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Research paper

A nurse-led critical care outreach program to reduce readmission to the intensive care unit: A quasi-experimental study with a historical control group

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ABSTRACT

Introduction: Various critical care outreach services have been developed and evaluated worldwide; however, the conflicting findings indicate the need to strengthen the outreach service research. This study aimed to evaluate the effects of a nurse-led critical care follow-up program on intensive care unit (ICU) readmission and hospital mortality in patients with respiratory problems discharged from the ICU in Hong Kong.

Methods: A quasi-experimental study design, with a historical control and a prospective intervention for 13 months, was used. The intervention group received a nurse-led, multidisciplinary ICU follow-up program in addition to the usual care. The outcome measures included ICU readmission within 72 h after ICU discharge, all ICU readmission (ICU readmission irrespective of the time frame after ICU discharge), hospital mortality, and 90-day mortality rate. Logistic regression analysis was used to determine the predictors for ICU readmission within 72 h.

Results: A total of 369 participants (the intervention group: 185; the control group: 184) were recruited. A significant reduction in ICU readmission within 72 h was observed in the intervention group compared to the control group ($p = 0.001$), even after controlling for confounders (odds ratio: 0.158, $p = 0.007$). The intervention group also demonstrated a significant reduction in all ICU readmission ($p < 0.001$) and hospital mortality ($p = 0.042$), but not on 90-day mortality ($p = 0.081$), when compared with the control group. This nurse-led ICU follow-up program was shown to be cost-effective, saving an estimated US$ 145,614 for a period of 13 months.

Conclusion: The findings demonstrated that a nurse-led multidisciplinary ICU follow-up program was a beneficial and cost-saving strategy to avert ICU readmission in patients with respiratory problems after ICU discharge. It also highlighted the competent role of ICU nurses in planning and leading the implementation of a multidisciplinary program. The results contributed to the database of an innovative follow-up program to inform the practice worldwide.

1. Introduction

Health care on intensive care units (ICU) focuses on the most critically ill patients and consumes a significant portion of medical expenses. In the United States, the critical care costs in 2005 were US $ 81.7 billion which represented 13.4% of hospital costs, 4.1% of national health expenditure, and 0.66% of the gross domestic product.[1] A study in four European countries including Germany, Italy, Netherlands, and United Kingdom reported a direct cost per ICU day ranging from US$ 1,385 to US$ 2,401.[2] In Hong Kong, an estimated cost per ICU bed per day is US $ 3,129.[3] Therefore, intensive care services require high expenditure. Readmission to ICU could further increase the consumption of costs and medical resources.

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Readmission to ICU within 72 h after ICU discharge is known as early readmission[4] and that from 72 h to seven days is known as late readmission.[4,5] The ICU readmission rate varies across different countries or regions: for example, it ranges from 4 to 14% in the United States[6] and 5–10% in Hong Kong.[7] The ICU readmission rate is of great concern as it is associated with increased mortality and prolonged ICU stay and hospital stay in readmitted patients.[6] It has been reported that compared to those without an ICU readmission, patients with an ICU readmission have a twofold to 10-fold increase in mortality rate and a doubled length of ICU stay.[8,9] In Hong Kong, approximately 20% of patients die in hospital before ICU discharge hospitalisation.[10] ICU readmission has been recognised as a quality indicator of critical care.[11] In addition, patients may experience high risk for mortality and adverse events after their transfer from ICU. A study in Australia reports that about 30% patients experience adverse events including hospital-acquired infections, complications such as deep vein thrombosis, and cardiac or respiratory arrest that may require ICU readmission after their transferring to wards from ICU.[12] All these highlight the importance of implementing a cost-effective measure to avert ICU readmission and reduce hospital mortality in patients after ICU discharge.

Critical care outreach (CCO) services have been provided as a strategy to prevent ICU readmission via timely monitoring, early detection, and management of deteriorating patients and coaching ward nurses to equip them with knowledge and skills to take care of patients after their transfer to the general ward.[13] The CCO services have been developed according to local needs in different countries, such as Medical Emergency Team (MET) in Australia,[14] Rapid Response Team in the United States,[15] and the CCO team in the United Kingdom.[16] For example, the Intensive Care Liaison Nurse Service (ICU LN), which is often an important component in MET service in Australia, is a service primarily provided by ICU nurses and involves the provision of follow-up visits to the patients at wards after ICU discharge and assists in urgent review of acutely ill patients who meet the modified early warning score (MEWS) criteria.[17–19] The MEWS is a track and trigger system to facilitate ward nurses to early identify patient's deteriorating condition and thus prompt the ward nurses to call the doctor.[20,21] The MEWS criteria are based on vital signs scores. Usually, an MEWS score of $\geq$4 is used as a "triggering" to initiate the call. An integrative review and meta-synthesis of the scope and the impact of ICU LN services and outreach services concluded that these outreach services improved communication channels between ICU and ward nurses and reduced the incidents of adverse events in wards as well as ICU readmission.[22]

