Can the Multidimensional Prognostic Index Improve the Identification of Older Hospitalized Patients with COVID-19 Likely to Benefit from Mechanical Ventilation? An Observational, Prospective, Multicenter Study

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ABSTRACT

Objective: Data on prognostic tools for indicating mechanical ventilation in older people with COVID-19 are still limited. The aim of this research was to evaluate if the Multidimensional Prognostic Index (MPI), based on the Comprehensive Geriatric Assessment (CGA), may help physicians in identifying older hospitalized patients affected by COVID-19 who might benefit from mechanical ventilation.

Design: Longitudinal, multicenter study.

Settings and Participants: 502 older people hospitalized for COVID-19 in 10 European hospitals.

Methods: MPI was calculated using 8 different domains typical of the CGA. A propensity score, Cox’s regression analysis was used for assessing the impact of mechanical ventilation on rehospitalization/mortality for 90 days’ follow-up, stratified by MPI ≥ 0.50. The accuracy of MPI in predicting negative outcomes (ie, rehospitalization/mortality) was assessed using the area under the curve (AUC), and the discrimination with several indexes like the Net Reclassification Improvement (NRI) and the Integrated Discrimination Improvement (IDI).

Results: Among 502 older people hospitalized for COVID-19 (mean age: 80 years), 152 were treated with mechanical ventilation. In the propensity score analysis, during the 90-day follow-up period, there were 44 rehospitalizations and 95 deaths. Mechanical ventilation in patients with MPI values ≥ 0.50, indicating frailer participants, was associated with a higher risk of rehospitalization/mortality (hazard ratio 1.56, 95% CI 1.09–2.23), whereas in participants with MPI values < 0.50 this association was not

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significant. The accuracy of the model including age, sex, respiratory parameters, and MPI was good \((AUC = 0.783)\) as confirmed by an NRI of 0.2756 \((P < .001)\) and an IDI of 0.1858 \((P < .001)\), suggesting a good discrimination of the model in predicting negative outcomes.

Conclusions and Implications: MPI could be useful for better individualizing older people hospitalized by COVID-19 who could benefit from mechanical ventilation.

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Materials and Methods

Study Design and Population

For the aims of this research, we included (1) patients \(> 65\) years of age, (2) consecutively admitted to the hospital with ascertained diagnosis of COVID-19 through nasopharyngeal swab with real-time polymerase chain reaction, and (3) able to sign an informed consent. Exclusion criteria were age \(< 65\) years, unwillingness to participate in the study, and inability to give informed consent. The period of enrollment and follow-up was between April 2020 and August 2021. At the time of enrollment, vaccines against COVID-19 were not available. The patients were enrolled after admission in each ward across 10 European centers located in Italy (5 centers, \(n = 272\) participants included), Spain (1 center, \(n = 46\)), Czech Republic (1 center, \(n = 153\)), Portugal (1 center, \(n = 34\)), and Germany (2 centers, \(n = 43\)).

This was a prospective, observational study conducted according to the World Medical Association’s 2008 Declaration of Helsinki, the guidelines for Good Clinical Practice, and the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. The ethical committees of each of the centers formally approved the study. Informed consent was given by participants who underwent initial evaluation and/or their proxies in case of an inability to understand and sign the informed consent (eg, severe dementia) for their clinical records to be used in clinical studies according to the Local Law.

Outcomes

Data regarding the outcomes of interest were ascertained using administrative data, such as death certificates and medical records during a maximum follow-up period of 90 days from the admission in each ward. The primary outcome of our research was a composite end point made of rehospitalization and all-cause mortality. Secondary outcomes were these end points, singularly considered. Dates of death were identified from death certificates and dates of readmission in hospital using medical records.

Exposure: Mechanical Ventilation

Mechanical ventilation was recorded as NIV and orotracheal intubation using medical records during hospitalization.

