Characteristics of patients readmitted to intensive care unit: a nested case-control study

OY Tam *, SM Lam, HP Shum, CW Lau, Kenny KC Chan, WW Yan

ABSTRACT

Objectives: To evaluate the pattern of unplanned readmissions to the intensive care unit and identify patients at risk of readmission.

Design: Nested case-referent study.

Setting: Tertiary hospital, Hong Kong.

Patients: A total of 146 patients with unplanned intensive care unit readmission were compared with 292 control patients who were discharged from the intensive care unit alive and never readmitted. Cases and controls were matched for age, gender, and disease severity.

Main outcome measures: Patient demographics, initial and pre-discharge clinical parameters, reasons for readmission, and outcomes were studied.

Results: During the 30-month study period, the readmission rate was 5.1%. Readmitted patients had significantly higher mortality and longer mean hospital lengths of stay (both P<0.001). Most patients in this cohort (36.3%) were readmitted for a respiratory cause. Based on classification tree analysis, postoperative patients with sepsis (adjusted P=0.043), non-operative septic patients with fluid gain 24 hours pre-discharge (adjusted P=0.013), and non-septic patients with increased sputum quantity on discharge (adjusted P=0.006) were significantly associated with intensive care unit readmission.

Conclusion: Incomplete resolution of respiratory conditions remained an important reason for potentially preventable intensive care unit readmission. Attention to fluid balance and sputum quantity before intensive care unit discharge might prevent unplanned intensive care unit readmission.

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New knowledge added by this study

- The characteristics of patients readmitted to the intensive care unit (ICU) for worsening of pre-existing conditions were different from those readmitted for new complications.
- Risk factors for readmission identified in this study included sepsis during the index admission; positive fluid balance, excessive sputum quantity, weak limb power, higher base excess, and lower haematocrit pre-discharge.

Implications for clinical practice or policy

- Early identification of patients at risk and appropriate preventive measures could improve ICU readmission rates and patient outcomes.

Introduction

According to various studies, patient readmission rates to the intensive care unit (ICU) range from 5% to 10%.[1-5] Consistently, readmitted patients had much poorer outcomes, higher hospital mortality, and their length of stay (LOS) in hospital was longer.[1,3,5-9] Readmissions due to premature ICU discharge are potentially preventable, and may be attributed to deterioration of the primary or existing medical condition. Nevertheless, some readmissions are unavoidable, as there can be occurrence of new complications at any time after initial ICU discharge. Other factors possibly contributing to ICU readmissions are organisational factors, such as ICU occupancy, and availability within a step-down unit.[5,10,11] Although the early readmission rate has been advocated as an indicator of ICU performance, there is little evidence of a correlation between early ICU readmissions and overall quality of ICU care.[2,5,12,13] Risk factors have been identified for ICU readmission.[5,7,11,14-16] Readmitted patients tend to be older, and have higher severity scores on initial admission and on discharge.[1,5,8,15,17] Recently, Gajic et al[18] produced a prediction model with acceptable validity.

This present study aimed to identify factors

associated with unplanned ICU readmissions by comparing severity-matched cases and controls, whilst focusing on patient variables at the time of ICU discharge. As it had been repeatedly shown that the initial disease severity of a patient was associated with readmissions, we hypothesised that by comparing severity-matched patients, we might identify modifiable risk factors for ICU readmissions, especially those that were potentially preventable.

再入住深切治療病房的患者的特徵：巢式病例對照研究

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目的：探討病人未經預約再入住深切治療病房（ICU）的情況，並識別重返ICU的高危病人。

設計：巢式病例對照研究。

安排：香港一所大學醫院。

患者：為146個未經預約入住ICU的病例與292個存活並沒有再次入住ICU的對照病例進行了比較。病例組與對照組的年齡、性別和疾病的嚴重程度相匹配。

主要結果測量：病人的人口學數據、入住和離開ICU時的臨床數據、再次入住ICU的病患和結果。

結果：在為期30個月的研究期間，再入住率為5.1%。再入住ICU的病人的死亡率和平均住院天數顯著較對照組差（P<0.001）。呼吸問題是最常見再入住ICU的原因（36.3%）。基於分類樹分析，與重返ICU有顯著相關的病患為：手術後敗血症患者（調整後的P值為0.043）、離開ICU前24小時液體正平衡的非手術後膿毒症患者（調整後的P值為0.013）和離開ICU前痰量多的非感染性病人（調整後的P值為0.006）。

結論：未能完善解決病患的呼吸系統問題仍然是可預防再入住ICU的一個重要原因。離開ICU時注意患者的體液平衡和痰量有助預防病人重返ICU。

Methods

The study was carried out in the ICU of Pamela Youde Nethersole Eastern Hospital, Hong Kong. This was a 20-bed closed system, mixed medical-surgical adult unit, which provided comprehensive intensive care service to patients in all specialties, except burns, transplant, and cardiothoracic surgery. A nested case-control design was therefore used to facilitate data collection.

Patient selection and data collection

Patients with unplanned ICU readmission during the same hospitalisation episode were taken as the study cases. Only the first readmission was used for analysis, whilst patients who died during their index ICU admission and those with elective readmissions were excluded. Each study case was compared with two control patients. Closest matches were selected according to the order of age (range, ± 5 years), initial disease severity according to the Acute Physiology and Chronic Health Evaluation (APACHE) IV risk of death (ROD) [range, ± 5 years], and gender. When there were more than two matched patients, the two having the closest date of ICU admission to the case were selected as controls.

