplant, or liver cirrhosis. The median number of days from the onset to hospitalization was 4 (range, 0-14). The proportions of elderly patients, smokers, pneumonia, and those with a fever of ≥38°C lasting longer than 3 days were significantly higher in the OXY group than in the NOXY group.

The numbers of patients with a high KAPAS-1 and high KAPAS-2 were 54 and 63, respectively. No patients died of COVID-19.

Correlations between the KAPAS and oxygen requirement

Box-and-whisker plots of the KAPAS by oxygen requirement

The box-and-whisker plots of the KAPAS by oxygen requirement are shown in Fig. 1. The median KAPAS-1 values in the OXY and NOXY groups were 6.5 [interquartile range (IQR), 5.75-8] and 3 (IQR, 0-6), respectively ($p<0.001$) (Fig. 1A). The median KAPAS-2 values in the OXY and NOXY groups were 9 (IQR, 7-11) and 4 (IQR, 1-7), respec-

Table 2. Patient Characteristics at the Time of Admission.

	Total (n=117)	OXY (n=20)	NOXY (n=97)	p value
Sex				
Female	48 (41.0%)	6 (30.0%)	42 (43.3%)	0.395
Male	69 (59.0%)	14 (70.0%)	55 (56.7%)	
Age				
Median, range	56, 0-100	69, 22-93	54, 0-100	0.028
≥75 years	29 (24.8%)	5 (25.0%)	24 (24.7%)	0.035
65-74 years	19 (16.2%)	7 (35.0%)	12 (12.4%)	
Smoking history				
Current or past smoker	23 (19.7%)	7 (35.0%)	16 (16.5%)	0.019
Pack-years (median, range)	29, 1.5-120	45, 1.5-80	19, 5-120	
Hemodialysis	3 (2.6%)	1 (5.0%)	2 (2.1%)	1
Pregnancy after 37 weeks	0	0	0	-
Pneumonia				
less than half of one side	25 (21.4%)	10 (50.0%)	15 (15.5%)	<0.001
more than half of one side	3 (2.6%)	1 (5.0%)	2 (2.1%)	
both sides	23 (19.7%)	7 (35.0%)	16 (16.5%)	
less than 25%	43 (36.8%)	14 (70.0%)	29 (29.9%)	<0.001
more than or equal to 25%	8 (6.8%)	4 (20.0%)	4 (4.1%)	
Fever of 38°C or higher lasting more than 3 days	25 (21.4%)	11 (55.0%)	14 (14.4%)	<0.001
Saturation 94 or 95%	23 (19.7%)	7 (35.0%)	16 (16.5%)	0.112
Serious impression	1 (0.9%)	1 (5.0%)	0	0.38
No symptoms	14 (12.0%)	0	14 (14.4%)	0.152
Diabetes	27 (23.1%)	6 (30.0%)	21 (21.6%)	0.606
Chronic respiratory disease	9 (7.7%)	2 (10.0%)	7 (7.2%)	1
Cardiovascular disease	10 (8.5%)	1 (5.0%)	9 (9.3%)	0.854
Poorly controlled hypertension	1 (0.9%)	0	1 (1.0%)	1
Chronic kidney disease (GFR <30)	5 (4.3%)	1 (5.0%)	4 (4.1%)	1
Obesity				
BMI ≥30	10 (8.5%)	2 (10.0%)	8 (8.2%)	0.542
30>BMI≥25	20 (17.1%)	5 (25.0%)	15 (15.5%)	
Malignant tumor	9 (7.7%)	2 (10.0%)	7 (7.2%)	1
Immunosuppressive condition	4 (3.4%)	0	4 (4.1%)	0.804
Use of steroids or immunosuppressive drugs	3 (2.6%)	0	3 (3.1%)	0.984
Blood transplant, bone marrow transplant, immunodeficiency, or HIV infection	1 (0.9%)	0	1 (1.0%)	1
Organ transplant	0	0	0	-
Liver cirrhosis	0	0	0	-
Days from onset of illness to hospitalization (median, range)	4, 0-14	4, 1-14	4, 0-14	0.524

GFR: glomerular filtration rate, BMI: body mass index

tively (p<0.001) (Fig. 1B). Both median KAPAS values were significantly higher in the OXY than in the NOXY groups.