Despite the wide implementation of CCO services, a clear or an optimal typology of CCO services is lacking,[23] resulting in the wide variations in CCO services such as staffing (e.g., nurse-led or doctor-led), the services provided (e.g., direct bedside support on general wards or telephone "hotline" advice), and the patients targeted (e.g., all patients discharged from the ICU or those with high risk for ICU readmission), as well as the conflicting results regarding the effectiveness of CCO services on reducing ICU readmission.[5,24] Another variant CCO model is the Australian ICU LN Service, which has been implemented as a separate service from MET service in many hospitals in Australia and may have the potential to avert ICU readmission in a cost-effective way.[22] Currently, there is no such CCO service or ICU LN service implemented in Hong Kong, leaving the beneficial effects of such service in Hong Kong ICU patients unknown. In this study, we developed an outreach service similar to the ICU LN model but with support from ICU doctors and evaluated the effects of this service on ICU readmission and mortality rates in patients discharged from the ICU with primary respiratory problems. These patients were chosen because of their high risk for ICU readmission.[12,25,26] In addition, the findings of this study would help to identify the optimal typology of CCO service.

2. Methods

2.1. Study design

This was a quasi-experimental study with a historical control group. Those who had been admitted to ICU from September 2014 to September 2015 (13 months) were recruited for the historical control group, whereas the intervention group included those who admitted to ICU from October 2015 to October 2016 (13 months). The choosing of historical control group was because it would be unethical to deprive patients at high risk of ICU readmission from receiving the ICU follow-up care. Participants in the intervention group received the ICU follow-up program on top of the usual care, whereas the control group received the usual care only.

2.2. Setting and participants

Patients were recruited from one regional hospital in the Hong Kong East Cluster, a 2300-bed acute care tertiary hospital. The ICU was a 22-bed mixed medical–surgical unit with an average annual admission of 1500 patients in the study periods. Patients who met the following criteria were included: (1) adult patients $\geq$18 years old; (2) first ICU admission and staying in the ICU for at least 24 h; and (3) having at least one of the following respiratory problems associated with increased risk of ICU readmissions: (i) high respiratory rate at $\geq$26/min, documented poor coughing effort, or moderate sputum content before discharge to general wards; (ii) use of noninvasive mechanical ventilation; or (iii) have tracheostomy established during ICU stay.

Patients were excluded if they were being transferred to other hospitals or transferred directly from the ICU to the cardiac care unit of the study hospital. The control group was identified using the same inclusion and exclusion criteria and using administrative data retrieved from the Clinical Data and Report System (CDARS), Clinical Management System, and Clinical Information System (CIS).

2.3. ICU follow-up program

A CCO team was formed, consisting of one nurse consultant (NC), one advanced practice nurse, and senior ICU doctors. Both the NC and advanced practice nurse were qualified ICU nurses with at least 10 years' experience. This ICU follow-up program was led by the NC. The nurse team members provided follow-up. The senior ICU doctors supported the program and provided ICU follow-up visits when needed.

2.3.1. Contents of the ICU follow-up program

An ICU follow-up protocol (Fig. 1) was developed and followed by all team members and ward nurses to ensure the consistency of the program. The ICU follow-up service was provided from 9 am to 5 pm, 7 days per week. The program contained 5 core components: structured follow-up visits at the general wards, standardised vital signs monitoring, the application of a revised track and trigger system, bedside coaching of general ward nurses, and consultation.

i) Structured follow-up visits at general wards

The first follow-up visit was initiated within 24 h by the nurse members after patients were discharged to general wards. This was followed by two daily follow-up visits. During each visit, patients' general health conditions and their vital signs, in terms of the

