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Original Article

The impact of open to collaborative care model in cardiovascular surgical unit

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Abstract

Background: When compared with open care model, a closed one improves patient care in intensive care units (ICUs), mixed ICUs, surgical ICUs and trauma centers. We wanted to evaluate the benefit of a collaborative care model in highly specialized cardiovascular care unit.
Methods: This study was a retrospective, observational study conducted in the cardiovascular care unit of a teaching hospital. All patients who were above 20 years old and had received cardiovascular operation were enrolled for data collection and analysis.
Results: A total of 270 subjects were enrolled for analysis during the 2-year study period. In the collaborative care model, the CVSU length of stay ($p = 0.001$) and CVSU-free days ($p = 0.0008$) were significantly better than those in an open care model.
Discussion: The collaborative care model improved postoperative outcome in the cardiovascular surgical unit for those needing prolonged ICU care.

Keywords: Cardiovascular surgery; Collaborative care model; Intensive care unit; Intensivist; Open care model

1. Introduction

Intensive care units (ICUs) are set up for critically ill patients and are the costliest units in hospitals. From the data of Taiwan's Bureau of National Health Insurance, ICU fees accounted for 25% of overall hospitalization costs in 2003.[1] Effective management is important to reduce the length of ICU stay, ICU mortality rate and hospital mortality rate.[2–5] Moreover, high-quality supportive care in the ICU is a key factor impacting hospital costs, complications and mortality affecting critical ill patients.

The delivery of care service in ICU falls into three broadly defined models. The first one is an "open" intensive care unit. The assignment of patient care and order prescription are based on the primary field of the patient's physicians. The physicians may work outside the ICUs. They are not always available to manage the patients in ICU promptly. The second is a "closed" intensive care unit. In this model, only the intensivists are responsible for patient care in the ICU. The intensivists make the clinical decisions

Conflicts of interest: The authors declare that they have no conflicts of interest related to the subject matter or materials discussed in this article.

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and write the orders. They almost always stay in the ICU during their work hours to manage patients immediately.[6,7] This situation is also called critical care specialist, or an intensivist care model. The third one is the "collaborative" care model, which is considered to be another type of intensivist care model. In such setting, especially for surgical patients, the critical care involves an intensivist and a surgeon who is the primary admitting physicians.[8–10] The care decisions and orders were given in consensus. Patients are continuous served by primary admitting physicians and prompt actions by intensivists while the surgeon is working elsewhere. Reports from medical and traumatic intensive care units has disclosed that the intensivist care model, compared with open, can improve outcomes, reduce hospital mortality, length of ICU stay and augment cost-effectiveness.[8–13] But there are fewer articles examining the usefulness of the collaborative care model in a highly specialized surgical ICU.

In Taiwan, many ICUs, medical or surgical, used the "open" setting before. In order to assure high quality of critical care, a fixed intensivist in each ICU is necessary for annual hospital accreditation from the Department of Health of Taiwan and the Taiwan Joint Commission on Hospital Accreditation. Our hospital changed from using the old open care model of Cardiovascular Surgical Unit (CVSU) to the collaborative care model in April 2010. Pulmonologists certified in critical care were assigned to the CVSU as collaborative intensivists working with cardiovascular surgeons. Since the CVSU is a highly specialized care unit and patients there are more critical than in other ICUs, we compared in this study the effectiveness of post-operation intensive care in open versus collaborative care model in our CVSU.

2. Methods

2.1. ICU settings

Taipei Veterans General Hospital is a 3000-bed teaching hospital in Taiwan. This hospital contains 238 ICU beds allocated in 13 different ICUs carrying different missions. CVSU is one of them, and its main mission is dedicated care of patients recovering from open-heart and great-vessel surgery and heart transplant. The CVSU is a 16-bed unit that includes the 6-bed CVSU-A (Cardiovascular Surgical Unit A) and the 10-bed CVSU-B (Cardiovascular Surgical Unit B). The CVSU-A is designed as an upgraded recovery room for cardiovascular surgery and is directly connected to the operating room. Most patients are observed and extubated in this place before being transferred to ordinary ward. Some patients are so sick due to uncontrolled diseases that even after surgery, they may pass away in the CVSU-A. Those who survive in the CVSU-A and need prolonged ICU care are further transferred to the CVSU-B. In this study, we only enrolled those who had been admitted to the CVSU-B, i.e. those who could not be stabilized soon after surgery, for further analysis.

