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Original Article

The Impact of Implementing Critical Care Team on Open General Intensive Care Unit

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Background: There are a plethora of literatures showing that high-intensity intensive care unit (ICU) physician staffing is associated with reduced ICU mortality. However, it is not widely used in ICUs because of limited budgets and resources. We created a critical care team (CCT) to improve outcomes in an open general ICU and evaluated its effectiveness based on patients' outcomes.

Methods: We conducted this prospective, observational study in an open, general ICU setting, during a period ranging from March of 2009 to February of 2010. The CCT consisted of five teaching staffs. It provided rapid medical services within three hours after calls or consultation.

Results: We analyzed the data of 830 patients (157 patients of the CCT group and 673 patients of the non-CCT one). Patients of the CCT group presented more serious conditions than those of the non-CCT group (acute physiologic and chronic health evaluation II [APACHE II] 20.2 vs. 15.8, $p<0.001$; sequential organ failure assessment [SOFA] 5.5 vs. 4.6, p=0.003). The CCT group also had significantly more patients on mechanical ventilation than those in the non-CCT group (45.9% vs. 23.9%, $p<0.001$). Success rate of weaning was significantly higher in the CCT group than that of the non-CCT group (61.1% vs. 44.7%, p=0.021). On a multivariate logistic regression analysis, the increased ICU mortality was associated with the older age, non-CCT, higher APACHE II score, higher SOFA score and mechanical ventilation ($p<0.05$).

Conclusion: Although the CCT did not provide full-time services in an open general ICU setting, it might be associated with a reduced ICU mortality. This is particularly the case with patients on mechanical ventilation.

Key Words: Critical Care; Intensive Care Units; Mortality

Introduction

There are so many literatures showing that a high-intensity intensive care unit (ICU) physician staffing is associated with a reduced ICU mortality[1-10]. Its rationale is that physicians can prevent or attenuate morbidity and mortality and thereby can improve the outcomes because they are skilled in not only treating critically-ill patients but also immediately detecting and then resolving problems[11]. But a high-intensity ICU physician staffing is not widely used in ICUs in many countries because of limited budgets and resources. According to Young and Birkmeyer[12], about 15% of all ICU patients were treated in ICUs that meet the Leapfrog standard in the United States. Recent published studies have shown that at least 95% of total ICU patients were managed by critical care physicians for the entire stay in about 18.6% (23/123) of ICUs in the United States[13]. According to a white paper published by the Korean

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Society of Critical Care Medicine (KSCCM), only 17.3% of total ICUs were equipped with high-intensity ICU physicians who can work over eight hours a day[14].

Given the above background, we created the critical care team (CCT) to improve outcomes in an open general ICU and evaluated its effectiveness based on patients' outcomes.

Materials and Methods

1. Study design

We conducted this prospective, observational study in an open, general ICU setting during a period ranging from March of 2009 to February of 2010. The study was approved by the Ethics Committee and Institutional Review Board (IRB) of Chungju Hospital, Konkuk University. Written informed consent was waived because the observational study had the prospective nature and it was conducted to provide rationale of the ICU care policy of our institution by the IRB.

2. Critical care team

Our hospital is a secondary referral hospital equipped with 445 beds except for ICU ones. In addition, its open general ICU has 26 beds where there are 55 board-certified teaching staffs. The CCT consisted of five teaching staffs, each of which includes one pulmonologist, one gastroenterologist, one vascular/trauma surgeon, one pediatrician and one neurologist. The CCT performed the activity only for patients of the CCT group. Each member of the CCT was expected to play its own role; the management of airway and mechanical ventilation (the pulmonologist), the examination of all the abdominal problems including gastroduodenofibroscopy (the gastroenterologist), the related surgical operations and procedures including tracheostomy and chest tube drainage (the vascular/trauma surgeon), the management of mechanical ventilation in the absence of the pulmonologist and cardiopulmonary resuscitation in developed unexpected arrests (the pediatrician) and the treatment of delirium/seizure and acute mental deterioration of patients assigned to the CCT (the neurologist).

It was activated by patients' needs, calling criteria based on the medical emergency response improvement team (MERIT) study[15] or each member's decision. Patients' needs were defined when patients of the CCT group complained to the CCT members or ICU nurses about their three symptoms (pain, dyspnea, and palpitation). In these cases, at least one CCT member directly examined patients and discussed or, if necessary, managed patients' symptoms with other remaining CCT members. We educated the ICU nurses about MERIT criteria in our ICU conference one month before the start of the study. Attending ICU nurses would call CCT members who could be reached if patients of the CCT group met MERIT criteria. The decision of the CCT member was defined when any CCT members needed to discuss the condition or treatment plan of patients of the CCT group with other CCT members. We directly called CCT members without consultation and then discussed with them for the management of patients in future. Otherwise, we provided some treatments including procedures. We were the CCT members who were not full-time high-intensity ICU staffs, but provided rapid medical services, including consultation, within three hours after calls or consultation. We also regularly examined patients and managed patients during rounding after patients were assigned to the CCT group. Of the CCT members, at least one member on duty always covered at night and during weekends. Although the CCT members were on vacation, they were recommended to provide consultation, if necessary, by accessing a web-based remote control program.