Direct discharge from ICU to home or to another hospital and patients with documented "Do not resuscitate" instruction upon ICU discharge were excluded. Data from 1 January 2008 to 31 June 2010 were obtained for all cases and controls retrospectively, and included their demographic data, functional status and co-morbidities, pre-discharge physiological parameters and laboratory findings, treatments and interventions during the index admission, and time to readmission. The immediate cause of readmission was determined from detailed review of the medical record and was categorised to be of new complication (acquired after ICU discharge) or worsening of a pre-existing condition. Reasons for readmission were classified into eight major categories according to the organ system involved.

Definitions

The index ICU admissions were defined as the first admission of a case, and the only admission of a control. A patient's pre-existing conditions included the chief medical problem leading to the index ICU admission and its complications. Self-care ability was according to the Karnofsky performance status score.[19] Diagnosis of sepsis was based on the clinical judgement of attending physicians with or without microbiological proof. Discharges between 09:00 and 17:59 were daytime discharge. The proportion of ICU beds occupied at time 23:59 of each calendar day was regarded as the ICU occupancy for that day. Early readmissions were defined as readmissions within 72 hours of the index admission discharge, unless stated otherwise.

Statistical analyses

Values were expressed as mean ± standard deviation (SD) or the number of cases and proportions, as appropriate. Categorical variables were compared using the Pearson Chi squared test or Fisher's exact test, as appropriate. The Student *t* test or Mann-Whitney *U* test was used to compare quantitative data. Binary logistic regression with forward stepwise elimination was used for multivariate analysis. Predictor variables of readmission with P≤0.1 in the univariate analysis were included in the multivariate logistic regression. Variables with substantial missing data (>15%) were excluded.

At post-hoc analysis, the classification

tree model was employed to identify risks for readmission. This is a standard data mining statistical tool, using non-parametric testing to classify cases into subgroups of the dependent variable, based on the values of the independent variables. Exhaustive Chi squared Automatic Interaction Detector (CHAID) was the splitting method. The analysis was conducted in a stepwise fashion using the Pearson Chi squared test. The predictor variable with the smallest Bonferroni adjusted P value and yielding the most significant split was chosen, and nodes were created that maximised group differences on the outcome. A terminal node was produced when the smallest adjusted P value for any predictor was not significant or the number of cases in the child node was <50. Statistical analyses were conducted using the Statistical Package for the Social Sciences (Windows version 16.0; SPSS Inc, Chicago [IL], US).

Results

Patient characteristics are summarised in Tables 1 and 2. There were no statistical significant differences between readmissions and controls in

TABLE 1. Patient characteristics during their first intensive care unit (ICU) admission for those who were readmitted and those who were not (controls)*

Patient characteristic	Controls (n=292)	Readmissions (n=146)	P value
Age (years)	65.6 ± 16.2	65.7 ± 15.5	0.95
Male	192 (65.8%)	98 (67.1%)	0.78
APACHE IV ROD	0.3 ± 0.3	0.3 ± 0.3	0.84
APACHE IV APS	60.8 ± 30.1	60.9 ± 30.0	0.97
APACHE IV score	74.3 ± 32.1	74.3 ± 31.3	0.98
APACHE IV–predicted LOS (days)	5.4 ± 2.2	4.9 ± 2.2	0.01
Index admission LOS (days)	4.1 ± 5.0	6.1 ± 7.4	0.004
Hospital stay prior to index admission (days)	2.6 ± 5.2	5.2 ± 12.3	0.018
Index admission type (non-operative)	177 (60.6%)	75 (51.4%)	0.06
Outcome			
Hospital LOS (days)	22.2 ± 25.0	67.3 ± 66.4	<0.001
Mortality	20 (6.8%)	45 (30.8%)	<0.001
Physiological variables			
RR on discharge (/min)	20.2 ± 4.8	21.4 ± 5.0	0.013
Fluid balance 48-hour pre-discharge (L)	0.01 ± 1.8	0.4 ± 1.6	0.022
Sputum quantity on discharge†			
Nil / mild	227 (77.7%)	96 (65.8%)	0.01
Moderate / copious	65 (22.3%)	49 (33.6%)	
Best limb power 5/5 on discharge	155 (53.1%)	58 (39.7%)	0.008
Presence of sepsis during index admission	122 (41.8%)	82 (56.2%)	0.004
Laboratory results			
pH	7.4 ± 0.1	7.5 ± 0.1	0.015
Bicarbonate (mmol/L)	25.3 ± 4.6	26.4 ± 4.6	0.014
Base excess (mmol/L)	1.3 ± 4.1	2.5 ± 3.9	0.004
Haemoglobin (g/L)	107.8 ± 21.3	102.9 ± 20.3	0.024
Haematocrit	0.3 ± 0.1	0.3 ± 0.1	0.02
Albumin (g/L)	29.2 ± 6.7	27.3 ± 6.6	0.009
Treatment			
Required invasive mechanical ventilation at any time during index admission	132 (45.2%)	79 (54.1%)	0.079
Required re-intubation at any time during index admission	7 (2.4%)	9 (6.2%)	0.048
Required tracheostomy at any time during index admission	17 (5.8%)	15 (10.3%)	0.091
Last dialysis performed prior to ICU discharge (days)	1.7 ± 2.8	4.7 ± 6.4	0.043

