Is my patient ready for a safe transfer to a lower-intensity care setting? Nursing complexity as an independent predictor of adverse events risk after ICU discharge

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ABSTRACT

Background: Patients discharged from intensive care units (ICUs) are at risk for adverse events (AEs). Establishing safe discharge criteria is challenging. No available criteria consider nursing complexity among risk factors.
Objectives: To investigate whether nursing complexity upon ICU discharge is an independent predictor for AEs.
Methods: Prospective observational study. The Patient Acuity and Complexity Score (PACS) was developed to measure nursing complexity. Its predictive power for AEs was tested using multivariate regression analysis.
Results: The final regression model showed a very-good discrimination power (AUC 0.881; $p<0.001$) for identifying patients who experienced AEs. Age, ICU admission reason, PACS, cough strength, $PaCO_2$, serum creatinine and sodium, and transfer to Internal Medicine showed to be predictive of AEs. Exceeding the identified PACS threshold increased by 3.3 times the AEs risk.
Conclusions: The level of nursing complexity independently predicts AEs risk and should be considered in establishing patient's eligibility for a safe ICU discharge.

Introduction

Patients admitted to intensive care units (ICUs) are, in general, eligible for discharge if they reach physiologic stability and when continuous/advanced monitoring and treatment are no longer required.[1] Nevertheless, at the time of ICU discharge, patients may be affected by several dysfunctions related to the ICU admission reasons and may still require ongoing active interventions or exhibit a high level of functional deficit. These problems may persist during the recovery phase, and a significant proportion of these patients never regain their pre-ICU health status.[2] To prevent the risk of adverse events, all these factors should be considered before discharging the patient to general wards.[1,3]

Adverse events are defined as any event or injury, expected or not, caused by inadequate medical management or by negligent or substandard care, which influenced patient stability.[4,5] Adverse events may result in consequences such as clinical deterioration, cardiopulmonary arrest, medical emergency team activation, unplanned readmission to the ICU, prolonged hospital stay, or even death.[6,7] In general, adverse events are not unexpected, being often anticipated by a progressive worsening in a patient's clinical conditions,[8–10] so they may be prevented if an adequate standard of care is ensured after ICU discharge.[11] Unfortunately, for patients transferred from the ICU to a general ward, the intensity of medical and nursing care that can be provided decreases dramatically, leading to the risk of staff not quickly recognizing, understanding, and treating key changes in clinical conditions.[12,13]

In particular, outside the ICU, the nurse-to-patient ratio and the nursing skill mix may be inadequate compared to the patient's acuity and complexity due to conditions such as unstable vital signs, acute confusion, or high dependency in activities of daily living (ADL) as well as the need to manage devices such as central venous catheters or tracheostomy or to administer and monitor multiple medications or complex treatments (e.g., continuous intravenous drug infusions, artificial nutrition). The combination of factors such as increased nursing workloads, poor nursing staffing, and lack of adequate medical and nursing skills to care for clinically challenging patients may lead to insufficient patient surveillance and a greater risk of adverse events in the post-ICU unit.[14–18]

For all the above reasons, establishing when an individual patient is ready for a safe discharge from the ICU and what is the most appropriate

Abbreviations: ADL, Activities of Daily Living; APACHE II, Acute Physiology And Chronic Health Evaluation; ATP, adenosine triphosphate; AUC, area under receiver operating characteristics curve; AVPU, alert, verbal, pain, unresponsive; CI, confidence interval; CVI, content validity index; FiO_2, fraction of inspired oxygen; ICU, intensive care units; IQR, interquartile range; NEWS, National Early Warning Score; OR, odds ratio; $PaCO_2$, partial pressure of arterial carbon dioxide; PACS, Patient Acuity and Complexity Score; PaO_2, partial pressure of oxygen

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destination ward is a challenging decision that is mostly based on the discharging physician's clinical judgment, often according to subjective and difficult to reproduce criteria.[19] More objective criteria for a safe transfer from the ICU to hospital wards should be adopted to prevent serious adverse events and to improve patient outcomes and reduce healthcare costs.[18] The availability of criteria that can provide an effective risk stratification for adverse events at the time of ICU discharge may help guide clinical decision-making. Several risk stratification tools have been proposed, but most have been focused on predicting a single outcome (e.g., hospital mortality or ICU readmission), and none have considered the activation of emergency teams following ICU discharge or excessive hospital length of stay as an unwanted outcome. Moreover, although the level of nursing workload in the ICU has been found predictive for the occurrence of adverse events,[19–22] no study has demonstrated the role of the level of nursing complexity at discharge as an independent risk factor.[23] The development and validation of further predictive models for the occurrence of adverse events after ICU discharge has been strongly advocated.[1]

Therefore, the aim of this study was to investigate whether the nursing complexity level upon ICU discharge is an independent predictor of the risk for adverse events in the discharge ward (i.e., patient deterioration, unplanned ICU readmission, prolonged length of stay or death), adjusted for routinely measurable demographic, comorbid, medical, and laboratory variables.