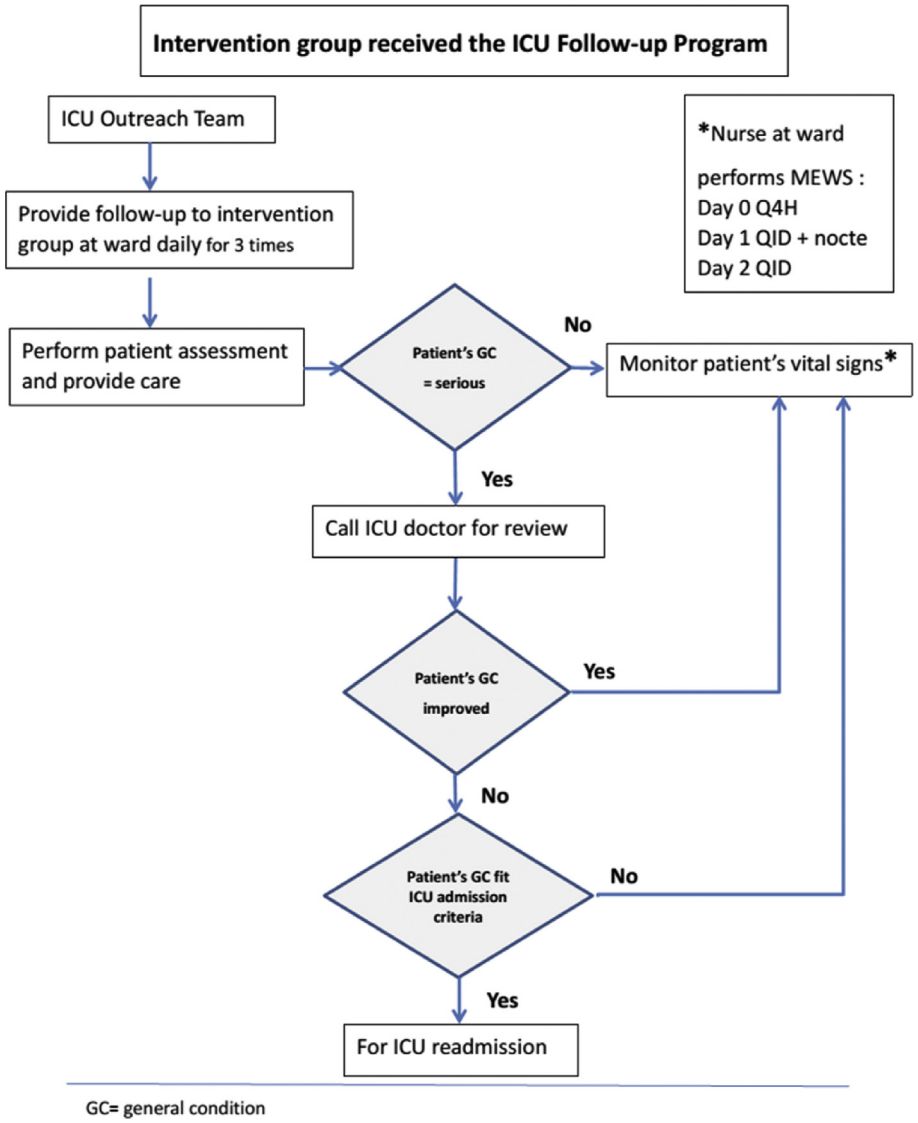

Fig 1. The ICU follow-up protocol. GC = general condition; ICU = intensive care unit; MEWS = modified early warning score.

MEWS, were assessed and recorded. Based on the results of assessment, nursing care or related actions were suggested. The follow-up was terminated when the patient met one of the following conditions:

a Improved general condition, as indicated by MEWS score of ≤2 upon the third follow-up visit. A higher score indicates more severe heath condition.[27]
b Readmitted to the ICU.
c Discharge home or transfer to another hospital before the third follow-up visit; or
d Died.

ii) Standardised vital signs monitoring

Ward nurses were tasked to monitor patients' vital signs and record MEWS results every 4 h on the first day of discharge to general wards, four times a day on day two, and twice per day on day three and beyond, according to the patient's condition. The standardised vital signs monitoring allowed ward nurses to detect early deterioration of patients' condition and initiate timely treatment accordingly.

iii) Application of revised track and trigger system

The MEWS requires periodic observation of the five physiological parameters ("tracking") with predetermined criteria ("triggering") for calling the attendance of the doctor.[21] In this study, a lower MEWS score of ≥3 was used instead of the standard MEWS trigger score of ≥4 as the "triggering" to initiate a call for outreach team, as a lower "triggering" score may prevent the delayed response to a patient's deterioration which was considered leading to high ICU readmission rates in the study site.[7]

iv) Bedside coaching of ward nurses

Ward nurses were coached at bedsides by the outreach team nurse members with the knowledge and skills about how to care for patients with respiratory problems. Core topics covered were as follows: (1) the importance of respiratory rate monitoring and its relationship to patient's clinical condition[12]; (2) regular vital signs monitoring and MEWS recording and the "triggering" score to call ICU outreach team; and (3) tracheostomy care, including examining the characteristics of the sputum, checking the application of

tracheal cuff pressure, and evaluating the effectiveness of the humidification to the tracheostomy. Additional patient care, such as the care of central venous catheter and the use of portable ventilator at a patient's bedside, was provided by the outreach team when needed.

v) Consultation

Ward nurses were encouraged to consult the ICU outreach team when in doubt about caring the post-ICU discharge patients, especially for those with MEWS ≥3 or with other health concerns such as increased pain and agitation or any abnormal values on the MEWS.

2.4. Usual care

The usual care in wards included irregular vital signs monitoring and the MEWS documentation. Furthermore, a standard MEWS trigger score of ≥4 was used as the "triggering" to call the ward doctor. For patients with tracheostomy, unlike the care provided in a systemic way in the intervention group, the ward nurses performed simple tracheostomy care such as daily dressing to the tracheostomy and tracheal suctioning of sputum.

2.5. Data collection and data source

Patients were screened by the NC according to the inclusion and exclusion criteria. The eligible patients were invited to participate in this study. Baseline data were collected after obtaining the written consent.

2.5.1. Sociodemographic and clinical data

The demographic (age and sex) and clinical data [including Acute Physiology and Chronic Health Evaluation (APACHE IV), Glasgow Coma Scale, ICU length of stay, admission status and sources, parent specialties, diagnosis, comorbidities, and risk factors for ICU readmission] were collected.

2.5.2. Primary and secondary outcomes

The primary outcome was the ICU readmission within 72 h. The secondary outcomes included all ICU readmission (all ICU readmission irrespective of the time frame after ICU discharge), hospital mortality, and 90-day mortality rate. Data of interest were reviewed and retrieved from Clinical Data and Report System (CDARS), Clinical Management System (CMS), and Clinical Information System (CIS) in the studied hospital. The number and time spent for follow-up visits were also recorded.

2.6. Ethical consideration

This study was conducted in accordance with the ethical principles in the Declaration of Helsinki (2017).[28] Ethics approvals were obtained. Informed consent was obtained from the participants or their next-of-kin for those with cognitive impairment before commencement of the intervention.