Abbreviations: APACHE = Acute Physiology and Chronic Health Evaluation; APS = acute physiology score; LOS = length of stay; ROD = risk of death; RR = respiratory rate

* Values are expressed as mean ± standard deviation or No. (%) of cases

† Data were missing for one patient in the readmission group for sputum quantity

terms of age, APACHE IV score, APACHE IV acute physiology score, and APACHE IV ROD. The mean (± SD) APACHE IV ROD was 0.3 ± 0.3 in both controls and readmitted group (P=0.84). Despite the APACHE IV score and ROD being matched, there was a statistically significant difference in the mean APACHE IV–predicted LOS between the groups (5.4 ± 2.2 days in controls vs 4.9 ± 2.2 days in the readmitted group; P=0.01).

Incidents, patient demographics, and organisational factors

During this 30-month period, 3202 patients were admitted to the ICU, 380 of whom died in the ICU (361 during their first ICU admission). Of the 2841 patients discharged from the ICU alive following their first ICU stay, 146 went on to have another unplanned ICU admission (ie readmission). Of the 2643 non-readmitted eligible patients who were discharged, 292 were used as matched controls (Fig 1). Thus the unplanned readmission rate was 5.1% (146/2841) among patients surviving their first ICU admission, and the early (within 72 hours) unplanned readmission rate was 2.3% (66/2841). In our case-control cohort (146 readmissions + 292 controls = 438), 191 (43.6%) patients were from general wards, 186 (42.5%) were from operating theatres, 52 (11.9%) were direct admissions from the emergency department, and the remaining admissions were from other sources including coronary care unit and other hospitals. There were 187 (42.7%) medical patients, 146 (33.3%) were surgical and 71 (16.2%)

TABLE 2. Patient characteristics for those readmitted for worsening of pre-existing conditions and those who readmitted for new complications*

Patient characteristic	Worsening of pre-existing condition (n=82)	New complication (n=64)	P value
Age (years)	66.1 ± 15.8	65.0 ± 16.9	0.69
Male	50 (61.0%)	48 (75.0%)	0.07
APACHE IV ROD	0.3 ± 0.3	0.3 ± 0.3	0.35
APACHE IV APS	63.1 ± 30.1	57.9 ± 30.1	0.30
APACHE IV score	76.6 ± 32.5	71.3 ± 31.6	0.32
APACHE IV–predicted LOS (days)	5.7 ± 2.1	5.1 ± 2.2	0.10
Index admission LOS (days)	7.2 ± 8.8	4.7 ± 4.8	0.028
Time to readmission (days)	5.0 ± 7.6	14.7 ± 23.4	0.002
Early readmission			
<72 Hours	45 (54.9%)	21 (32.8%)	0.006
<48 Hours	33 (40.2%)	9 (14.1%)	<0.001
<24 Hours	26 (31.7%)	5 (7.8%)	<0.001
Elective index admissions	10 (12.2%)	17 (26.6%)	0.027
Non-operative index admissions	50 (61.0%)	25 (39.1%)	0.009
Parent specialty			
Medicine	41 (50.0%)	17 (26.6%)	0.004
Surgery	22 (26.8%)	29 (45.3%)	0.009
Outcome			
Hospital LOS (days)	68.8 ± 69.0	65.2 ± 63.5	0.75
Mortality	25 (30.5%)	20 (31.3%)	0.92
Physiological variables and treatment			
Highest RR			
24-Hour pre-discharge	27.4 ± 4.0	25.8 ± 4.6	0.03
48-Hour pre-discharge	29.2 ± 4.6	27.0 ± 4.5	0.009
Sepsis during index admission	54 (65.9%)	28 (43.8%)	0.008
Pulmonary sepsis	35 (42.7%)	7 (10.9%)	<0.001
Non-pulmonary sepsis	19 (23.2%)	21 (32.8%)	0.71
Received non-invasive mechanical ventilation at any time during index admission	11 (13.4%)	1 (1.6%)	0.01

Abbreviations: APACHE = Acute Physiology and Chronic Health Evaluation; APS = acute physiology score; LOS = length of stay; ROD = risk of death; RR = respiratory rate