Materials and methods

Study design, setting, and population

This was a prospective observational study conducted at the general ICU of Trieste University Hospital. This is an 866-bed hospital accredited by the Joint Commission International and divided into two different sites. Depending on their clinical characteristics, critically ill patients can be admitted to the general, cardiovascular or postoperative cardiac surgery ICUs. The study ICU has 13 beds and admits almost 800 patients a year who primarily suffer from surgery complications, acute cardiovascular or respiratory failure, major trauma, or severe infections or sepsis. All the consecutive adult patients ($\geq$ 18 years old) admitted to the ICU and having an ICU stay of at least 24 h were enrolled. Patients were excluded if they died before ICU discharge, or if they were discharged despite their serious clinical conditions because no further active interventions were planned (e.g., patients on end-of-life care). During the study period, no protocol was available to guide the discharge disposition; all discharges were established by ICU physicians on the basis of their clinical judgment.

Since simpler rules to establish the appropriate sample dimension (e.g., rules of thumb) have been questioned, the study sample size was determined based on the expected effect size, defined as "a quantitative reflection of the magnitude of some phenomenon that is used for the purpose of addressing a question of interest".[24] A minimum required sample size of 139 patients was calculated a priori for a multiple regression model including up to 15 predictors to detect an anticipated effect size (f^2) of 0.15 (corresponding to a "medium" effect size,[25] chosen for convenience to obtain a sufficiently meaningful and realistic effect size without excessively expanding the sample size) with a probability of a type I error of 0.05 and a desired statistical power level of 0.8.[26] Expecting the risk of 5% of the patients to be excluded due to relevant missing after-discharge data, it was decided to prospectively recruit at least 146 patients.

Ethical aspects

The study was conducted according to the ethical principles stated by the Declaration of Helsinki. A formal approval was obtained from the hospital authorities. At hospital admission, all enrolled patients or her/his legal representative authorized the use of their clinical data for study purposes. All the enrolled patients were cared according to the intervention established by the ICU and discharge ward physicians and nurses and no additional therapeutic or diagnostic procedure related to the study was requested or provided.

Study variables

The collected variables were chosen based on their potential to be related to a high risk for adverse events after ICU discharge. In particular, in addition to information about patient's characteristics at ICU admission, several variables describing patient's conditions at ICU discharge were collected, as described below in detail.

Conditions at ICU admission

Data on patient demographics, past medical history, the modality (from operating room after surgery, from emergency department, from ward) and the reason (categorized as: postoperative care, severe trauma, cardiorespiratory disease, cerebrovascular accident) for admission were documented; the Acute Physiology and Chronic Health Evaluation (APACHE II)[27] score was calculated within 24 h after the ICU admission. Patients were classified into five age groups ($\geq$ 44; 45–54; 55–64; 65–74; $\geq$ 75 years) according to the categories of increased risk established for the APACHE II score. The possible impact of comorbidities on patient outcome was assessed through the Charlson comorbidity index; a threshold of $\geq$ 5 was considered to identify subjects with a high burden of comorbidity.[28]

Level of nursing complexity

Data on nursing complexity were collected on the basis of a holistic assessment of the patients prior to ICU discharge through the Patient Acuity and Complexity Score (PACS), a tool developed for the study purpose, taking a cue from a previously proposed index.[29] PACS items considered a number of conditions (compromised functional status, mental confusion or sleep disturbances, complexity of drug administration, unstable vital signs) potentially related to incremental patient's complexity: the higher patient's complexity, the higher the need for direct/indirect nursing care and active surveillance, the higher the risk of adverse events in the post-ICU unit if an adequate standard of care cannot be ensured.[11]