ROC curves and calibration plots of the KAPAS for oxygen requirement

The ROC curves of the KAPAS for oxygen requirement are shown in Fig. 2. The AUCs of the KAPAS-1 and KAPAS-2 were 0.777 [95% confidence interval (CI), 0.689-0.864] and 0.825 (95% CI, 0.741-0.91), respectively. Since the AUCs of both KAPASs were higher than 0.7, both KAPASs were deemed acceptable for predicting oxygen requirement. The maximum values of Youden's index for the KAPAS-1 and KAPAS-2 were 4 and 6, respectively. Calibration plots are shown in Fig. 3.

Contingency tables with the KAPAS and oxygen requirement

The contingency tables with the KAPAS and oxygen requirement are shown in Table 3. The proportions of a high KAPAS-1 and low KAPAS-1 in the OXY group were 90.0% (n=18) and 10.0% (n=2), respectively, and those in the NOXY group were 37.1% (n=36) and 62.9% (n=61), respectively (p<0.001) (Table 3A). The proportions of a high KAPAS-2 and low KAPAS-2 in the OXY group were 90.0% (n=18) and 10.0% (n=2), respectively, and those in the NOXY group were 46.4% (n=45) and 53.6% (n=52), respectively (p<0.001) (Table 3B). For both KAPASs, the proportions of a high KAPAS were significantly higher in the OXY than in the NOXY groups.

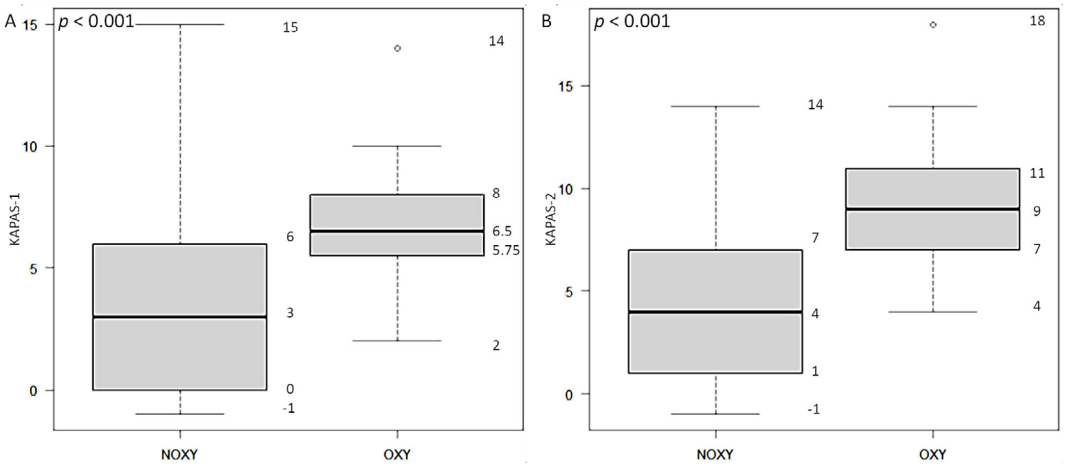

Figure 1. **Box-and-whisker plots of KAPAS by oxygen requirement. A: KAPAS-1, B: KAPAS-2. KAPAS: Kanagawa admission priority assessment score**