3. Study subjects

In the current study, criteria for ICU admission were based on the guidelines by the American College of Critical Care Medicine and Society of Critical Care Medicine[16]. The chief of ICU and an attending physician who assumed responsibility for patient's care determined ICU admission according to the priority of above criteria. An attending physician of the department was assigned to each ICU patient according to his or her primary reason for ICU admission. Inclusion criteria

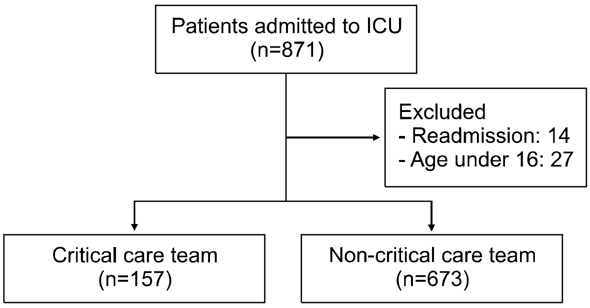

Figure 1. Flow diagram of the study. ICU: intensive care unit.

for the CCT group include 1) patients to whom any members of the CCT were assigned at ICU admission and 2) non-CCT patients who were allowed to take the management by the CCT members during ICU stay with the agreement of non-CCT physicians although they initially belonged to the non-CCT group at ICU admission. Moreover, exclusion criteria include 1) readmission to the ICU during a certain hospital stay and 2) age of 〈16 years. A flow diagram describing the recruitment of our study subjects is shown in Figure 1.

For the current study, we collected such patient data as demographic data, underlying diseases, primary reasons for ICU admission, ICU mortality rates, lengths of ICU stay, acute physiologic and chronic health evaluation II (APACHE II) scores and sequential organ failure assessment (SOFA) scores at ICU admission, the number of patients on mechanical ventilation and success rates of weaning. Success of weaning was defined as a complete autonomy from the ventilator for at least 48 hours, with oxygen saturation (breathing room air or O_2) of $>$90%, and absence of any fatiguing pattern of breathing (tachypnea, marked use of neck inspiratory muscle and asynchronous or paradoxical movements of chest wall and abdomen) by Rochester[17].

4. Statistical analysis

All the data were expressed as mean±standard deviation, but non-normally distributed data were expressed as median and interquartile ratio (IQR). Between the two groups, nominal variables were compared using the Chi-square test or Fisher's exact test. In addition, mean values were compared using Student's t-test between the two groups. Non-normally distributed continuous variables were compared using the Mann-Whitney U test between the two groups. We used a multivariate logistic regression model to adjust confounding variables for an analysis of the ICU mortality rates. An initial model was composed of variables that were determined to be significant and clinically important on univariate analysis. This model included age, sex, medical/surgical patients, underlying diseases (chronic respiratory disease and malignancy), the APACHE II scores and SOFA scores seen on mechanical ventilation, CCT and length of ICU stay. Backward elimination was performed by the likelihood ratio method. Model adequacy was assessed by the Hosmer-Lemeshow goodness-of-fit test. Data are presented as odds ratios with 95% confidence intervals. All the statistical analyses were performed using the SPSS version 17.0 (SPSS Inc., Chicago, IL, USA).

Results

We analyzed the data of 830 patients (157 patients of the CCT group and 673 patients of the non-CCT one), but excluded cases of readmission during the same hospitalization. Our clinical series included 505 men (60.8%) and 518 medical patients (62.4%). The mean age of patients was 61.1±18.0 years. Length of ICU stay and the period of mechanical ventilation were presented as both median and IQR (the length of ICU stay, 4 days; range, 2～8 days; and the period of mechanical ventilation, 69 hours; range, 25.5～228.5 hours). In association with the mechanical ventilation, severity scores and variables showed that the APACHE II score at admission was 16.7±9.6 points, the SOFA score was 4.8±3.5 points, the number of patients on mechanical ventilation was 233 (28.1%) and the success rate of weaning was 49.8% (116/233). In addition, the ICU mortality rate was 12.7% (105/830). The primary reasons of ICU admission include 201 cases (24.2%) of cerebrovascular diseases, 166 cases (20%) of trauma, 158 cases (19%) of gastrointestinal and hepatobiliary diseases, 93 cases (11.2%) of cardiovascular diseases, 82 cases (9.9%) of respiratory diseases, 34 cases (4.1%) of renal or urologic diseases, 22 cases (2.7%) of metabolic or endocrinologic diseases and 74 cases (8.9%) of close monitoring. The most common underlying disease was cerebrovascular disease that was seen in 310 patients (37.3%). There were 75 patients (9%) who received a 'do-not-resuscitate (DNR)' order including withdrawal of treatment by next of kin. The CCT was activated at the total frequency of 1,246 (123 times by patients' needs, 887 times by the MERIT study criteria and 236 times by the CCT member's decision).