* Values are expressed as mean ± standard deviation or No. (%) of cases

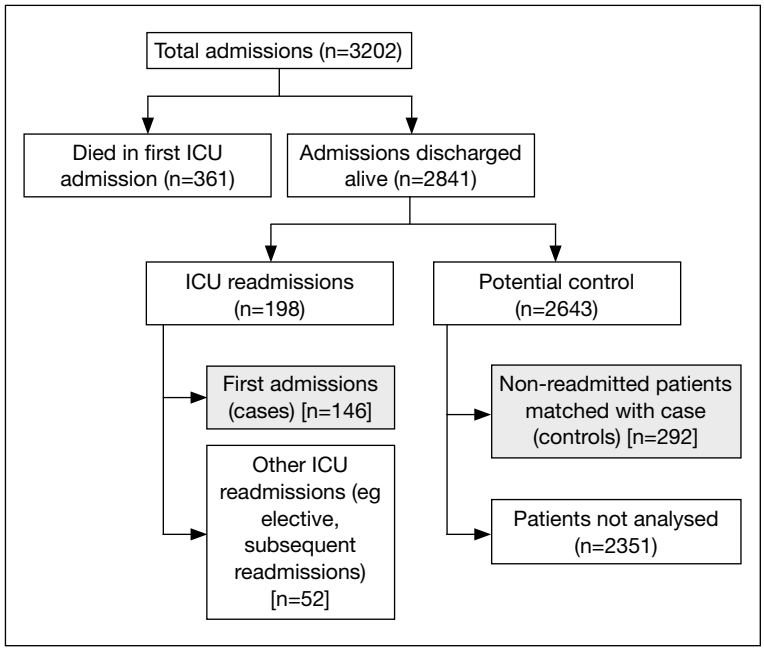

FIG 1. Flowchart of intensive care unit (ICU) admissions

were neurosurgical patients. Of the 438 patients, 363 (82.9%) were emergency admissions.

Among the 146 readmitted patients, 36 (24.7%) had neurological diseases, 35 (24.0%) had gastrointestinal diseases, and 28 (19.2%) had respiratory diseases as their initial/primary admission diagnosis. Readmitted patients had spent significantly more days in hospital than controls prior to their index admissions (5.2 ± 12.3 vs 2.6 ± 5.2 days; P=0.018; Table 1). Self-care ability before ICU admission and presence of co-morbidities did not differ significantly in the two groups.

Of the 146 unplanned readmitted patients, 66 (45.2%) were early readmissions (within 72 hours of the index admission discharge), 42 (28.8%) were within 48 hours, and 31 (21.2%) within 24 hours. The overall readmission rate for daytime discharges was 5.2% (130/2500), while for nighttime discharges it was 5.1% (16/314). The early readmission rate for daytime discharges was 2.3% (57/2500), while for nighttime discharges it was 2.9% (9/314). The ICU occupancy and nighttime discharges did not have a significant impact on overall readmissions (P=0.844) and readmissions within 72 hours (P=0.096). Higher ICU occupancy was significantly associated with early readmissions (within 48 and 24 hours), compared with late readmissions beyond 48 and 24 hours (*t* test, P=0.029 and 0.049, respectively).

Reasons for readmission and patient outcomes

Among the unplanned readmissions (n=146), 53 (36.3%) were for respiratory causes, 82 (56.2%) for worsening of pre-existing conditions, and 64 (43.8%) for new complications. Among the 82 patients with worsening of pre-existing conditions, 22 (26.8%) had a respiratory admission diagnosis compared to 6/64 (9.4%) who were readmitted for new complications (P=0.008). Postoperative patients accounted for 32/82 (39.0%) of the patients readmitted with worsening of pre-existing conditions, as opposed to 39/64 (60.9%) who were readmitted for new complications (P=0.009).

Compared with patients readmitted for new complications, those readmitted for worsening of pre-existing conditions had significantly longer mean (± SD) index ICU LOS durations (7.2 ± 8.8 vs 4.7 ± 4.8 days; P=0.028) and shorter mean times to readmission (5.0 ± 7.6 vs 14.7 ± 23.4 days; P=0.002). Among those who were readmitted for worsening of pre-existing conditions, the highest proportion was for respiratory problems (36/82, 43.9%). The reasons for readmission for new complications were diverse, but respiratory problems were still the most common (17/64, 26.6%).

Patient outcomes in terms of hospital mortality and mean hospital LOS were significantly worse in the readmitted group, despite being matched for initial severity (Table 1). The difference in outcomes in patients readmitted for worsening of pre-existing conditions or new complications was not statistically significant (Table 2). Patients readmitted early within 72 hours (13/66, 19.7%) had significantly lower mortality than those readmitted beyond 72 hours (32/80, 40%; P=0.008).

Risk factors for readmission

Significant findings in the univariate analysis comparing readmissions and controls are shown in Table 1. Factors examined that were not significant included admission type (elective or emergency), admission source; self-care ability before ICU admission; presence of co-morbidities; admission diagnosis; ICU discharge time; ICU occupancy on discharge day; mean arterial blood pressure, heart rate, fractional inspired oxygen (FiO_2), Glasgow Coma Scale (GCS) score on discharge; partial pressure of carbon dioxide in arterial blood, partial pressure of oxygen in arterial blood (PaO_2), white cell count, platelet count, clotting profile, and serum levels of urea, creatinine, and total bilirubin on discharge; whether any anti-arrhythmic agents, inotropic agents, invasive mechanical ventilation, non-invasive ventilation (NIV), tracheostomy, dialysis given at any time during index admission; intubation time; and time from extubation to discharge. Characteristics of patients readmitted for worsening of pre-existing problems and for new complications are shown in Table 2. Patients readmitted for worsening of pre-existing problems had higher mean respiratory rates pre-discharge; more sepsis (especially pulmonary),

TABLE 3. Binary logistic regression on predictors of intensive care unit (ICU) readmission

	Odds ratio* (95% confidence interval)	P value
Fluid balance in the last 48 hours of index admission	1.249 (1.083-1.440)	0.002
Base excess	1.097 (1.035-1.162)	0.002
Hospital stay prior to index admission	1.047 (1.012-1.082)	0.007

* Odds ratio refers to odds associated with a unit increase in the predictor variable. For predictors of ICU readmission, Nagelkerke R^2 statistics was 0.139. Hosmer-Lemeshow goodness-of-fit test was not significant (P=0.645)

and more likely to receive NIV. Similarly, patients readmitted early (within 72 hours) also had higher respiratory rates on discharge and were more likely to receive NIV than those readmitted late.