2.7. Statistical analysis

All analyses were performed using the IBM SSPS for Windows, version 24 (Armonk NY: IBM Corp). Descriptive statistics including mean SD, percentage, and median were used as appropriate to summarize the demographic, clinical, and the outcome data. For group comparison, Student *t*-test or Mann-Whitney *U* test was used according to the distribution of the data. Pearson Chi-square tests or Fisher's exact test was used for categorical variables as appropriate. Binary logistic regression analysis with backward approach was used to explore the independent predictors for ICU readmission within 72 h after the adjustment of confounding factors which were identified as those baseline variables with significant difference between the study groups. Intention-to-treat principal was followed during data analysis. A p value of 0.05 (two-tailed) was considered statistically significant.

3. Results

A total of 1743 ICU admissions were identified from October 2015 to October 2016, of which 185 were eligible and recruited into the intervention group. During the course of study, two participants were lost due to death and transferring to another hospital, resulting in 183 participants remaining at the end of the study. Out of the 1646 ICU admissions recorded in the CDARS and CIS for the period of September 2014 to September 2015, 184 cases were eligible and included in the historical control group. All the 185 patients in intervention group and the 184 patients in the control group were included in final data analysis. The contextual factors including the hospital and the ICU environment of the study site remained relatively stable. Staff mix in the involved wards remained constant throughout the whole study period.

3.1. Demographic and clinical characteristics of patients

A total of 369 patients were included (the intervention group: 185 the control group: 184). The details of demographic and clinical characteristics of these patients and the comparisons on these characteristics between study groups are presented in Table 1. The mean age of all participants was 66.5 (±16.0) years old, with 66.1% of male. The mean ICU stay was 11.8 (±12.68) days. Most of the participants (93.8%) were admitted to ICU in an emergency condition either directly from accident & emergency department (A&ED), general wards, or after emergency surgery. More than 50% of the patients were admitted to the ICU from the general wards, 25.5% from the operating theatre, and 13.6% from the A&ED. Among all the recruited patients, about 40% were admitted to the ICU with a diagnosis of sepsis, 17.6% with neurosurgical/neurological diseases (e.g., subarachnoid haemorrage due to cerebral artery aneuyrsum, intracerebral haemorrage, traumatic brain injury, or meningitis), and 16.3% with respiratory diseases (e.g., pneumonia, exacerbation of chronic obstructive pulmonary diseases, or respiratory failure). For the participants (11.9%) with cardiovascular problems, they were mostly related to heart failure or acute myocardiac infarction. The remaining disease diagnosis in this sample included gastrointestinal problems (e.g., biliary tract infection, acute pancreatitis, or gastrointestinal surgery), spinal cord injury, and head and neck surgery. In terms of comorbidities, 18.7% of participants were comorbid with one or two illnesses. In addition, 63.2% of participants had two or three risk factors for ICU readmission, with respiratory rate ≥26/min being the most frequently reported risk factor (61.2%), followed by poor coughing effort/moderate amount of sputum (42.8%) and noninvasive mechanical ventilation (35%).

When comparing the 2 study groups, the intervention group demonstrated a younger age ($p = 0.014$), a better health condition as indicated by the lower APACHE IV score ($p = 0.014$), a higher median value of GCS ($p = 0.027$), and fewer comorbidities ($p = 0.005$) than the control group. There were more patients receiving a tracheostomy done for poor coughing effort and risk of sputum retention in the intervention group.

3.2. Services provided through the ICU follow-up program

A total of 531 follow-up visits were provided, among which nurse team members contributed nearly 68% of the total visits. The

Table 1
Demographic and clinical health characteristics of patients in the intervention and control groups.