MPI

The MPI was made at the admission into the medical ward and included information from 8 different domains of the CGA, in order to give clinical prognostic information. MPI was calculated using the following parameters:

1. Functional status was estimated based on the Activities of Daily Living index.
2. Independence status was based on the performance of instrumental activities of daily living.

The coronavirus disease (COVID)-19 pandemic increased the interest in best medical practices in older adults with acute respiratory failure. COVID-19, particularly in older people before the vaccination, was characterized by a rapid worsening of the disease, and at the same time, the limited efficacy of specific antiviral therapies increased the risk of intensive care unit (ICU) overcrowding and finally mortality. Finally, the usefulness of MPI was recently confirmed in terms of prognostic importance in COVID-19 in both hospital and nonhospital settings. However, whether MPI can be used as a tool in the selection of older people with acute respiratory failure who are at high risk of noninvasive ventilation (NIV) failure was still unknown, even if this tool seems to be useful for better identifying older people with acute respiratory failure who are at high risk of noninvasive ventilation (NIV) failure.22

During the COVID-19 pandemic, the limited availability of mechanical ventilation and the advanced mean age of symptomatic patients requiring hospitalization aroused relevant ethid dilemmas that are still not solved, such as which patients best take advantage from mechanical ventilation. This pandemic showed once again the need of prognostic criteria able to identify those older individuals with COVID-19 who can benefit or not from intensive treatments, such as mechanical ventilation. Moreover, evidence-based prognostic rules could be useful to optimize resources because, as widely confirmed, age and comorbidities are not sufficient. A pivotal systematic review regarding the use of prognostic tools in COVID-19 showed that proposed models are poorly reported, at high risk of bias, with a probably optimistic performance. Other authors concluded that clinicians should use their clinical experience, particularly in older people, waiting for validated prognostic tools.

There is a general agreement that the strongest and most consistent predictors of mortality in older people include comorbidity and functional status and that in this regard the Comprehensive Geriatric Assessment (CGA), which explores information on clinical, functional, and psychosocial domains of the older people, seems to be very useful to give prognostic information. A seminal systematic review published 1 decade ago found several prognostic indexes potentially useful in older people, but these tools should be based on a multidimensional assessment, including some key factors, such as certain comorbid conditions, social support, and functional, biological, and cognitive factors. The main problem for the prognosis in older people, even with COVID-19, is that one size does not fit all, further motivating the clinical usefulness of the CGA. In this sense, the Multidimensional Prognostic Index (MPI) is a well-validated CGA-based prognostic tool very useful to predict short- and long-term mortality risk and is commonly used in hospitalized older patients. Several multicenter studies have extensively reported that MPI has an excellent accuracy and calibration in predicting negative clinical outcomes during hospitalization. Indeed, the MPI has been validated in more than 54,000 older adults with the most common chronic and acute age-related diseases in more than 50 international studies. MPI seems to be useful for better tailoring pharmacologic and nonpharmacologic interventions in older people. Finally, the usefulness of MPI was recently confirmed in terms of prognostic importance in COVID-19 in both hospital and nonhospital settings. However, whether MPI can be used as a tool in the selection of older people with COVID-19 candidates to mechanical ventilation is still unknown, even if this tool seems to be useful for better identifying older people with acute respiratory failure who are at high risk of noninvasive ventilation (NIV) failure.

Given this background, the aim of this research was to evaluate if the CGA-based MPI assessed at hospital admission can help physicians in identifying older patients with COVID-19 who might benefit from mechanical ventilation in terms of rehospitalization and mortality rate at 90 days’ follow-up, across several European centers.
3. Cognitive status was measured using the Short Portable Mental Status Questionnaire.26
4. Comorbidity was assessed using the Cumulative Illness Rating Scale,27 which uses a 5-point ordinal scale (score 1–5) to estimate the severity of pathology in each of 13 systems. Based on the ratings, the Cumulative Illness Rating Scale—Comorbidity Index score, reflecting the number of concomitant diseases, was derived from the total number of categories in which moderate or severe levels (grade from 3 to 5) of disease were identified (range from 0 to 13).
5. Nutritional status was investigated with the Mini Nutritional Assessment—Short Form,28 which includes information on several nutritional aspects.
6. Risk of developing pressure sores was evaluated through the Exton Smith Scale.29
7. Medication use was defined according to the Anatomical Therapeutics Chemical Classification code system (ATC classification), and the number of drugs used by patients at admission was also recorded.
8. Social domain was categorized in living alone, with family (or with other support), and in institution.