Factors identified as predisposing to ICU readmissions in the multivariate logistic regression were: positive fluid balance in the last 48 hours of the index admission, higher base excess on discharge, and longer hospital stays prior to the index admission (Table 3). Other covariates included: index admission LOS; admission type (postoperative or non-operative); physiological variables including respiratory rate, cardiac rhythm, sputum quantity, and best limb power on discharge; presence of sepsis during the index admission; haematocrit (HCT) on discharge; treatment including mechanical ventilation, re-intubation and tracheostomy during the index admission; and time to last dialysis prior to ICU discharge. Serum albumin values on discharge were excluded, because missing data exceeded 15%.

Classification tree analysis

Tree model 1 shows the determinant factors associated with ICU readmission (Fig 2a). The most significant predictor was whether or not the patient suffered from sepsis during the index admission (adjusted P=0.004, χ^2 = 8.093). Patients with postoperative sepsis (adjusted P=0.043, χ^2 = 4.086) and non-operative sepsis with fluid gain on discharge (adjusted P=0.013, χ^2 = 13.181) increased the readmission risk further. For non-septic patients, sputum quantity on discharge had a significant impact on readmissions (adjusted P=0.006, χ^2 = 7.528). Tree model 2 demonstrates that septic patients without full limb power at discharge from the ICU had a higher risk of deterioration than those with any other pre-existing condition (Fig 2b). In contrast to readmissions due to new complications, postoperative patients with a HCT of ≤0.34 were at highest risk (Tree model 3, Fig 2c).

Discussion

In our cohort, 5.1% of those who survived their first ICU admission were readmitted to the ICU; early readmissions amounted to 2.3%. The outcome of readmitted patients was significantly worse than that of those not readmitted, despite being matched for illness severity in terms of APACHE ROD when initially admitted to the ICU. This outcome discrepancy signifies the importance of identifying patients at high risk of deterioration after initial discharge from intensive care. The readmitted group had a significantly shorter APACHE IV–predicted LOS than the controls. Despite this, the actual ICU LOS in the controls was shorter than predicted, while in the readmitted group, it was longer than predicted. This suggested that despite being matched for initial severity, readmitted patients had poorer responses to treatment or had already endured longer initial ICU stays. Not surprisingly, delay in ICU admission increased a patient's risk of readmission; readmitted patients had significantly longer mean values for hospital LOS prior to their index ICU admission, apart from being a significant predictor of ICU readmission in the multivariate analysis. Our study also demonstrated that patients readmitted for worsening of pre-existing conditions and for new complications had different characteristics, but comparable outcomes.

The influence of pulmonary status on the risk of readmission is not debated. Previous studies found pulmonary disorder to be the leading cause of readmissions.[1,3,7,15,20,21] The effect of sputum quantity on readmission was likely attributable to insufficient cough effort and retention of secretions by patients. Critically ill patients with neuromuscular complications from severe polyneuropathy and myopathy or deconditioning and weakness were at great risk of sputum retention and nosocomial pneumonia. They were also at risk of hypoventilation and type 2 respiratory failures.[22,23] Similar findings were reported in patients with severe head trauma.[24,25] In our cohort, patients with neurological diseases constituted the highest proportion of readmissions. Resource allocation for early rehabilitation in the ICU might be warranted.[23] Good airway and pulmonary care is crucial for post-discharge patients in step-down units. On the other hand, reducing ventilator-associated pneumonia (VAP) rates by adhering to VAP prevention bundles during the ICU stays may be a way to reduce readmission rates.[26,27]

Another finding in this study was the effect of fluid balance in the pre-discharge period. Previous studies have illustrated the association of fluid overloading and deleterious outcomes in critically