Demographic and clinical health characteristics	All patients (n = 369)	Intervention group (n = 185)	Control group (n = 184)	Statistical test	p value
Male (%)	244 (66.1)	119 (64.3)	125 (67.9)	$\chi^2 = 0.537$	0.464
Female (%)	125 (33.9)	66 (35.7)	59 (32.1)		
Age, mean (±SD)	66.5 ± 16.0	64.4 ± 15.5	68.5 ± 16.3	$t = -2.472$	0.014
APACHE IV score, mean (±SD)	82.8 (31.00)	78.85 (31.75)	86.76 (29.73)	$t = -2.467$	0.014
APACHE IV risk of death, mean (±SD)	0.3602 ± 0.2636	0.3344 ± 0.2595	0.3860 ± 0.2658	$t = -1.887$	0.06
ICU LOS (days), mean (±SD)	11.8 (12.68)	11.72 (10.05)	10.44 (14.86)	$t = 0.974$	0.331
GCS, median (IQR)	12 (6–15)	14 (7–15)	11 (6–15)	#	0.027
Admission type (%)					
Nonoperation	275 (74.5)	135 (73)	140 (76.1)	$\chi^2 = 0.471$	0.492
After operation	94 (25.5)	50 (27)	44 (23.9)		
Admission status (%)					
Emergency	346 (93.8)	172 (93)	177 (96.2)	$\chi^2 = 1.869$	0.172
Elective	20 (6.2)	13 (7)	7 (3.8)		
Admission sources (%)					
Accident & emergency	50 (13.6)	30 (16.2)	20 (10.9)	$\chi^2 = 5.174$	0.27
General ward	213 (57.7)	100 (54.1)	113 (61.4)		
Operating theatre	94 (25.5)	50 (27)	44 (23.9)		
Others	12 (3.2)	5 (2.7)	7 (3.8)		
Parent specialties					
Medical wards	236 (64)	119 (64.3)	117 (63.6)	$\chi^2 = 0.022$	0.883
Nonmedical wards					
Neurosurgical	61 (16.5)	35 (18.9)	26 (14.1)		
Surgical	43 (11.7)	12 (6.5)	31 (16.8)		
Ear, nose, and throat	20 (5.4)	15 (8.1)	5 (2.7)		
Orthopaedic	3 (0.8)	2 (1.1)	1 (0.5)		
Gynaecology	2 (0.5)	1 (0.5)	1 (0.5)		
Oncology	4 (1.1)	1 (0.5)	3 (1.6)		
Disease category (%)					
Sepsis	147 (39.8)	79 (42.7)	68 (37)	$\chi^2 = 18.168$	0.003
Neurosurgical/Neurological	65 (17.6)	37 (20)	28 (15.2)		
Respiratory	60 (16.3)	36 (19.5)	24 (13)		
Cardiovascular	44 (11.9)	11 (5.9)	33 (17.9)		
Gastrointestinal	24 (6.5)	8 (4.3)	16 (8.7)		
Others	29 (7.9)	14 (7.6)	15 (8.2)		
Number of comorbidities					
0	300 (81.3)	159 (85.9)	141 (76.6)	$\chi^2 = 10.744$	0.005
1	63 (17.1)	21 (11.4)	42 (22.8)		
2	6 (1.6)	5 (2.7)	1 (0.6)		
Number of risk factors					
1	136 (36.8)	62 (33.5)	74 (40.2)	$\chi^2 = 4.671$	0.097
2	205 (55.6)	104 (56.2)	101 (54.9)		
3	28 (7.6)	19 (10.3)	9 (4.9)		
Risk factors					
RR ≥ 26/min	226 (61.2)	88 (47.6)	138 (75)	$\chi^2 = 29.248$	<0.001
NIV	129 (35)	49 (26.5)	80 (43.5)	$\chi^2 = 11.714$	0.001
Tracheostomy	117 (31.7)	76 (41.1)	41 (22.3)	$\chi^2 = 15.055$	<0.001
Poor coughing effort/moderate amount of sputum	158 (42.8)	114 (61.6)	44 (23.9)	$\chi^2 = 53.574$	<0.001

Note: # = Mann–Whitney U test; SD = standard deviation; IQR = interquartile range (25%, 75%); ICU LOS = intensive care unit length of stay; APACHE IV score = Acute Physiological and Chronic Health Evaluation IV score; GCS = Glasgow Coma Scale; RR = respiratory rate; NIV = noninvasive mechanical ventilation.

majority (98.9%) of participants received the first follow-up visit, and more than 95% received the second and third ICU follow-up visits. The reasons for not receiving ICU follow-up visits included early ICU readmission, transfer out to other hospital, discharge to home, or death. Three participants received four follow-up visits due to their deteriorating condition; one participant received seven visits as the need of support for the participant and ward nurses on care management of tracheostomy tube. The average time spent for each of the first three visits was 10.03 (±5.54), 9.06 (±5.03), and 8.25 (±5.0) minutes, respectively. The total time spent on all visits was about 81 h. During the follow-up, problems identified were mostly respiratory-related care such as tracheostomy care, inadequate attention to risk of sputum retention, and the inaccuracy of respiratory rate taking and recording. Therefore, respiratory-related care such as use of tracheal suctioning to clear copious sputum, guidance on choosing appropriate device for respiratory humidification to prevent tracheostomy tube blockage, and referrals to chest physiotherapy were the most frequently suggested actions by the ICU outreach team. Furthermore, bedside coaching and feedback to ward nurses about nursing skill and knowledge of care related to tracheostomy tubes, respiratory rate monitoring, record and report, and the emergency management related to tracheostomy care were also provided.

3.3. ICU readmission and hospital mortality

The primary and secondary outcomes of the study are shown in Table 2. During the study period, three patients requiring ICU readmission within 72 h were reported in the intervention group, whereas 17 patients in the control group required early ICU readmission, and such difference was significant (1.6% vs. 9.2%, $p = 0.001$). In addition, the intervention group also demonstrated a lower rate of all ICU readmission rate (9.7% vs. 23.9%, $p < 0.001$) and hospital mortality (17.8% vs. 26.6%, $p = 0.042$) than the control group. Although the control group reported a higher 90-day mortality rate (22.8%), the difference in

Table 2
Comparison of the outcome variables between two groups.

Outcome variables	All patients (n = 369)	Intervention group (n = 185)	Control group (n = 184)	Statistical test	*p*
Primary outcome (%)					
ICU readmission within 72 h	20 (5.4)	3 (1.6)	17 (9.2)	[a]	0.001
Secondary outcomes (%)					
All ICU readmission	62 (16.8)	18 (9.7)	44 (23.9)	$\chi^2 = 13.275$	<0.001
Hospital mortality	82 (22.2)	33 (17.8)	49 (26.6)	$\chi^2 = 4.126$	0.042
90-day mortality	71 (19.2)	29 (15.7)	42 (22.8)	$\chi^2 = 3.035$	0.081

ICU = intensive care unit; χ^2 = chi-square tests.
[a] Fisher's exact test.