For each domain, a tripartite hierarchy was used, that is, 0 = no problems, 0.5 = minor problems, and 1 = major problems, based on conventional cutoff points derived from the literature for the singular items.30 The sum of the calculated scores from the 8 domains was divided by 8 to obtain a final MPI risk score ranging from 0 = no risk to 1 = higher risk of mortality. MPI requires between 15 and 25 minutes for its complete execution.31 In Supplementary Table 1, we reported as ¼
do data items.12 The sum of the calculated scores from the 8 domains was divided by 8 to obtain a

The association between mechanical ventilation and the outcomes of interest was measured using a Cox regression analysis, using a propensity-score model. The results were reported as hazard ratios (HRs) with their 95% CIs. Because the interaction MPI by mechanical ventilation in predicting the composite and the singular outcomes was significant (P < .05), we have reported the HRs stratified according to an MPI value less or more than 0.50 that was identified as the best cutoff as sensitivity and specificity using the Youden index.32

The accuracy of prognostic factors predicting negative outcomes during follow-up, in terms of area under the curve (AUC), was analyzed using different models, that is, age and sex, age, and sex, and PaO2/FiO2, and age, sex, PaO2/FiO2 combined with MPI score. The categorization of AUC is fully reported in Supplementary Table 2.33,34

The improvement in model performance was evaluated by the inclusion of MPI into the model. Calibration was analyzed using the C-statistics. The predicted probabilities derived by the models without MPI were then classified into 2 different risk categories (50%) used to build reclassification tables for patients with negative events (death or rehospitalization) and without these events. Improvement in risk prediction by adding the MPI to age, sex, and PaO2/FiO2 was then assessed estimating the Net Reclassification Improvement (NRI) and the Integrated Discrimination Improvement (IDI).35,36 Briefly, the NRI focused on reclassification tables built separately for patients with and without events and quantifies the correct movement in predefined categories (upward for events and downward for nonevents); the IDI can be defined as an average over the range of all possible risk cutoffs of the improvements on sensitivity minus the worsening on specificity.

All analyses were performed using the SPSS 21.0 for Windows (IBM Corp, Armonk, NY) and Stata, 14.0. All statistical tests were 2-tailed, and statistical significance was assumed for a P value < .05.

Results

Of the 548 subjects recruited, 502 were analyzed after removing the nine without calculable MPI scores and the 37 lost to follow-up. Overall, 174 participants died during the 90 days of follow-up, mainly in 2020 (118 participants) compared with 2021 (56).

Among the 502 people initially included, 152 (30.3%) underwent mechanical ventilation, as shown in Table 1. The people experiencing a mechanical ventilation were significantly frailer [MPI = 0.55 ± 0.24 (mechanical ventilation) vs 0.47 ± 0.23 (no mechanical ventilation); P = .001], but similar in terms of mean age (P = .11) and the proportion of females (P = .62) than their counterparts. Among the clinical signs/symptoms, dyspnea (P < .001), fever (P = .01), and cough (P < .001) were associated more frequently to mechanical ventilation compared to patients not undergoing mechanical ventilation. A significantly higher presence of bilateral ground-glass opacities at radiographic examination was present in people that needed mechanical ventilation. Finally, participants undergoing mechanical ventilation did not differ in terms of serum inflammatory parameters compared with their counterparts, although they reported worse arterial blood gas parameters in terms of PaO2/FiO2, Po2, PCO2, and Pco2 (Table 1).