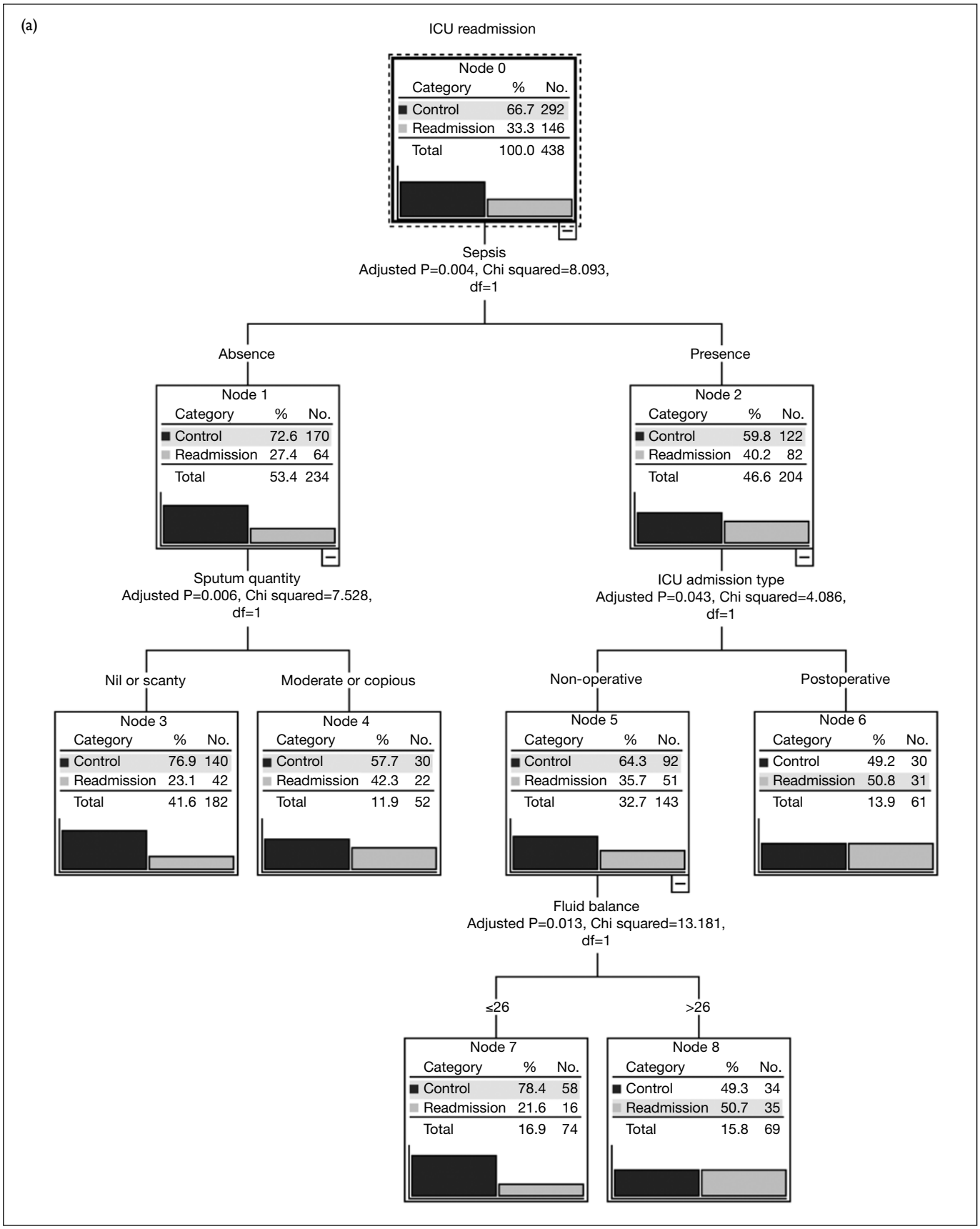

FIG 2. (a) Tree model 1: analysis for predictors of intensive care unit (ICU) readmission. (b) Tree model 2: analysis of ICU readmission due to worsening of pre-existing conditions. (c) Tree model 3: analysis of ICU readmission due to new complications

Fluid balance: fluid balance (mL) in the last 24 hour of index admission discharge