- The patient's functional ability considered aspects related to the ADLs, since performing nursing procedures to support patients in bathing/hygiene, feeding, elimination, or mobilization/positioning can take to nurses several hours in any shift.[30]
- Aspects related to mental status (e.g., confused or delirious patients) and sleep/wake cycle were considered due to their impact on necessary nursing care and surveillance.[31]
- Actions related to drug preparation, administration, and recording have a dramatic impact on nursing workload, requiring a significant portion of the work shift and exposing patients to the risk related to medication error, especially for intravenously and continuously delivered drugs.[32,33] The need for medication administration was considered according to the complexity related to the administration route and necessary surveillance frequency.
- The necessary frequency of nursing clinical monitoring was determined based on the National Early Warning Score (NEWS),[34,35] since this tool showed the highest discriminative ability compared to several other EWSs.[36] The NEWS is based on six vital signs (AVPU score, heart frequency, respiratory rate, systolic blood pressure, body temperature, and oxygen saturation) and is increased for patients who require oxygen. Each parameter is scored up to 3 points according to the amplitude of deviance from its physiological range. The sum of the six scores determines the aggregated NEWS, according to which a higher severity level is identified, and a different frequency and intensity of clinical monitoring or an escalation of clinical care is required.[34] The association between the NEWS

and the maximum intervals to ensure between patients' assessments were derived from previously suggested criteria.[37]

Overall, the PACS considered seven fields of assessment, each scored in four categories (ranging from 1 to 4 points; possible score range: 7 to 28 points) to indicate a low, moderate, high, or very high level of patient complexity/acuity and, consequently, the incremental levels of the expected nursing workload and surveillance (Fig. 1). The content validity of PACS was assessed in order to establish the extent to which the considered items were representative of the entire domain that the score aimed to measure.[38] Content validity was evaluated by a panel of six expert nurses (three ICU nurses and three general ward nurses) with more than five years of clinical experience. First, the panel discussed the score and gave suggestions and comments on how to improve the tool. Subsequently, the panel judged each item by using a four-point Likert scale as follows: (1) not relevant; (2) slightly relevant; (3) fairly relevant; (4) very relevant. The content validity index (CVI) was used to measure content validity of each PACS item and the scale as a whole. A CVI of 0.80 or above was considered as acceptable.[39] A mean CVI = 0.96 was obtained at the items level and a mean CVI = 0.86 at the score level. Further, the PACS intra-rater reliability was assessed on a sample of 10 patients via test-retest method as a measure of the ability of the tool to provide consistent scores over time. Since retested patients must be in a clinically stable condition in the interim period,[40] a three-hour interval was established between the two assessments, in particular due to the possibility of substantial changes in vital parameters. A very strong intra-rater correlation was documented (Pearson's $r = 0.969$; $p < 0.001$).

All the data needed to assign the PACS were collected close to the ICU discharge time, so as to be representative of the patient's condition on arrival in the destination ward.

Cough strength

Particularly in patients extubated after mechanical ventilation, outcomes are dependent on airway competence, that is, the ability to generate a strong cough to clear the airway.[41] Cough strength was scored upon ICU discharge by inviting the patients to cough three times based on the following assessment[42]: "no cough:" audible air movement through the airway but the absence of a cough response; "weak cough:" feeble cough attempts, with the inability to expel secretions, if present; "strong cough:" effective cough attempts, resulting in the expulsion of secretions, if present.

Laboratory data

For the following laboratory data, the worst documented values within 12 h before ICU discharge (considered as a proxy of the most critical patient conditions while the discharge time was approaching) were recorded.

Since both blood hemoglobin and oxygen contents play a critical role in ensuring an adequate oxygen delivery to allow a normal mitochondrial oxygen consumption and ATP production,[43] both anemia and hypoxemia may cause critical deterioration in a patient's condition.[44] Data on hemoglobin and oxygenation (measured as arterial partial pressure of oxygen to fraction of inspired oxygen ratio [PaO_2/FiO_2]) were collected; patients were thus categorized into two groups according to hemoglobin (mild or nonanemic: $\geq$ 11 g/dL; moderate or severe anemia: $<$ 11 g/dL)[45] and PaO_2/FiO_2 (mild or nonhypoxic: $\geq$ 200; moderate or severe hypoxemia: $<$ 200)[46] levels.