90-day mortality rate between study groups was not significant (15.7% vs. 22.8%, p = 0.081).

To further evaluate the intervention effect, multivariate analysis was performed for ICU readmission within 72 h after ICU discharge and hospital mortality as they were supposed to be greatly influenced by the service and may better reflect the service effect. Binary logistic regression analysis was performed with adjusting potential confounding factors that were identified as baseline factors with significant difference between the study groups. These confounders included age, APACHE IV score, GCS, disease category, number of comorbidities, and all risk factors. The results of logistic regression analysis showed that after adjusting for potential confounders, receiving intervention (OR = 0.158, 95% confidence interval [CI]: 0.041, 0.602, p = 0.007), being transferred out to medial wards (OR = 0.265, 95% CI: 0.095, 0.741, p = 0.011), and having tracheostomy (OR = 0.198, 95% CI: 0.042, 0.927, p = 0.04) could predict a reduced risk of ICU readmission within 72 h (Table 3). Regarding the predictors of hospital mortality, receiving intervention was associated with a decrease in hospital mortality, but such a decrease was not significant (OR = 0.622, 95% CI: 0.362, 1.069, p = 0.086). Age, being male, APACHE IV risk of death, and having a tracheostomy were all identified as being associated with an increased hospital mortality (all p < 0.05) (Table 3).

Table 3
Predictors for ICU readmission within 72 h and hospital mortality.

Factors	B	Adjusted OR	95% CI	p value
Predictors for ICU readmission within 72 h				
Intervention	−1.847	0.158	0.041–0.602	0.007
Medical wards	−1.327	0.265	0.095–0.741	0.011
Tracheostomy	−1.622	0.198	0.042–0.927	0.04
Predictors for hospital mortality				
Age	0.026	1.026	1.006–1.047	0.010
Sex (male)	0.719	2.052	1.134–3.713	0.017
APACHE IV risk of death	1.611	5.009	1.828–13.723	0.002
Tracheostomy	0.929	2.531	1.395–4.592	0.005
Intervention	−0.474	0.622	0.362–1.069	0.086

APACHE IV score = Acute Physiological and Chronic Health Evaluation IV score; CI = confidence interval; ICU = intensive care unit; OR = odds ratio.

3.4. Cost evaluation

The cost evaluation of the follow-up program was carried out based on the reduction of ICU readmission within 72 h after ICU discharge and the product of the ICU experts' hourly salary. As a reduction of 14 ICU readmissions within 72 h after ICU discharge observed in the intervention group, a total of 63 ICU days were then saved considering an estimated average ICU length of stay of 4.5 days for each readmission. This converts to a saving of around HK$ 1,216,530 when the cost of an ICU bed is HK$ 24,410 per day (US$ 3,129) and the cost of a general hospital bed is estimated to be HK$ 5,100.[3] The manpower cost of delivering 81 h of follow-up visits was estimated to be HK$ 80,738. Thus, the estimated net saving was HK$ 1,135,792 (US$ 145,614). Furthermore, the costly ICU beds would be saved to those in needed, thus optimising all patients' access to ICU services.

4. Discussion

This study aimed to evaluate the effect of an ICU follow-up program on ICU readmission, hospital mortality rate, and 90-day mortality rate in patients with respiratory problems discharged from the ICU. The results indicated a beneficial effect of this program on reducing ICU readmission and hospital mortality rate after ICU discharge. Moreover, the ICU follow-up program could predict a reduced risk of ICU readmission within 72 h after controlling for confounding factors. In addition, this study also demonstrated that ICU follow-up program was a cost-effective strategy to avert ICU readmission.

Averting readmission to ICU and preventing death after ICU discharge are the main objectives for ICU outreach services.[5] The present study found a significant reduction in ICU readmission and hospital mortality after implementing an ICU follow-up service. However, conflicting results were reported in the literature. For example, a significant reduction in hospital mortality and ICU readmission was reported in an English study after patients received CCO visits,[29] whereas no significant findings were found in either an Australian study[5] or a more recent Canadian study.[30] In addition, a recent systematic review and meta-analysis supported the beneficial effects of outreach service on reducing ICU readmission (risk ratio: 0.87, 95% CI: 0.76, 0.99, p = 0.03) but not hospital mortality (risk ratio: 0.84, 95% CI: 0.66, 1.05, p = 0.10).[24]

Several factors may need to be considered when interpreting these heterogeneous findings, including patient characteristics, nature of the service provided, and healthcare contexts. In terms of the target population, the present study focused on the patients with respiratory problems who were at a great risk of ICU readmission rather than all the patients after ICU discharge as in the Australian[5] and Canadian studies.[30] A focus on the high-risk population may maximise the benefits of an outreach service, whereas the large variation in risk factors of patients after ICU discharge may make it difficult to provide consistent service and to estimate service effects,[31] leading to the significant findings in the present study but the nonsignificant findings in the Australian[5] and Canadian studies.[30] Second, the nature of services provided was different. Large variations in CCO services have been reported.[23,32] For example, the track and trigger system that allows the early detection of deterioration was applied in the present study but not mentioned in the CCO services in the Canadian study.[30] The lack of such a system may result in the inadequate or late response to deteriorating patients and thus no significant reported reduction in