The baseline characteristics of the study are presented in Table 1. Sex and age were similar between the two groups. But patients of the CCT group presented more serious conditions than those of the non-CCT group (APACHE II 20.2 vs. 15.8, $p<0.001$; SOFA 5.5 vs. 4.6, $p=0.003$). The CCT group also had significantly more patients on mechanical ventilation than the non-CCT group (45.9% vs. 23.9%, $p<0.001$). The CCT group had a significantly longer ICU stay than the non-CCT

Table 1. Baseline characteristics of the study (n=830)

	CCT group (n=157)	Non-CCT group (n=673)	p-value
Sex, male	100 (63.7)	405 (60.2)	0.416
Age, yr	63.6±18.5	60.6±17.8	0.059
Patient, medical	104 (66.2)	414 (61.5)	0.271
DNR cases	19 (12.1)	56 (8.3)	0.137
Underlying disease			
Cardiovascular	22 (14)	102 (15.2)	0.717
Cerebrovascular	66 (42)	244 (36.3)	0.177
Respiratory	35 (22.3)	60 (8.9)	<0.001
Diabetes mellitus	7 (4.5)	36 (5.3)	0.650
Malignancy	5 (3.2)	13 (1.9)	0.359
Chronic liver disease	2 (1.3)	48 (7.1)	0.005
Chronic kidney disease	10 (6.4)	47 (7.0)	0.784
None	59 (37.6)	283 (42.1)	0.350
On MV	72 (45.9)	161 (23.9)	<0.001
APACHE II score	20.2±9.5	15.8±9.5	<0.001
SOFA score	5.5±3.6	4.6±3.4	0.003

Values are presented as mean±SD or number (%).
CCT: critical care team; DNR: do not resuscitation; MV: mechanical ventilation; APACHE: acute physiologic and chronic health evaluation; SOFA: sequential organ failure assessment.

Table 2. Clinical outcomes of the study (n=830)

	CCT group (n=157)	Non-CCT group (n=673)	p-value
Length of ICU stay, day*	4 (2～13)	3 (2～7)	0.015
Length of MV, hr*	82.5 (29.3～226.3)	65 (24～229.5)	0.416
Success of weaning†	44 (61.1)	72 (44.7)	0.021
ICU mortality	22 (14)	83 (12.3)	0.569
ICU mortality, O/E value, n			
APACHE II<20	1/2.8	17/15.2	0.334
APACHE II≥20	21/22.4	66/64.6	0.691

Values are presented as number (%).
*Values are presented as median, interquartile ratio. †Patients on mechanical ventilation were 233 cases.
CCT: critical care team; ICU: intensive care unit; MV: mechanical ventilation; O/E: observed/expected; APACHE: acute physiologic and chronic health evaluation.

group (4 days vs. 3 days, p=0.015). Length of mechanical ventilation, ICU mortality and the number of DNR cases were similar between the two groups. Success rate of weaning was significantly higher in the CCT group than that of the non-CCT group (61.1% vs. 44.7%, p=0.021). Details of clinical outcomes are shown in Table 2. There were no significant differences in unadjusted ICU mortality rates between the two groups (14% in CCT vs. 12.3% in non-CCT). However, the ICU mortality rate associated with the mechanical ventilation was significantly lower in the CCT group than the non-CCT group (26.4% in the CCT vs. 44.1% in the non-CCT groups, p=0.01). Table 3 shows the baseline characteristics and clinical outcomes of patients on mechanical ventilation.