Serum lactate concentration can be used to depict an imbalance between energy supply, demand, and consumption[47]; the level of such a parameter was considered as a proxy of adequate tissue perfusion. A serum lactate level of $>$ 2 mmol/L ($>$ 18.2 mg/dL) was chosen as a critical threshold.[48]

The partial pressure of arterial carbon dioxide ($PaCO_2$) was collected as a measure of the alveolar ventilation (normal values: 35 to 45 mmHg). Data on serum creatinine level were documented (normal values: 0.6–1.4 mg/dL), since high values are related to poor renal function, while low levels can be considered a surrogate for poor skeletal muscle mass and sarcopenia, which are independently associated with increased hospital mortality.[49] The sodium (normal values: 135–145 mEq/L) and potassium (normal values: 3.5–5.4 mEq/L) serum levels were also documented, since their nonoptimal correction before ICU discharge was previously described as related to poor outcomes.[50,51] The above parameters were subsequently categorized according to the value belonging or not belonging to the respective normal ranges.

Other variables

Upon ICU discharge, the presence of an intervention considerable as a risk factor when managed in a general ward was documented: noninvasive ventilation, tracheal intubation, tracheostomy, arterial or central venous catheters, ongoing vasoactive drugs, and enteral or parenteral nutrition.

The length of mechanical ventilation (h; 0 if patient was never mechanically ventilated during the ICU stay), length of ICU stay (h), and the destination at discharge (medical, surgical, or step-down

SCORE	FIELD OF ASSESSMENT						
	Walking and transfer	Self-care: Feeding	Self-care: Bathing/Hygiene	Self-care: Continence	Mental status and sleep/wake cycle	Minimum frequency of clinical monitoring	Drug administration
1	Independent with mobility	Independent with feeding	Independent with bathing/hygiene	Complete self-control over urination and defecation	Fully conscious and oriented, no sleep disturbances	NEWS ≤ 2 Low level monitoring (every 6 -12 hours)	Oral drugs administration or no pharmacological therapy
2	Needs help in walking	Needs partial help with feeding	Needs help getting in or out of the tub or shower	Urinary catheterization, with or without bowel incontinence	Occasional disturbances of cognition and perception, no sleep disturbances	NEWS = 3–5 Medium level monitoring (every 4 hours)	Intramuscular or subcutaneous drug administration
3	Needs help in moving between two nearby surfaces	Needs total help with feeding	Needs help with bathing more than one part of the body	Occasional bowel or urinary incontinence or need for enema	Continuous disturbances of cognition and perception, or disturbed sleep/wake cycle	NEWS = 6–9 High level monitoring (1 hourly)	Intermittent drugs/fluids intravenous infusions
4	Needs help in moving from one bed position to another	Enteral or parenteral nutrition	Totally dependent for bathing/hygiene	Permanent bowel or urinary incontinence	Drowsiness, unconsciousness, lethargy or coma	NEWS ≥ 9 Critical level monitoring (every 30 minutes)	Continuous drugs/fluids intravenous infusions

Fig. 1. The Patient Acuity and Complexity Score (PACS). The seven fields of assessment are scored from 1 to 4 points. The PACS total score can range from 7 to 28 points: the higher the score, the higher the level of patient complexity/acuity, the higher the expected nursing workload and surveillance.

units) were collected from the clinical documentation. Moreover, the presence of an "out-of-hour discharge" was documented if patients were discharged from the ICU during nighttime shifts (between 8 PM and 7 AM), as this practice was described as strongly associated with both in-hospital death and ICU readmission.[52]

Outcome measures

The occurrence of adverse events was considered when at least one of the following situations happened: (1) patient deterioration with consequent resuscitation interventions of the medical emergency team in the discharge ward; (2) unplanned readmission to the ICU; (3) hospital length of stay after ICU discharge $\geq$ 30 days; (4) hospital death.[6]

Data analysis

The continuous variables were displayed as medians and interquartile ranges (IQRs) and the nominal variables as numbers and percentages. Unadjusted comparisons between the groups were analyzed via a χ test, Fisher's test, or Mann–Whitney's *U* test, as appropriate.