2.2. Study design

In this retrospective study, the surgical reports and per-operative records were collected for all post-operation patients admitted to our CVSU-B. The study period was from April 1st, 2009, one year before the collaborative care model started, to March 31st, 2011. Obtaining informed consent from patients was judged unnecessary by the Institutional Review Board of Taipei Veterans General Hospital.

Patients were excluded from the study if they were younger than 20 years old, had been admitted to CVSU for less than 24 h, had received no cardiovascular surgery, had incomplete clinical data (the chart unavailable of any reason), had undergone heart transplantation, or had received simple vascular surgery only, such as stent grafting for aortic aneurysm.

The first study period (April 2009 to March 2010) was for investigation of open ICU service. During this period, the surgical team (an attending physician, fellows and residents as a team) was the one and the only caregiver. They still had other works outside the CVSU, such as outpatient clinics, general ward rounds or other operations. They remained on call to the CVSU but were not always available immediately. The second study period (April 2010 to March 2011) looked at collaborative ICU service. During those days, two medical intensivists certified by the Taiwan Society of Critical Care Medicine cooperated with surgeons for patient care in the CVSU. During daytime of weekdays, at least one of the two intensivists stayed in the CVSU. Surgeon and intensivists decided on all patients' critical management together. If opinions differed, they would discuss further and arrive at a final decision. The medical intensivists remained on call at night and through the weekend. Other CVSU settings including the nursing staff, duty shifts of CVSU residents and CVSU equipment were the same in open and collaborative care models.

2.3. Data collection

Patient socio-demographic characteristics and operation type were obtained by chart review. Charlson Comorbidity index (CCI)[14–16] was calculated from medical records. Status of operation was classified as emergency, urgent and elective surgery. The urgency of operation was defined based on guidelines of the Society of Thoracic Surgeons.[17] Operations were divided into coronary artery bypass grafting (CABG) and non-CABG. The latter included vascular heart surgery, aortic surgery, aneurysm repair, repair of ventricular rupture, pericardial-window creation and cardiac tumor surgery.

The patient outcome measurements include 30-day mortality rate (calculated from the first day in the CVSU),[18] mortality rate after discharge from CVSU, ICU length of stay, ICU-free days and ICU re-admission rate within 14 days. ICU-free days were calculated as 30 days minus ICU length of stay. If the patient had stayed in the ICU for more than 30 days or expired in the ICU, the ICU-free days would be zero.[18] Ventilator-associated outcome variables were days on mechanical ventilation, ventilator free days and ventilator weaning rate in ICU.[19] Successful weaning was defined as extubation or discontinued mechanical ventilation for more than 72 h. Long-term outcomes included hospital length of stay and hospital mortality rate.

2.4. Statistical analysis

Statistical analysis included exploratory data analysis (EDA) and modeling of selected outcome variables discussed in the section above. Data collection and analysis were performed with the aid of SPSS software (SPSS 16.0 for Windows, SPSS, Inc., Chicago, IL) and in the R environment using standard packages.[20]

Exploratory analysis was based on contingency tables for categorical outcomes and on mean comparison for continuous variables. The selected explanatory variables as well as the outcome variables were split by the ICU care type (collaborative vs. open care). In the contingency tables, we used chi-squared test to evaluate statistical significance of an association between the ICU care type and the qualitative variable. Mean comparison included testing with parametric *t*-test and non-parametric equivalence – Mann–Whitney U-test. Testing based on the two methods allowed for eliminating false-positive results in case when data distribution departed from normal. In the summary table, continuous observations are expressed as mean ± standard deviation (SD); qualitative (categorical) as a fraction of a total count.