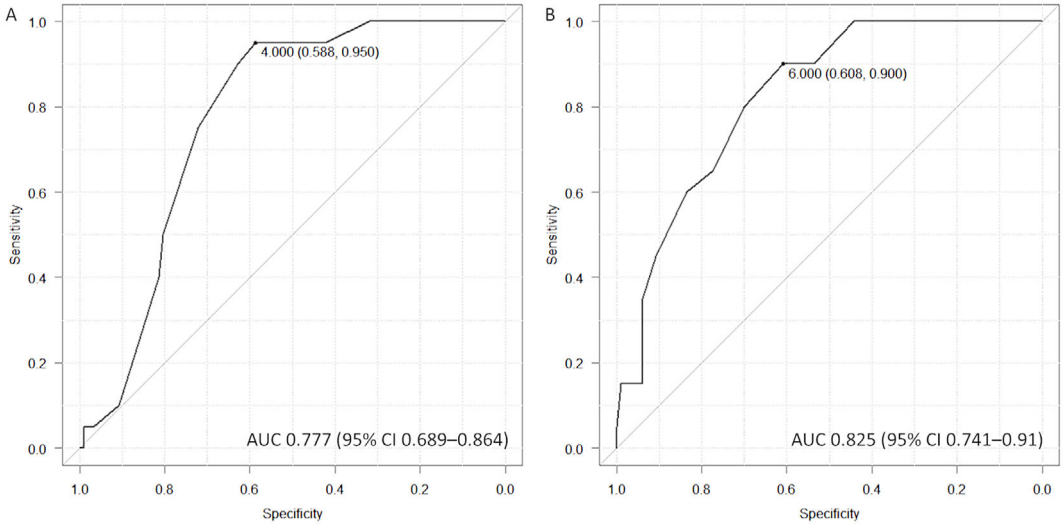

Figure 2. **Receiver operating characteristic curves of KAPAS for oxygen requirement. A: KAPAS-1, B: KAPAS-2. AUC: area under the curve, CI: confidence interval, KAPAS: Kanagawa admission priority assessment score**

Discussion

We validated the KAPAS, which was developed to determine the need for hospitalization, in patients admitted to Atsugi City Hospital. We found that this score was correlated with oxygen requirement. To prevent the collapse of the healthcare system caused by a rapid increase in COVID-19 patients, a few scoring systems for assessing the likelihood of requiring hospitalization have been developed. Sun et al. (19) reported the COVID-19 Acuity Score (CoVA), an outpatient screening score with 30 predictors to estimate the risk of hospitalization, critical illness, or death. This score was developed using data from Massachusetts General Hospital's respiratory illness clinics and emergency department and was designed so that automated scoring could be incorporated into electronic medical records. The specificity was 90%, and the sensitivity was 66% in the prospective validation cohort. Kitajima et al. (20) also developed a scoring system consisting of age, oxygen saturation, and C-reactive protein that predicted the need for oxygen supply, although there was no validation cohort for this scoring system. The sensitivity and specificity were 68.4% and 79.0%, respectively. Salvatore et al. (21) developed the CovHos score to predict the need for in-hospital treatment, using a formula consisting of sex, age, alveolar to arterial oxygen gradient, neutrophil-to-lymphocyte ratio, and C-reactive protein level. The sensitivity and specificity in the validation cohort were 82% and 74%, respectively. Yamada et al. (22) developed a scoring system to predict the need for oxygen therapy based on age, gender, BMI, symptoms, and comorbidities. This score system was different for each of three age groups: young, 18-39 years old; middle aged, 40-64 years old; and elderly, ≥65 years old. The respective sensitivity and speci-

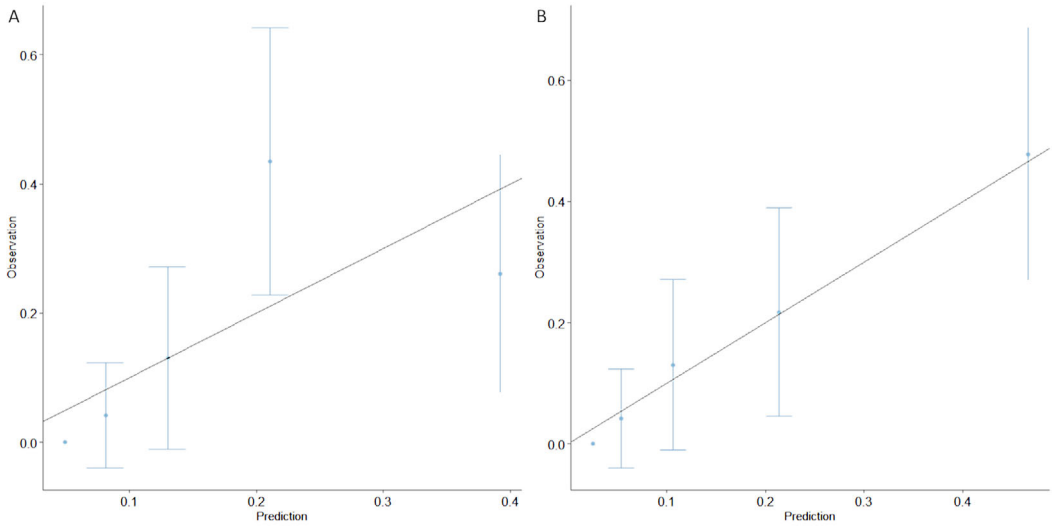

Figure 3. **Calibration plots for predicting oxygen requirement. A: KAPAS-1, B: KAPAS-2. KAPAS: Kanagawa admission priority assessment score**