The ability of the PACS to predict the considered adverse event's occurrence was tested, and two categories of patients ("low risk" and "high risk") were created based on the identified optimal cut-off value. Variables related to the occurrence of adverse events with a *p*-value < 0.1 in the bivariate analyses were tested through multiple forward stepwise logistic regression models. Accordingly, all the categorical variables were transformed to dichotomic dummy variables (e.g., PACS: high risk = 1, low risk = 0; anemia: moderate to severe = 1, no or mild anemia = 0; destination at ICU discharge: Internal Medicine = 1, Step-Down Unit or General Surgery = 0). The results were presented as odds ratios (ORs) with corresponding 95% confidence intervals (CIs). The determination coefficient of the regression models was calculated based on the Nagelkerke R^2. The performance of the predictive score and the whole logistic models in discriminating between patients having experienced or not experienced a serious adverse event was tested by calculating the area under the receiver operating characteristics curve (AUC) according to the following criteria: 0.50 to 0.59 = poor; 0.60 to 0.69 = moderate; 0.70 to 0.79 = good; 0.80 to 0.89 = very good; and $\geq$ 0.90 = excellent discrimination.[53] The maximum Youden index (*J*)[54] was considered as the optimal cut-off value.

Since the predictive model's performance could have been overestimated as simply established on the sample used to build it, the possible "over-optimism" in the final model's performance was tested using the bootstrapping technique, as this analysis was recommended for estimating the internal validity of predictive logistic regression models.[55] The bootstrap was performed by applying one-thousand times the logistic model to a new sample of subjects of the same number extracted from the original sample. The difference between the bootstrap and the original AUC represented the optimism for the study data set.

All the statistical analyses were performed using the software IBM SPSS Statistics, version 24.0 (Armonk, NY, US: IBM Corp.); the bootstrapping procedure was performed through a web-based software.[56,57] For all tests, an alpha level of $p \leq 0.05$ was set for statistical significance.

Results

The study started on March 20, 2015, and ended on September 11, 2015. During this period, 189 patients were admitted to the ICU. Most patients (n = 64; 43.2%) were admitted for post-operative care after elective or urgent surgery. Twenty-seven patients died in ICU, while 14 were transferred to a different hospital. No patients were discharged from the ICU with an end-of-life care plan. Overall, 148 patients constituted the study population; for each, the complete outcome data were available.

Table 1
Main characteristics of the study population (N = 148).

Variable	Statistics
Age	67.5; 54.0–76.8
Sex (male)	*91 (61.5%)*
Charlson comorbidity index	3.0; 2.0–5.0
APACHE II score on admission	16.0; 12.0–21.0
PACS (points)	17.5; 15.0–21.0
Length of mechanical ventilation (hours)	9.5; 6.0–124.3
Length of stay in ICU (hours)	38.3; 64.0–167.8
Haemoglobin (g/dl)	9.9; 8.9–11.1
No more than moderate anaemia	*137 (92.6%)*
Severe anaemia	*11 (7.4%)*
PaO_2/FiO_2 ratio	221.2; 150.7–289.8
Mild- or non-hypoxemia	*14 (9.5%)*
Moderate to severe hypoxaemia	*51 (34.5%)*
$PaCO_2$ (mmHg)	37.0; 33.6–40.5
Normal levels	*81 (54.7%)*
Hypo or hypercapnia	*67 (45.3%)*
Serum lactate (mg/dL)	10.0; 7.3–13.8
> 18.2 mg/dL	*17 (11.5%)*
Serum sodium (mEq/L)	139.0; 137.0–142.0
Normal levels	*125 (85.4%)*
Hypo or hypernatremia	*23 (15.5%)*
Serum potassium (mEq/L)	3.8; 3.6–4.0
Normal levels	*130 (87.8%)*
Hypo or hyperkalaemia	*18 (12.2%)*
Serum creatinine (mg/dL)	0.7; 0.6–1.1
Normal levels	*86 (58.1%)*
Low or high levels	*62 (41.9%)*

ICU: Intensive Care Unit; PACS: Patient Acuity and Complexity Score. APACHE: Acute Physiology and Chronic Health Evaluation.
Plan text: median; interquartile range. Italic text: number (percentage).

The enrolled population's main characteristics are described in Table 1. No difference was found between male and female age (female: 71.0, IQR 53.3–79.0; male 66.0, IQR 54.0–75.0; p = 0.113). Most patients (34; 35.4%) belonged to the $\geq$ 75 years age class, followed by 65–74 (24; 25.0%), 45–54, and 55–64 (both: n = 17; 17.7%) and $\leq$ 44 years (n = 4; 4.2%). During their stay in ICU, 122 patients (82.4%) underwent mechanical ventilation; no patient was discharged while mechanical ventilation (invasive or noninvasive) was still ongoing. Thirty-seven patients had both a length of MV and a stay in ICU > 75th percentile of the enrolled population (corresponding to 125 h and 200 h, respectively). Most patients were transferred to a general surgery unit. No "out-of-hour discharges" occurred.