For decreasing the role of potential confounders on outcomes of interest from the 502 people initially included, using a propensity score accounting for age, gender, and MPI, 91 patients undergoing mechanical ventilation (2 orotracheal intubation and 89 NIV) were matched to 182 controls (Table 1). People undergoing mechanical ventilation were significantly more represented in pneumonia suggestive of COVID-19 vs their counterparts, although they reported worse arterial blood gas parameters in terms of PaO2/FiO2, and age, sex, PaO2/FiO2 combined with MPI score. The categorization of AUC is fully reported in Supplementary Table 2.33,34

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gas profile indicates that the use of mechanical ventilation was related to the acute respiratory failure severity.

During the 90-day follow-up period, in the propensity-score analysis, 44 rehospitalizations and 95 deaths were observed. Table 2 shows the analyses regarding follow-up outcomes during the follow-up period using mechanical ventilation as exposure and rehospitalization and mortality as outcomes, divided according to the median value of the MPI (ie, 0.50). Mechanical ventilation was associated with a higher risk of negative outcomes (HR 1.56, 95% CI 1.09-2.23; \(P = .01\)), rehospitalization (HR 2.00, 95% CI 1.04-4.27; \(P = .03\)), and mortality (HR 2.16, 95% CI 1.34-3.48; \(P = .001\)), but only in frail people (ie, people with an MPI >0.50). On the contrary, no significant association was observed between mechanical ventilation and negative outcomes in people having an MPI score <0.50 (Table 2).

The receiver operating characteristic operator curve using different combinations of age, sex, \(\text{PaO}_2/\text{FiO}_2\) ratio and MPI as exposure and the incidence of rehospitalization/mortality during follow-up as outcome demonstrated that \(\text{PaO}_2/\text{FiO}_2\) ratio did not increase the prognostic accuracy of age and sex (AUC = 0.674, 95% CI 0.617-0.730), while adding the MPI score led to a good predictive value (AUC = 0.783, 95% CI 0.733-0.833, \(P < .001\)) (Figure 1). As shown in Table 3, these findings were confirmed by the estimated NRI of 0.2756 (\(P < .001\)), suggesting that adding the MPI to the model with age, sex, and \(\text{PaO}_2/\text{FiO}_2\) ratio, about 28% of patients were correctly reclassified and the estimated IDI of 0.1858 (\(P < .001\)) was achieved, overall suggesting a significant improvement from a clinical point of view (Table 3).

**Discussion**

In this observational, longitudinal study, involving older people hospitalized across different European countries, we found that mechanical ventilation was associated with a higher risk of negative outcomes at 3 months of follow-up in frail older people hospitalized for COVID-19 compared with less frail individuals. Moreover, our