Table 3. **Contingency Tables with KAPAS and Oxygen Demand. A, KAPAS-1; B, KAPAS-2.**

A				
		OXY	NOXY	Total
KAPAS-1	High (≥5)	18 (90.0%)	36 (37.1%)	54
	Low (<5)	2 (10.0%)	61 (62.9%)	63
Total		20	97	117
p<0.001				
B				
		OXY	NOXY	Total
KAPAS-2	High (≥5)	18 (90.0%)	45 (46.4%)	63
	Low (<5)	2 (10.0%)	52 (53.6%)	54
Total		20	97	117
p<0.001				

KAPAS: Kanagawa admission priority assessment score

ficity with proposed cut-off values of each group in the validation cohort were as follows: 32.1% and 98.0% in young people; 90.1% and 52.9% in middle-aged people; and 94.5% and 19.8% in elderly people.

Compared to the abovementioned scoring systems, the KAPAS has several advantages. The KAPAS is a simple system that does not require complex calculations or categorization. It can also be scored immediately, since it does not involve laboratory test values, which are typically not available at the initial outpatient assessment. These advantages are important for actual triage to determine which patients should be admitted, as the number of patients to be triaged is tremendous when infection rates increase.

Our study showed that both KAPAS values were significantly higher in the OXY group than in the NOXY group, and both were acceptable for predicting oxygen requirement, given that the AUCs were >0.7. To evaluate the cut-off value, we calculated the maximum values of Youden's index for the KAPAS-1 and KAPAS-2, which were 4 and 6, respectively. It is acceptable that the actual cut-off value of the KAPAS introduced by Kanagawa Prefecture is 5. The present study showed that a high KAPAS was significantly correlated with oxygen requirement, and the sensitivities of the KAPAS-1 and KAPAS-2 were high (both 90.0%), although the specificities of KAPAS-1 and KAPAS-2 were less so (62.9% and 53.6%, respectively). This indicated that most of the patients with a low KAPAS had no oxygen requirement. Our study supported the notion that the KAPAS may be useful for determining which patients are most likely to require hospitalization and may be useful as a tool for preventing healthcare system collapse.

In addition, we propose that when there are not enough inpatient beds due to an explosive increase in the number of patients, it may be useful to temporarily increase the cut-off value to optimize the balance between sensitivity and specificity. In fact, since the KAPAS was introduced to determine hospitalization priority on December 7, 2020, by Kanagawa Prefecture, the bed occupancy rate in Kanagawa Prefecture has not exceeded 91% despite a rapid and drastic increase in the number of COVID-19 patients in Japan (17). The KAPAS may thus have contributed to avoiding all beds being occupied by COVID-19 patients.

Several limitations associated with the present study warrant mention. First, inpatients were included in this study, but outpatients were not. However, because it was recommended that COVID-19 patients >65 years old or with underlying diseases be hospitalized as a principle in Japan, many patients with mild COVID-19 were included in this study. We determined that we were still able to sufficiently validate the usefulness of the KAPAS. Second, the number of patients included in this study was not large. There were factors associated with the KAPAS that patients in this study did not have. Larger-scale validation studies are thus needed. Third, patients infected with mutant SARS-CoV-2 or post-

vaccination infections were not included in this study. The KAPAS, version 3 (KAPAS-3), which added the vaccination history as a factor to KAPAS-2, was introduced in August 2021 (23). Further studies are therefore needed to determine if the KAPAS is useful in the treatment of these patients as well.

In conclusion, a high KAPAS was significantly correlated with oxygen requirement. Thus, KAPAS may be useful for deciding which patients are most likely to require hospitalization and for selecting non-hospitalized patients who should be carefully monitored so that immediate action can be taken when inpatient care is needed.

The authors state that they have no Conflict of Interest (COI).

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