After ICU discharge, 15 patients (10.1%) required the medical emergency team's intervention due to an acute clinical deterioration; 11 needed an unplanned ICU readmission. Twenty-three patients (15.5%) died before hospital discharge. Among the 123 who survived, 17 (11.5%) had a hospital length of stay $\geq$ 30 days. Overall, 46 patients (31.1%) experienced at least one adverse event.

In the bivariate analysis, the PACS was significantly higher ($p < 0.001$) for patients experiencing adverse events (22.0, IQR 17.0–24.0) compared to those who did not (17.0, IQR 15.0–19.0). The PACS showed a good discrimination power (AUC 0.761; 95% CI: 0.676–0.847; $p < 0.001$) at separating those patients who experienced serious adverse events from those who did not. The optimal cut-off value of the PACS to predict the occurrence of serious adverse events was 21.5 (*J*: 0.424). A total of 34 (23.0%) patients were discharged from the ICU with a PACS $\geq$ 22.

The occurrence of serious adverse events was significantly ($p < 0.05$) related to the presence of PACS $\geq$ 22, severe/moderate hypoxemia and anemia, serum sodium and creatinine out of normal ranges, a poor cough strength, a longer length of mechanical ventilation and ICU stay, the presence of tracheostomy or enteral nutrition upon ICU discharge, and Internal Medicine as the discharge ward (Table 2).

Table 2
Demographic and clinical characteristics of patients ($N = 148$) according to the occurrence of serious adverse events after ICU discharge.

Variable	No adverse event	Any adverse event	p-value
Age (≥ 55 years)[¥]	71 (79.6%)	38 (82.6%)	0.097
Sex (male)	63 (61.8%)	28 (60.9%)	0.918
Charlson comorbidity index (high risk)	32 (31.4%)	18 (39.1%)	0.356
Reason for ICU admission			0.066
Cardio-respiratory disease	30 (69.8%)	13 (30.2%)	
Cerebrovascular accident	9 (50.0%)	9 (50.0%)	
Major trauma	13 (56.5%)	10 (43.5%)	
Post-operative care	50 (78.1%)	14 (21.9%)	
PACS (high risk)	10 (9.8%)	24 (52.2%)	<0.001
Anaemia (moderate to severe)	67 (65.7%)	39 (84.8%)	0.017
Hypoxemia (moderate to severe)[§]	37 (36.3%)	27 (58.7%)	0.011
$PaCO_2$ (abnormal range)	41 (40.2%)	26 (56.5%)	0.065
Serum lactate (out of normal range)	11 (10.8%)	6 (13.0%)	0.690
Serum sodium (out of normal range)	11 (10.8%)	12 (26.1%)	0.017
Serum potassium (out of normal range)	12 (11.8%)	7 (15.2%)	0.561
Serum creatinine (out of normal range)	36 (35.3%)	26 (56.5%)	0.015
Cough strength			<0.001
No- or weak cough	22 (21.6%)	30 (65.2%)	
Strong cough	80 (83.3%)	16 (16.7%)	
Length of MV > 125 h[‡]	20 (19.6%)	17 (37%)	0.024
Tracheostomy	9 (8.8%)	12 (26.1%)	0.005
Central venous catheter	64 (62.7%)	29 (63.0%)	0.972
Enteral nutrition	31 (30.4%)	23 (50.0%)	0.022
Parenteral nutrition	23 (22.5%)	9 (19.6%)	0.683
Destination at ICU discharge			0.023
General Surgery	63 (75.0%)	21 (25.0%)	
Internal Medicine	22 (52.4%)	20 (47.6%)	
Step-down Unit	17 (77.3%)	5 (22.7%)	
Length of stay in ICU > 200 h[‡]	20 (19.6%)	17 (37%)	0.024

PACS: Patient Acuity and Complexity Score. ICU: intensive care unit. MV: mechanical ventilation. ¥: $p > 0.10$ for comparisons performed by adopting any other age threshold (i.e., ≥ 45; ≥ 65; ≥ 75 years). §: PaO_2/FiO_2 ratio. ‡: threshold corresponding to 75° percentile of the enrolled population.