### Table 1
Baseline Clinical Characteristics by MPI Values

| Parameter | All Sample | Propensity Score |
|-----------|------------|------------------|
|           | No Ventilation | Mechanical Ventilation | \(P\) Value | No Ventilation | Mechanical Ventilation | \(P\) Value |
| Mean age, mean (SD) | 79.9 (7.9) | 81.1 (8.3) | .11 | 81.6 (7.6) | 81.4 (7.6) | .78 |
| Female gender, % | 57.9 | 60.3 | .62 | 40.1 | 45.1 | .44 |
| MPI domains, mean (SD) |          |                |            |                |            |
| ADL score | 3.2 (2.2) | 2.9 (2.4) | .005 | 2.8 (2.0) | 2.6 (1.9) | .56 |
| IADL score | 3.8 (2.9) | 2.8 (2.8) | <.001 | 2.3 (2.0) | 2.5 (2.1) | .36 |
| SPMSQ score | 3.1 (2.8) | 4.2 (3.7) | <.001 | 3.7 (3.0) | 3.9 (2.7) | .65 |
| ESS score | 15.1 (3.8) | 13.7 (4.3) | <.001 | 13.8 (3.4) | 13.8 (3.4) | .89 |
| MNA-SF score | 9.2 (3.5) | 7.7 (3.6) | <.001 | 7.3 (2.9) | 7.9 (2.8) | .08 |
| Number of medications | 5.7 (3.1) | 6.4 (3.2) | .04 | 6.5 (3.1) | 6.3 (3.1) | .68 |
| Living alone, % | 22.2 | 42.7 | .01 | 22.6 | 25.0 | .81 |
| IADL score | 8.06 (5.83) | 7.88 (3.97) | .70 | 7.39 (4.23) | 7.98 (4.15) | .94 |
| Arterial blood gas parameters, mean (SD) |            |                |            |                |            |
| pH | 7.44 (0.06) | 7.43 (0.09) | .42 | 7.43 (0.05) | 7.42 (0.09) | .37 |
| \(\text{PaO}_2/\text{FiO}_2\) ratio | 355 (147) | 224 (98) | <.001 | 368 (143) | 235 (106) | <.001 |
| \(\text{Pa}_2\) | 68.2 (25.8) | 52.7 (34.7) | <.001 | 66.3 (25.2) | 45.5 (36.8) | <.001 |
| \(\text{SpO}_2\) | 91.7 (9.9) | 86.9 (13.2) | <.001 | 92.7 (9.3) | 85.5 (13.1) | <.001 |
| \(\text{Pco}_2\) | 28.8 (16.4) | 36.2 (10.8) | <.001 | 25.7 (18.6) | 35.4 (10.8) | <.001 |
| Clinical and radiologic presentation |          |                |            |                |            |
| Bilateral ground-glass opacities (radiograph), % | 37.4 | 56.0 | <.001 | 28.6 | 50.0 | .001 |
| Pneumonia suggestive of COVID-19 (CT), % | 44.3 | 43.4 | <.001 | 39.6 | 40.7 | <.001 |
| Comorbidity |        |                |            |                |            |
| Fever, % | 45.8 | 58.7 | .01 | 47.8 | 56.7 | .20 |
| Cough, % | 32.4 | 53.6 | <.001 | 30.8 | 53.8 | <.001 |
| Diarrhea, % | 12.3 | 17.3 | .16 | 11.5 | 17.6 | .19 |
| Dyspnea, % | 50.3 | 76.8 | <.001 | 45.1 | 75.8 | <.001 |
| 4AT score, mean (SD) | 3.8 (4.2) | 4.1 (4.5) | .46 | 3.58 (4.10) | 4.43 (3.90) | .10 |

### Table 2
Outcomes of Interest, Stratified for the Median MPI Value, by Use of Mechanical Ventilation in Propensity Score Analysis

| Parameter | Composite Outcome* | Rehospitalization | Mortality |
|-----------|-------------------|-------------------|-----------|
|           | MPI < 0.50 | MPI > 0.50 | MPI < 0.50 | MPI > 0.50 | MPI < 0.50 | MPI > 0.50 |
| Sample size | 100 | 173 | 100 | 173 | 100 | 173 |
| Number of events | 44 | 17 | 27 | 27 | 27 | 68 |
| Percentage of events | 44.0 | 54.9 | 17.0 | 15.3 | 27.0 | 39.3 |
| No mechanical ventilation, HR (95% CI) | 1 (referent) | 1 (referent) | 1 (referent) | 1 (referent) | 1 (referent) | 1 (referent) |
| Mechanical ventilation, HR (95% CI) | 1.15 (0.68-1.94) | 1.56 (1.09-2.23) | 1.00 (0.37-2.73) | 2.00 (1.04-4.27) | 0.91 (0.41-2.02) | 2.16 (1.34-3.48) |
| \(P\) value | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 |

*Composite outcome is made by rehospitalization and mortality during follow-up period.
study indicates that the $\text{PaO}_2/\text{FiO}_2$ ratio, that is, the ratio between arterial oxygen partial pressure ($\text{PaO}_2$) and the fractional inspired oxygen ($\text{FiO}_2$), recommended as pivotal criterion for acute respiratory distress syndrome in COVID-19 and non–COVID-19 conditions,\textsuperscript{37} is poorly associated with prognosis in older people.