ICU readmission rate and mortality in the Canadian study.[30] Third, the studies reflect the very different healthcare contexts. For example, the lower ICU readmission rate at the baseline in the Australian study[5] than that in the present study (5.6% vs. 9.2%) may explain the different results between two studies. In addition, variations in characteristics of ICUs and the responsibilities undertaken by nurses or medical staff between different healthcare institutions might lead to variations in the reported benefits of outreach services.[31]

Because there is no prescribed ideal model for CCO services,[16] hospitals are recommended to develop their own CCO services to meet the local needs to maximise the beneficial effects of the services.[17,24] In the present study, the predefined population, localised track and trigger system, and close collaboration within the outreach team (nurses and ICU doctors) and between the outreach team and nurses in general wards may lead to the large proportion of patients receiving follow-up visits, which then contributed to the betterment of patients such as decreased ICU readmission and hospital mortality. Furthermore, the success of this CCO service may also indicate that ICU nurses are competent in planning and leading the implementation of a multidisciplinary program. Overall, this study revealed that the nurse-led ICU follow-up service could be cost-effective when trying to prevent ICU readmission, providing solid evidence for hospital policy-makers to support and invest such outreach service. However, as the provision of follow-up visits to patients after ICU discharge requires ICU nurses and doctors to spare time from their routines to fulfil the task, this may potentially increase their workload and needs to be considered when generalising the findings of the present study.

4.1. Limitations

Despite the promising findings of the present study, some limitations still exist and should be acknowledged. First, the small sample size, only 369 patients were included in this study. The small sample size may result in bias in estimating the intervention effects. Thus, the effect of the ICU follow-up program should be confirmed in a large population. Second, a nonrandomised controlled trial design may limit the power of detecting the true intervention effects as a randomised controlled study does. Furthermore, the less severe illness in the intervention group than in the control group at baseline may have impacted the low rate of ICU readmissions in the intervention group, although it was controlled as a confounder in statistical analysis. Therefore, studies with randomised controlled trial design are needed to further confirm the findings. Finally, there may have been a Hawthorne effect due to the CCO service being a new service at the study site to all staff involved and may have inspired the energetic delivery of the intervention and result in the overestimated intervention effects.

5. Conclusions

Nursing outreach service has extended critical care services beyond the confines of ICU to general wards to avert ICU readmission. It has also highlighted the competent role of ICU nurses in planning and leading the implementation of a multidisciplinary program. The results of this study showed that our nurse-led multidisciplinary ICU follow-up program could reduce ICU readmission and hospital mortality in patients with respiratory problems after ICU discharge in a cost-effective way. This study was first conducted in Hong Kong, and the results contributed to the database of an innovative follow-up program to inform the practice worldwide.

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CRediT authorship contribution statement

Hang Mui So: Conceptualization, Methodology, Project administration, Formal analysis, Investigation, Data curation, Writing - original draft, Visualization. **Wing Wa Yan:** Methodology, Project administration, Resources, Supervision, Writing - review & editing. **Sek Ying Chair:** Conceptualization, Methodology, Writing - review & editing.