Table 3 shows the results of the final regression model. Patients classified at a high acuity and nursing complexity (PACS ≥ 22) upon ICU discharge had a significantly higher adjusted risk of adverse events (OR 3.335; 95% CI 1.072−10.377; $p = 0.038$) compared to those who were scored at a low risk. Overall, the model demonstrated a very good discrimination power (AUC 0.881; 95% CI: 0.825−0.937; $p < 0.001$) in identifying patients who experienced adverse events. The bootstrap optimism estimate was 0.003; thus, the AUC corrected for optimism was 0.878 (95% CI 0.820−0.931), showing a good internal validity of the regression model.

Discussion

The present study's main result is that, in our population of patients discharged from the ICU, the level of acuity and nursing complexity independently predicted the risk of adverse events. The novelty of this study was to have measured the patient's acuity and nursing complexity level using the newly developed PACS. Exceeding the identified PACS threshold upon ICU discharge identified a 3.3 times greater risk of adverse events occurrence in the destination wards.

The PACS weighed the patient's complexity of care to be provided in wards different from the ICU, where the potential to ensure a high level of nursing surveillance or monitoring is deeply reduced. It is widely proven that in medical/surgical units an insufficient nurse staffing compared the required level of patient care, as well as the related risk of omissions in nursing care due to the increase in nursing workload, are linked to negative patient outcomes.[58,59] In a study considering the patient's functional status and need for specific nursing interventions at the time of ICU discharge, only the nursing demand for complex respiratory care (comprising a respiratory parameter assessment and pulmonary support interventions) was identified as independently predictive of adverse events.[19] Other studies considered the nursing workload level in the ICU as a potential predictor for the occurrence of adverse events;[20−22] however, since the nursing workload was quantified based on specific critical care treatments, this measure may not represent the need for nursing care in settings where such treatments were no longer provided. Furthermore, nursing workload depends not only on the characteristics of the intervention provided but also on the clinical severity and the complexity of care required by the patients.[60] In our investigation, both the patient's nursing needs and clinical condition were considered to calculate a comprehensive weighted score, with the aim of better representing the patient's overall complexity at ICU discharge (and thus at hospital ward admission).

Although a certain degree of residual instability and functional deficit is fully expected at ICU discharge, it is necessary to ensure that the patient's comprehensive conditions are compatible with the level of care deliverable in the destination ward. The present study's findings indicate that eight simple-to-assess conditions derived from the medical, nursing, and laboratory data (i.e., age, nursing complexity level, cough strength, abnormal levels of arterial $PaCO_2$, serum creatinine and sodium, major trauma or cerebrovascular accident as the ICU admission reason, and Internal Medicine as the discharge ward) can independently predict the risk of serious adverse events. To the best of our knowledge, this was the first study considering the level of needed nursing care and the patient's ability to have an effective cough strength for airway clearance as potential prognostic factors. Clinicians should consider delaying the patient's transfer until one or more modifiable compromised conditions are corrected (e.g., by treating electrolyte imbalances, normalizing vital signs, and/or improving ventilation), as their normalization could not be safely delegated to the destination ward. When the normalization of any condition is impossible to obtain in a reasonably short time (e.g., a high PACS score due to a highly compromised functional status requiring rehabilitation) or when the risk factor cannot be changed (e.g., age, reason for ICU admission), every effort should be made to adopt solutions to improve patient safety. For example, patients identified at a high risk of deterioration should be transferred to a Step-Down Care unit,[1] while the transfer from the ICU to Internal Medicine wards should always be carefully weighed in light of the risk for poor and unwanted outcomes. Unfortunately, in the "real world," this purpose is often undermined by workload pressure, ICU bed requirement for new admissions, and the lack of intermediate care beds.[61]

Safe transfer from the ICU is, in general, a complex process that does not end at the time of the ICU discharge.[62] The decision to discharge each individual patient should be discussed by ICU nurses and physicians to enhance and holistically combine all the relevant information. Moreover, the awareness about the existing gap between the level of care provided in the ICU and in the general wards should induce the sending and receiving units' healthcare providers to work together, considering an appropriate continuity of care as a shared collective responsibility.[63] A solution proposed to improve the outcome of patients discharged from the ICU is the "critical care transition program,"[64] usually consisting of experienced critical care nurses or other healthcare professionals who ensure proactive surveillance rounds and the regular follow-up of patients after ICU discharge and support ward nurses and physicians with the patient's care management.[65,66] Although the results of the published research are controversial, critical care transition programs have a strong potential to reduce the risk of adverse events.[67] However, it seems unrealistic to expect a significant patient outcome improvement through a transitional strategy based only on the recognition of

Table 3
Stepwise multiple logistic regression of adverse events occurrence on study variables (likelihood ratio: 115.807; $R^2 = 0.516$; $p < 0.001$).