When analyzing the data of the entire cohort, we observed that physicians used more frequently mechanical ventilation in frailer patients that were more affected by some clinical signs and symptoms typical of COVID-19 such as dyspnea, fever, and cough or worse arterial blood gas parameters. However, when matching using a propensity score patients undergoing mechanical ventilation or not during follow-up, we observed that frailer patients experienced a higher risk of negative outcomes than those not using this intervention, suggesting that multidimensional frailty should be taken into account for better use of mechanical ventilation in older people with COVID-19. Even if there is significant evidence that the early use of mechanical ventilation may reduce in-hospital mortality,\textsuperscript{38} literature suggests that mechanical ventilation is associated with a high rate of failure in older people in both noninvasive\textsuperscript{39} and invasive forms.\textsuperscript{40} Altogether, these data indicate that current criteria for mechanical ventilation are poorly applicable to older people, again indicating the need of prognostic tools that can help the physician in the daily clinical decision making.\textsuperscript{8} In this sense, the $\text{PaO}_2/\text{FiO}_2$ ratio is widely recognized as a pivotal indicator for the need of mechanical ventilation in ARDS.\textsuperscript{41} However, our study clearly showed that this parameter did not add anything in terms of accuracy to age and sex for predicting poor prognosis in older people. The use of the $\text{PaO}_2/\text{FiO}_2$ ratio was also reported in some COVID-19 experiences as important for prognosis and for using mechanical ventilation or opting not to,\textsuperscript{42,43} but these researchers were mainly focused on adults.

Our work supported the idea that multidimensional frailty, as assessed by MPI, is probably more important than the $\text{PaO}_2/\text{FiO}_2$ ratio in determining prognosis in older people. Using a propensity score matching between people treated with mechanical ventilation and controls that included age, gender, and MPI, we observed that MPI could be a good prognostic tool because frailest people, indicated by an MPI value $>0.50$, experienced a higher risk of mortality and rehospitalization even if mechanical ventilation was used. Moreover, comparing the 2 models (ie, $\text{PaO}_2/\text{FiO}_2$ ratio vs MPI), we observed that

![Fig. 1. Receiver operating characteristic curve using different combinations of age, sex, $\text{PaO}_2/\text{FiO}_2$, and MPI as exposure and the incidence of rehospitalization/mortality during follow-up.](image)

### Table 3

| Parameters | Statistics | $P$ Value |
|------------|------------|-----------|
| IDI Age, sex, $\text{PaO}_2/\text{FiO}_2$ + MPI | 0.1858 | <.001 |
| NRI Age, sex, $\text{PaO}_2/\text{FiO}_2$ + MPI | 0.2756 | <.001 |

| Events (n = 218) | Nonevents (n = 142) |
|------------------|---------------------|
| **With MPI** | **With MPI** |
| <0.50 | 13 | 16 | <0.50 | 43 | 40 |
| >0.50 | 27 | 162 | >0.50 | 8 | 51 |

NRI, corresponding estimated Net Reclassification Improvement. NRI focused on reclassification tables and quantifies the correct movement in categories (upward for events and downward for nonevents).