On univariate analysis, the increased ICU mortality was associated with chronic respiratory diseases, malignancy, medical patient, higher severity scores (APACHE II and SOFA), longer ICU stay and mechanical ventilation ($p<0.05$). On a multivariate logistic regression analysis with the adjustment of confounder, the increased ICU mortality was associated with the older age, non-CCT, higher APACHE II score, higher SOFA score and mechanical ventilation ($p<0.05$). Table 4 shows

Table 3. Baseline characteristics and clinical outcomes in patients on mechanical ventilation (n=233)

	CCT group (n=72)	Non-CCT group (n=161)	p-value
Sex, male	45 (62.5)	105 (65.2)	0.689
Age, yr	67.0±17.4	64.1±16.8	0.217
Patients, medical	44 (61.1)	79 (49.1)	0.089
DNR cases	16 (22.2)	45 (28)	0.358
Length of ICU stay, day*	8.5 (4∼15)	7 (3∼19.5)	0.639
Length of MV, hr*	82.5 (29.3∼226.3)	65 (24∼229.5)	0.416
APACHE II score	26.4±8.0	26.2±9.1	0.877
SOFA score	7.7±3.7	8.4±3.8	0.153
ICU mortality	19 (26.4)	71 (44.1)	0.010
ICU mortality, O/E value, n			
APACHE II<20	1/3.5	11/8.5	0.083
APACHE II≥20	18/24.4	60/53.6	0.038

Values are presented as number (%) or mean±SD.
*Values are presented as median, interquartile ratio.
CCT: critical care team; DNR: do not resuscitation; ICU: intensive care unit; MV: mechanical ventilation; APACHE: acute physiologic and chronic health evaluation; SOFA: sequential organ failure assessment; O/E: observed/expected.

Table 4. Prognostic factors associated with ICU mortality by multivariate logistic regression model

	Odds ratio (95% confidence interval)	p-value
Age	1.017 (1.001∼1.033)	0.042
Sex, female	1.119 (0.651∼1.923)	0.685
Length of ICU stay	0.983 (0.960∼1.007)	0.159
Patients, surgical	1.640 (0.918∼2.930)	0.095
Chronic respiratory disease	1.085 (0.525∼2.244)	0.826
Malignancy	1.622 (0.397∼6.628)	0.501
Critcal care team	0.525 (0.281∼0.980)	0.043
APACHE II score at ICU admission	1.039 (1.000∼1.080)	0.049
SOFA score at ICU admission	1.163 (1.058∼1.278)	0.002
On mechanical ventilation	8.694 (4.123∼18.333)	<0.001

ICU: intensive care unit; APACHE: acute physiologic and chronic health evaluation; SOFA: sequential organ failure assessment.

the prognostic factors associated with the ICU mortality in detail.

Discussion

We demonstrated here that the CCT in an open general ICU setting was associated with a reduced ICU mortality. It was especially effective in treating patients on mechanical ventilation. Additionally, we also demonstrated that the CCT improved the ICU mortality even in patients with more serious illness following the management by the CCT.

Our CCT model was similar to the rapid response system (RRS), which has been proposed as a strategy for better anticipation, especially preventing in-hospital cardiopulmonary arrests[18,19]. We applied the concept of the RRS as well as rapid critical care services in open general ICUs. Therefore, open general ICUs with limited resources could enhance survival rates by implementing the CCT system.

Our study demonstrated some merits. Firstly, it had a prospective observational study design without a historical control. Many studies conducted so far had used historical controls or before-after study design[1-5,9,10,20,21], and have performed a retrospective analysis[1,3-5,9,10]. The cross-sectional studies usually run the risk of selection bias associated with illness severity or utilization of resources. Secondly, the CCT provided rapid medical services to ICU patients within three hours after call or consultation. Despite a lack of the full-time coverage, it may show possibility of improving the ICU mortality. Thirdly, after adjustment for covariates, we demonstrated that both the APACHE II and SOFA scores were associated with the ICU mortality. This is in agreement with other studies showing that these severity scores were predictors of the ICU mortality[22-25].

However, this study had some limitations. Firstly, the finding was obtained from a single center study. This deserves further multicenter randomized studies. Secondly, the guidelines on critical care medicine (sepsis bundle, weaning protocol, stress ulcer prophylaxis protocol and deep vein thrombosis prophylaxis protocol) were prepared at nursing station of our ICU. But we did not examine the degree of compliance to these guidelines in both groups. Thirdly, the CCT was not effective in shortening the length of ICU stay although our study did not focus on it. Presumably, many physicians including the CCT members in our hospital might have been reluctant to transfer patients from stable to general wards based on the consideration that patients would be easily aggravated in general wards. This misconception should be overcome by constant education. Henceforth, further studies are warranted to improve this misconception after implementing the CCT system on a yearly basis.

In conclusion, we demonstrated not only that the CCT model in an open general ICU setting might be associated with the improved ICU mortality but also that the degree of effectiveness was especially remarkable in patients on mechanical ventilation. It can also be inferred that it would also improve the outcomes of patients at other open general ICUs when it is applied to them.

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