Abbreviations: df = degrees of freedom; ICU = intensive care unit

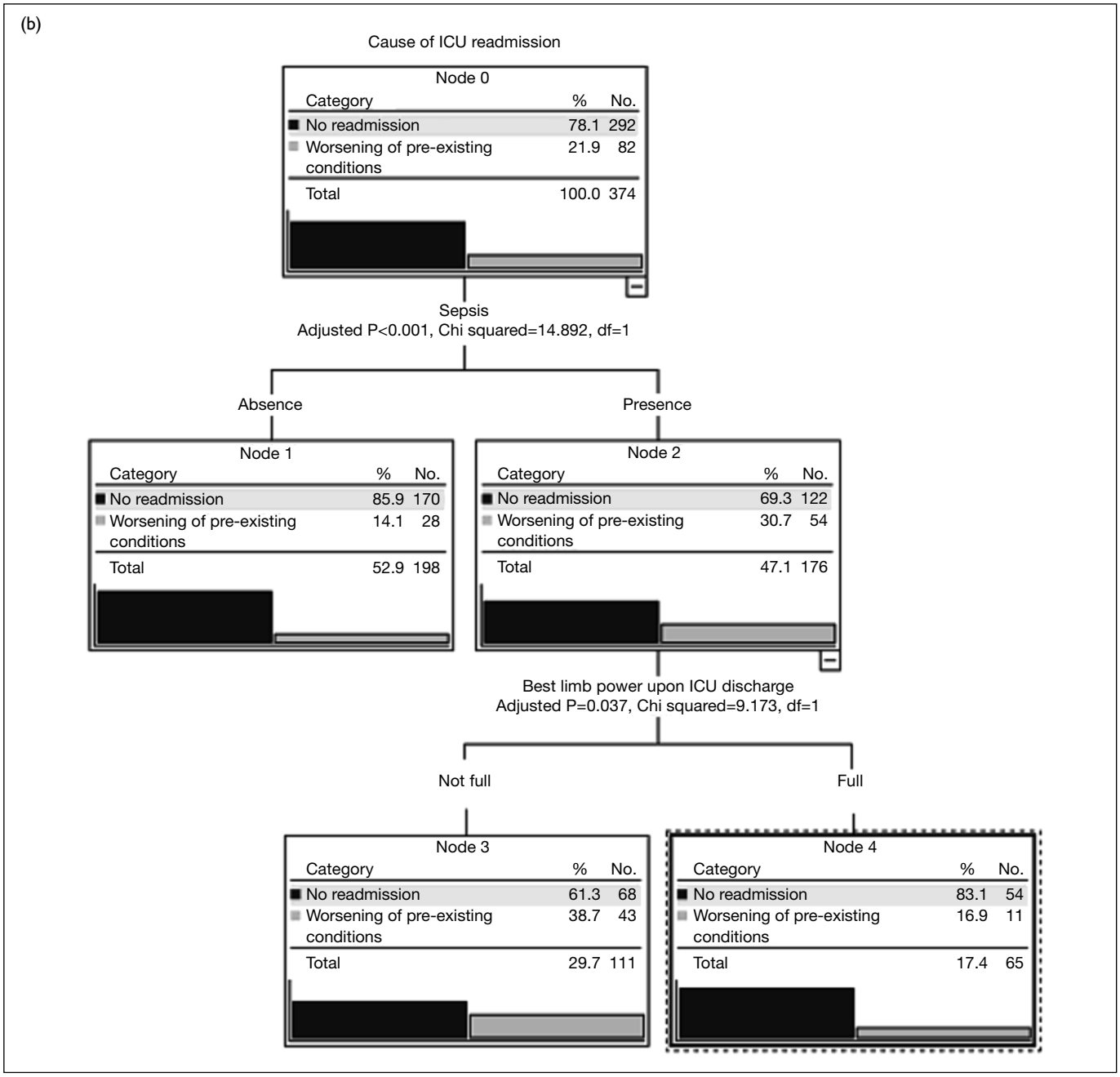

FIG 2. (cont'd) (b) Tree model 2: analysis of ICU readmission due to worsening of pre-existing conditions

ill patients, including those with sepsis,[28] acute kidney injury,[29] acute lung injury,[28,30] and following operations.[31] A single-centre study in Japan[32] found that weight gain at the time of initial ICU discharge had a negative linear relationship with the time to ICU readmission, as well as PaO_2-to-FiO_2 ratio. As vigorous fluid resuscitation is often necessary in the initial management of patients with critical illnesses, a proportion of those readmitted to the ICU with respiratory failure could have experienced lung oedema or atelectasis. The current study supports the finding that discharging patients with positive fluid balance leads to a higher readmission rate. Diuresis in critically ill patients could be recognised as a sign of recovery from their illness.

The association of HCT values at discharge and readmission was reported in previous studies, but a cutoff predictive value had not been specified.[4,7] In the tree analysis of the subgroup readmitted for new complications, postoperative patients with HCTs of ≤0.34 were associated with an increased risk of readmission. The corresponding haemoglobin levels