Predictor	B (SE)	Wald test	OR (95% CI)	*p*-value
PACS: "high risk" (≥ 22)	1.205 (0.579)	4.327	3.335 (1.072 to 10.377)	0.038
Cough strength: no- or weak-cough	1.569 (0.563)	7.759	4.800 (1.592 to 14.475)	0.005
$PaCO_2$: out of normal range	1.399 (0.518)	7.291	4.052 (1.468 to 11.186)	0.007
Creatinine: out of normal range	1.328 (0.498)	7.111	3.775 (1.422 to 10.021)	0.008
Sodium: out of normal range	1.215 (0.588)	4.270	3.370 (1.065 to 10.666)	0.039
Admitted in ICU: major trauma or CVA	1.803 (0.587)	9.426	6.070 (1.920 to 19.193)	0.002
Age: ≥ 55 years	1.498 (0.624)	5.762	4.473 (1.316 to 15.199)	0.016
Transfer to an Internal Medicine unit	1.202 (0.531)	5.128	3.326 (1.175 to 9.414)	0.024
Intercept	−**5.439 (0.968)**	*31.542*	*0.004 (/)*	*<0.001*

Variables excluded from the final model: anemia (moderate to severe); hypoxemia (moderate to severe); tracheostomy; length of stay in ICU > 75th percentile of the enrolled population.
OR: odds ratio; CI: confidence interval; PACS: Patient Acuity and Complexity Score; $PaCO_2$: arterial partial pressure of carbon dioxide; CVA: cerebrovascular accident.

clinical deterioration while on-call or during a planned follow-up in the destination ward[68] (i.e., effectively closing the stable door after the horse has bolted). Healthcare policy should support the adoption of broader, more complex organizational strategies to improve the outcome of patients discharged from ICUs.[68−71] First, safe and effective ICU discharge criteria should be adopted. Second, step-down or intermediate care beds should be available to transfer the most at-risk patients. Third, some aspects of the patient's discharge path should be proactively managed, for example by implementing verbal and written medical/nursing handover, including medication reconciliation, and by removing invasive devices and supports as soon as they are no longer clinically needed. Fourth, early physical and pulmonary rehabilitation focused on the early recovery of respiratory and functional abilities should be promoted. Finally, regular critical care transition follow-up should be ensured together with the implementation of Early Warning/Track-and-Trigger System hospital plans to promptly detect and treat patients' deterioration.

Limitations

This study does present some limitations that should be considered while interpreting the results. We adopted an observational study design as the most appropriate to provide information to describe the outcomes achieved in daily clinical practice.[72] Accordingly, we enrolled a sample of consecutively admitted patients in which confounding factors could not be controlled a priori. Moreover, the study population showed characteristics that are not necessarily representative (e.g., mean age, comorbidities, ICU length of stay) of other general ICU patients. Indeed, the case mix of patients enrolled during the study period showed a prevalence of admissions related to postoperative care and was characterized by relatively short ICU stay and low acuity (according to the APACHE II score). Consequently, despite the confirmed internal validity of the logistic regression model, the predictive power of the risk factors identified by the present study could be different when applied to different populations. Finally, a "medium" effect size was established to calculate the study sample size; however, a power analysis based on a smaller targeted effect size (and thus the recruitment of a larger population) could have led to different results. Given the relatively small sample enrolled, our results should be confirmed by replicating the study across different populations and with larger samples.

Conclusion

The decision to discharge each individual patient from the ICU should be made after drawing a composite picture of her/his clinical condition and considering the different aspects of the medical and nursing care, always bearing in mind that patients will be transferred to wards that can never ensure a level of treatment and surveillance similar to that in the ICU. The opportunity of using accurate screening criteria to support the decision-making discharge process could prevent unwanted adverse events and improve patient outcomes. In addition, a comprehensive clinical and organizational strategy should be adopted to guide patients' safe transition from the ICU to hospital wards.

Further studies are necessary to prospectively test the reliability of the identified variables in different ICU populations and to explore other potential predictors of serious adverse events after ICU discharge. Moreover, being based on simply and routinely collected data, the PACS could be tested and validated in other settings and populations.

Declaration of Competing Interest

No conflict of interest has been declared by the authors.

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