IDI, corresponding estimated Integrated Discrimination Improvement. A model's discrimination is the ability to distinguish subjects who will develop an event from those who will not. IDI focused on differences between sensitivity and "1 – specificity" for all possible cutoffs for models with and without MPI and does not require predefined risk categories.
inclusion of MPI improved the accuracy from a prognostic point of view, which is necessary for taking the correct therapeutic decision in older people. Finally, adding MPI to clinical and blood gas parameters can help to better discriminate older people in terms of prognosis, which is necessary for taking the correct clinical decisions. Altogether, these findings, to our knowledge the first in COVID-19, confirmed previous results showing that MPI could be useful not only for tailoring pharmacologic approaches in older people but also for helping the physician in the areas of medicine in which less evidence is available, such as artificial nutrition or the use of mechanical ventilation in older people.

The MPI is based on multidimensional assessment derived from a standardized CGA. This tool has been already recognized as a useful prognostic tool in hospitalized older adults with critical illnesses, such as pneumonia, heart failure, or acute myocardial infarction. Also in COVID-19 condition, MPI seems to be a useful tool for clinical decision making in both hospital and nonhospital settings. In the present research, we have further shown that this tool could be used in COVID-19 patients in order to avoid unnecessary interventions (such as orotracheal intubation) in frailter patients, because this solution could be followed by a negative prognosis. Therefore, our study reported a clinical application of the MPI in a topic in which no clear indications were given, that is, in older people affected by COVID-19 and needing mechanical ventilation. As already reported by several authors during the COVID-19 epidemic, the topic of prognosis is of critical importance in older people, and our findings remind us that it is very important to assess the individual multidimensional impairment to define to the best possible extent the trajectories of acute COVID-19, beyond the patient’s chronological age.

The findings of our study must be interpreted within its limitations. First, the observational nature of this research can introduce a selection bias in the findings. Second, we were not able to separate people in NIV from those undergoing orotracheal intubation, which is important in geriatric medicine. Finally, we were not able to compare the accuracy or discrimination of the MPI compared with other indexes indicating frailty because we did not collect sufficient information for these tools.

Conclusions and Implications

MPI could be useful for physicians for better individualizing older people hospitalized by COVID-19 who could benefit from mechanical ventilation, having a good accuracy, and leading to a significant discrimination in terms of prognosis. These findings further indicate that performing a CGA that includes information on multidimensional characteristics of patients (ie, functional, cognitive, nutritional, biological, and social aspects) might help the physician to refine patient selection for mechanical ventilation and to take into consideration not just clinical, radiologic, or arterial blood gas parameters, which seem to have poor prognostic value in older people.

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**Supplementary Table 1**
Calculation of MPI

| Score in Each Domain | Low Risk (Value = 0) | Moderate Risk (Value = 0.5) | High Risk (Value = 1) |
|----------------------|----------------------|-----------------------------|----------------------|
| ADL                  | 6-5                  | 4-3                         | 2-0                  |
| IADL                 | 8-6                  | 5-4                         | 3-0                  |
| SPMSQ                | 0-3                  | 4-7                         | 8-10                 |
| ESS                  | 16-20                | 10-15                       | 5-9                  |
| MNA-SF               | 12-14                | 8-11                        | 0-7                  |
| CIRS                 | 0                    | 1-2                         | ≥3                   |
| Number of drugs      | 0-3                  | 4-6                         | ≥7                   |
| Cohabitation status  | Family               | Nursing home                | Alone                |

Add the values of the single items and divide by 8.

ADL, activities of daily living; CIRS, Cumulative Illness Rating Scale; CRP, C reactive protein; ESS, Exton-Smith Scale; IADL, instrumental activities of daily living; MNA-SF, Mini Nutritional Assessment-Short Form; MPI, Multidimensional Prognostic Index; SPMSQ, Short Portable Mental State Questionnaire.

**Supplementary Table 2**
Categorization of Area Under the Curve and Harrell C Statistic

| Values    | Area Under the Curve | C Statistics |
|-----------|----------------------|--------------|
| 0.50-0.60 | Very poor            | No better than random chance |
| 0.60-0.70 | Poor                 | Poor         |
| 0.70-0.80 | Good                 | Good         |
| >0.80     | Very good            | Strong       |