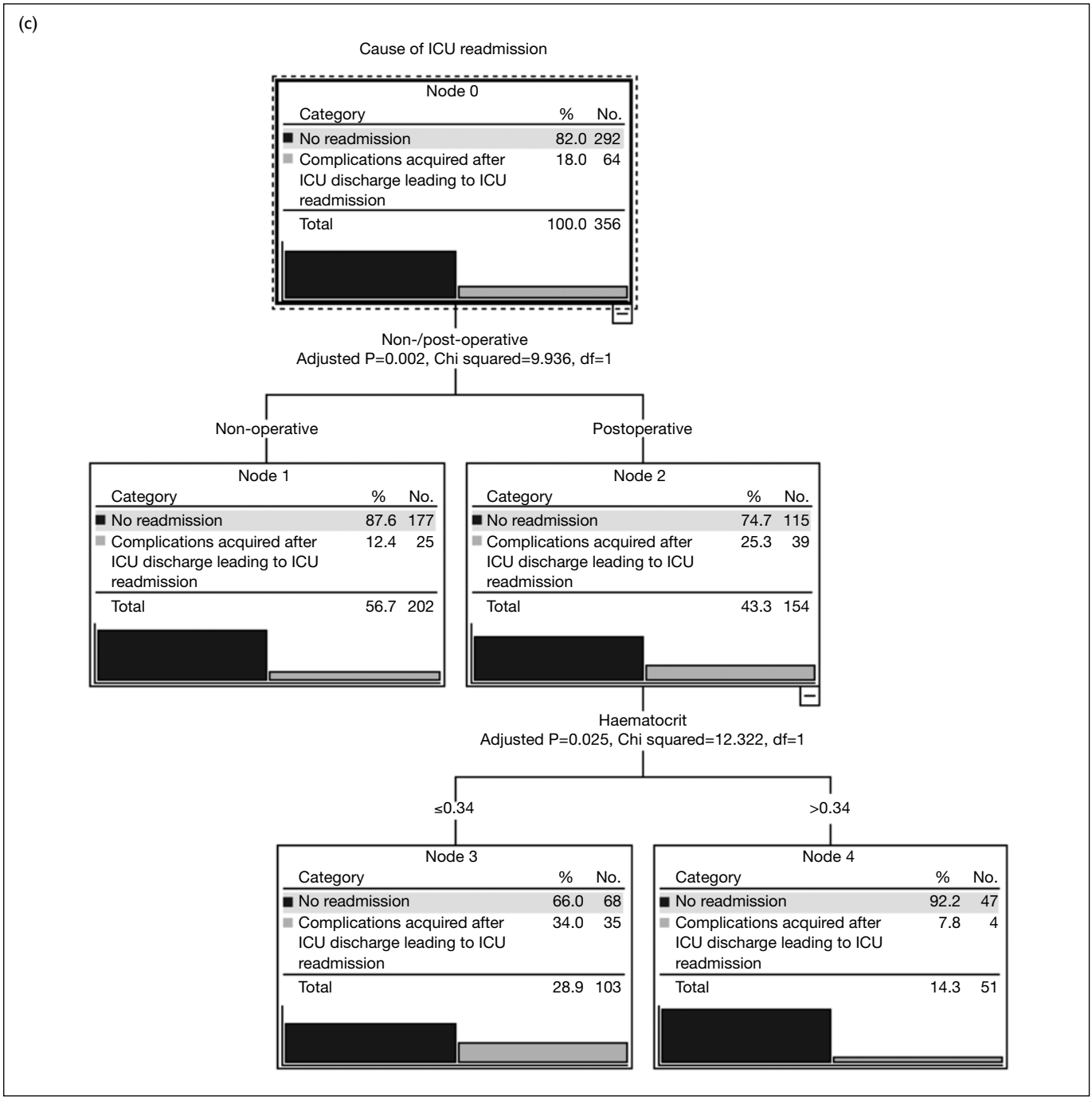

FIG 2. (cont'd) (c) Tree model 3: analysis of ICU readmission due to new complications

in patients with HCTs of 0.34 ranged between 110 and 120 g/L. Many confounders complicate the interpretation of HCT. In our cohort, control and readmitted patients were matched for age, gender, and initial disease severity. Thus, lower HCTs in the readmitted group could represent a more severe illness upon ICU discharge or more haemodilution. Yet, according to current transfusion practice in critically ill patients (based on the Transfusion Requirements in Critical Care study), outcomes in those with a restrictive transfusion threshold (7 g/L) were at least equivalent to using a liberal threshold (10 g/L).[33] In critically ill patients, observational studies have shown a significant association of red cell transfusions with mortality.[34] However, in a more recent multicentred study in Europe,[35] an extended Cox proportional hazards analysis showed that patients who received transfusion in fact enjoyed better survival. These contradictory findings remind us that there is no single value for the haemoglobin

concentration that justifies transfusion. Patients with poor cardiopulmonary reserve might benefit from a more liberal transfusion threshold.[34] In our cohort, postoperative patients with lower HCT values were most vulnerable to new complications that warranted ICU readmission. The stress of major operations to the cardiopulmonary status of an anaemic patient should not be overlooked.

The influence of base excess on readmission was observed in the logistic regression model. Common causes of alkalosis in critically ill patients include contraction alkalosis and renal compensation for respiratory acidosis. It is hypothesised that the majority of our patients with alkalosis were post-hypercapnic and higher readmission rates were seen in patients with more severe hypercapnia on initial presentation. On the other hand, 45% of patients in our cohort were discharged with alkalosis (arterial pH >7.45), whilst only 3.4% (n=15) were discharged with acidosis (arterial pH <7.35). This reflects the tendency to avoid discharging patients with acidosis in our daily practice.

A few previous studies identified the GCS score upon discharge as a risk factor for ICU readmission.[5,18] On the contrary, we found that whether or not a patient was discharged with full limb power predicted readmission for worsening pre-existing conditions. We hypothesise that a patient's GCS score upon ICU discharge reflects initial ICU admission severity and status, which was actually matched in our study. For example, a patient admitted with a low GCS score (and thus higher disease severity) is more likely to be discharged with a lower GCS score.

Strengths and limitations

Our case-control design enabled extensive data collection on pre-discharge status. Many of the collected variables have not been reported on previously. In the current study, readmitted and non-readmitted patients were matched for initial severity of illness in terms of APACHE IV ROD. Data collection was focused on the variables that occurred after ICU admission and were modifiable. However, variables reflecting initial disease severity and associated with readmission might have been overlooked. Moreover, the data abstraction and categorisation processes were not blinded to the outcome status of the subjects, and were therefore prone to information bias. Our study did not take into account the proportion of patients who had a poor physician-predicted chance of long-term survival and were therefore not readmitted. As this was a single-centre cohort, the importance of differences in case-mix and patterns of readmission in different ICUs should be recognised.

To the best of our knowledge, this was the first study employing the classification tree for analysis of ICU readmissions. Logistic regression is valuable in providing an indication of the relative importance of each predictor. Higher-order interactions between the predictor variables could be demonstrated in the classification tree analysis. If interactions between independent variables were present, the results of the multiple logistic regression might not be valid. By contrast, factors identified using the tree models might only have an important influence in specific subgroups. For example, the association of sputum quantity with readmission could be hidden if we considered all patients, but not among non-septic patients (Tree model 1).

Conclusion

Our cohort was consistent with previous studies, and suggested that patients having ICU readmissions had significantly poorer outcomes in terms of hospital mortality and hospital LOS. The characteristics of patients readmitted for worsening of pre-existing conditions and for new complications appeared to differ. Incomplete resolution of respiratory conditions remained an important reason for potentially preventable ICU readmission. Attention to patients' fluid balance and sputum quantity before ICU discharge might help to prevent unplanned ICU readmissions. Further study is warranted to investigate the effect of the HCT and pH on critically ill patients.

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