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References

[1] Halpern NA, Pastores SM. Critical care medicine in the United States 2000–2005: an analysis of bed numbers, occupancy rates, payer mix, and costs. Crit Care Med 2010;38(1):65–71.
[2] Tan SS, Bakker J, Hoogendoorn ME, Kapila A, Martin J, Pezzi A, et al. Direct cost analysis of intensive care unit stay in four European countries: applying a standardized costing methodology. Value Health 2012;15(1):81–6.
[3] Hospital Authority, Hong Kong. Fees and charges review result. 2016. Available from: http://gia.info.gov.hk/general/201612/15/P2016121500672_249763_1_1481803448655.pdf [Accessed 19 April 2018].
[4] Brown SES, Ratcliffe SJ, Halpern SD. An empirical derivation of the optimal time interval for defining ICU readmissions. Med Care 2013;51(8):706–14.
[5] Williams TA, Leslie GD, Elliott N, Brearley L, Dobb GJ. Introduction of discharge plan to reduce adverse events within 72 hours of discharge from the ICU. J Nurs Care Qual 2010;25(1):73–9.
[6] Brown SE, Ratcliffe SJ, Kahn JM, Halpern SD. The epidemiology of intensive care unit readmissions in the United States. Am J Respir Crit Care Med 2012;185(9):955–64.
[7 Intensive Care National Audit & Research Centre (ICNARC), Kong Hong. National and International benchmarked analyses of Hong Kong hospital Authority intensive care unit data: report on 2010 data (trends 2007-2010). 2012 [Unpublished data].
[8] Badawi O, Breslow MJ. Readmissions and death after ICU discharge: development and validation of two predictive models. PloS One 2012;7(11):1–15.
[9] Kramer AA, Higgins TI, Zimmerman JE. Intensive care unit readmission in U.S. hospitals: patients characteristics, risk factors, and outcomes. Crit Care Med 2012;40:3–10.
[10] Lam KW, Lai KY. Evaluation of outcome and performance of an intensive care unit in Hong Kong by Apache IV model: 2007-2014. J Emerg Med Crit Care 2017;1:16. https://doi.org/10.21037/jeccm.2017.07.02.
[11] Chan KS, Tan CK, Fang CS, Tsai CL, Hou CC, Cheng KC, et al. Readmission to the intensive care unit: an indicator that reflects the potential risks of morbidity and mortality of surgical patients in the intensive care unit. Surg Today 2009;39(4):295–9.
[12] Chaboyer W, Thalib L, Foster MMN, Ball C, Richards B. Predictors of adverse events in patients after discharge from the intensive care unit. Am J Crit Care 2008;17(3):255–63.
[13] Department of Health, United Kingdom. Comprehensive Critical Care: a review of adult critical care services. National Health Service report; 2012. Available from: http://webarchive.nationalarchives.gov.uk/20121014090959/http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/documents/digitalasset/dh_4082872.pdf [Accessed 19 April 2018]. Assessed at.
[14] Buist M, Harrison J, Abaloz E, Van Dyke S. Quality improvement report: six year audit of cardiac arrests and medical emergency team calls in an Australian outer metropolitan teaching hospital. Br Med J 2007;335(7631):1210.
[15] Beitler JR, Link N, Bails DB, Hurdle K, Chong DH. Reduction in hospital-wide mortality after implementation of a rapid response team: a long-term cohort study. Crit Care 2011;15(6). https://doi.org/10.1186/cc10547.
[16] Gao H, Harrison DA, Parry GJ, Daly K, Subbe CP, Rowan K. The impact of the introduction of critical care outreach services in England: a multicenter interrupted time-series analysis. Crit Care 2007;11(5). https://doi.org/10.1186/cc6163.
[17] Eliott SJ, Ernest D, Doric AG, Page KN, Worrall-Carter LJ, Thalib L, et al. The impact of an ICU liaison nurse service on patient outcomes. Crit Care Resusc 2008;10(4):296–300.
[18] Chaboyer W, Foster M, Kendal E. The intensive care unit liaison nurse: towards a clear role description. Intensive Crit Care Nur 2004;20:77–86.

[19] Endacott R, Chaboyer W, Edington J, Thalib L. Impact of an ICU liaison nurse service on major adverse events in patients recently discharged from ICU. Resuscitation 2010;81(2):198–201.
[20] Stenhouse C, Coates S, Tivey M, Allsop P, Parker T. Prospective evaluation of a Modified Early Warning Score to aid earlier detection of patients developing critical illness on a general surgical ward. Br J Anaesth 1999;84:663.
[21] National Institute for Health Research [NIHR]. Evaluation of outreach services in critical care – project SDO/74/2004. 2004. Available from: www.netscc.ac.uk/hsdr/files/project/SDO_FR_08-1404-074_V01.pdf [Accessed 19 April 2018]. Assessed at.
[22] Endacott R, Eliott S, Chaboyer W. An integrative review and meta-synthesis of the scope and impact of intensive care liaison and outreach services. J Clin Nurs 2009;18(23):3225–36.
[23] McDonnell A, Esmonde L, Morgan R, Brown R, Bray K, Parry G, et al. The provision of critical care outreach services in England: findings from a national survey. J Crit Care 2007;22(3):212–8.
[24] Niven DJ, Bastos JF, Stelfox HT. Critical care transition programs and the risk of readmission or death after discharge from an ICU: a systematic review and meta-analysis. Crit Care Med 2014;42(1):179–87.
[25] Timmers TK, Verhofstad MHJ, Moons KGM, Leenen LPH. Patients' characteristics associated with readmission to a surgical intensive care unit. Am J Crit Care 2012;21(6):e120–7.
[26] Tam OY, Lam SM, Shum HP, Lau CW, Chan KK, Yan WW. Characteristics of patients readmitted to intensive care unit: a nested case-control study. Hong Kong Med J 2014;20(3):194–204.
[27] Subbe CP, Kruger M, Rutherford P, Gemmel L. Validation of a modified early warning score in medical admissions. QJM-Int J Med. 2001;94(10):521–6.
[28] World Medical Association. WMA declaration of Helsinki - ethical principles for medical research involving human subjects. 2017. Available from: https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/ [Accessed 19 April 2018]. Assessed at.
[29] Harrison DA, Gao H, Welch CA, Rowan KM. The effects of critical care outreach services before and after critical care: a matched-cohort analysis. J Crit Care 2010;25(2):196–204.
[30] Stelfox HT, Bastos J, Niven DJ, Bagshaw SM, Turin TC, Gao S. Critical care transition programs and the risk of readmission or death after discharge from ICU. Crit Care Med 2016;42(3):401–10.
[31] Rosa RG, Maccari JG, Cremonese RV, Tonietto TF, Cremonese RV, Teixeira C. The impact of critical care transition programs on outcomes after intensive care unit (ICU) discharge: can we get there from here. J Thorac Dis 2016;8(7):1374.
[32] Pedersen A, Psirides A, Coombs M. Models and activities of critical care outreach in New Zealand hospitals: results of a national census. Nurs Crit Care 2016;21(4):233–42.