The main outcome variables are either counts of days or proportions. The nature of such observations usually yields a right-skewed distribution of positive values. In consequence, we decided to fit models based on Poisson distribution, which is frequently used for fitting count data.[21] Initially, we employed stepwise selection of the variables based on the AIC score that was indicating the best fit of the variable set. The final analysis contained indicators that in our opinion were reasonable selection for explaining the relationship between outcomes and the ICU care type while controlling for a number of possible confounders.

The coefficients obtained from the fitted models were exponentiated in order to obtain the value of a duration change (duration ratio) while holding other variables constant. The significance level was set at 0.05. The exponentiated regression coefficients ranged from 0 to infinity. Value of 1 indicated no duration change (number of days) in the analyzed outcome variable.

3. Results

The total number of patients admitted to the CVSU-B during the two study periods was 679. There were 409 patients who met the exclusion criteria. Most of them (329 patients) didn't receive cardiovascular surgery (Fig. 1). Finally, there were 270 subjects enrolled for further analysis. Of them, 127 patients were admitted during open ICU service and 143 patients were during the collaborative ICU service. There was no difference in baseline patient characteristics between those two study groups (Table 1). Even the pre-operative Charlson Comorbidity indexes were the same.

During the collaborative care model study period, the ICU length of stay (open vs. collaborative: 15.8 ± 15.7 vs. 10.6 ± 10.0; $p = 0.001$) and the number of ICU-free days (open vs. collaborative: 17.20 ± 9.9 vs. 20.7 ± 8.8; $p = 0.0008$) were significantly better than those observed for the open care model. While the weaning rate of CVSU ($p = 0.080$), the days on mechanical ventilator ($p = 0.26$) and ventilator-free days ($p = 0.21$) didn't differ significantly between the two care models, there was a favorable trend toward collaborative care model in hospital length of stay (open vs. collaborative: 48.2 ± 40.0 vs. 38.6 ± 28.6; $p = 0.051$). Other parameters, like 30-day mortality rate ($p = 1.00$), and hospital mortality rate ($p = 0.087$), were not significantly different (Table 2).

Table 3 shows the comparison of the four major outcome variables related to the clinical status of a patient that were taken into consideration during the observation period. The numbers of both CVSU days and CVSU-free days were affected by ICU care model, APACHE II score, hypertension and age when all other adjusting covariates were held constant (Table 3). In both presented outcomes, those results were consistent with crude analysis that we presented in Table 2. There was no relation to parameters associated with mechanical ventilator or mortality in our analysis.

4. Discussion

High-quality supportive care in ICUs is an important factor impacting patient survival following high-risk surgery. The American College of Surgeons states that postoperative care is the responsibility of the surgeon. The surgeon should participate in postoperative care and provide timely and appropriate therapy. This meets the best interest of the patient.[22] But, in another aspect, some studies comparing the closed and open systems have demonstrated that the closed care model provided a better outcome and also increased the cost-effectiveness.[23–26] Some reports showed that patients with trauma, abdominal aortic surgery, acute lung injury and esophageal resection had better outcomes in intensivist-staffed ICUs.[10,24,25] Those results led the Leapfrog Group to propose the ICU standard for intensivist-directed critical care.[27] The introduction of intensivists into surgical ICUs in our hospital raised the fear of loss of continuity of care and patients being more prone to complication. Since the shortage of surgical intensivists[10] is the situation worldwide, we used the collaborative model instead of strict close model to minimize this concern. The intensivists in this study fully met the requirements of the setting of ICU in Taiwan. In our CVS ICU, we placed emphasis on the collaborative work. Our intensivists and CVS surgeons worked side-by-side in the daily ICU care as well as made difficult decisions together and in a timing manner. Our collaborative care model provided round-the-clock service without compromise the continuity of post-operation care.

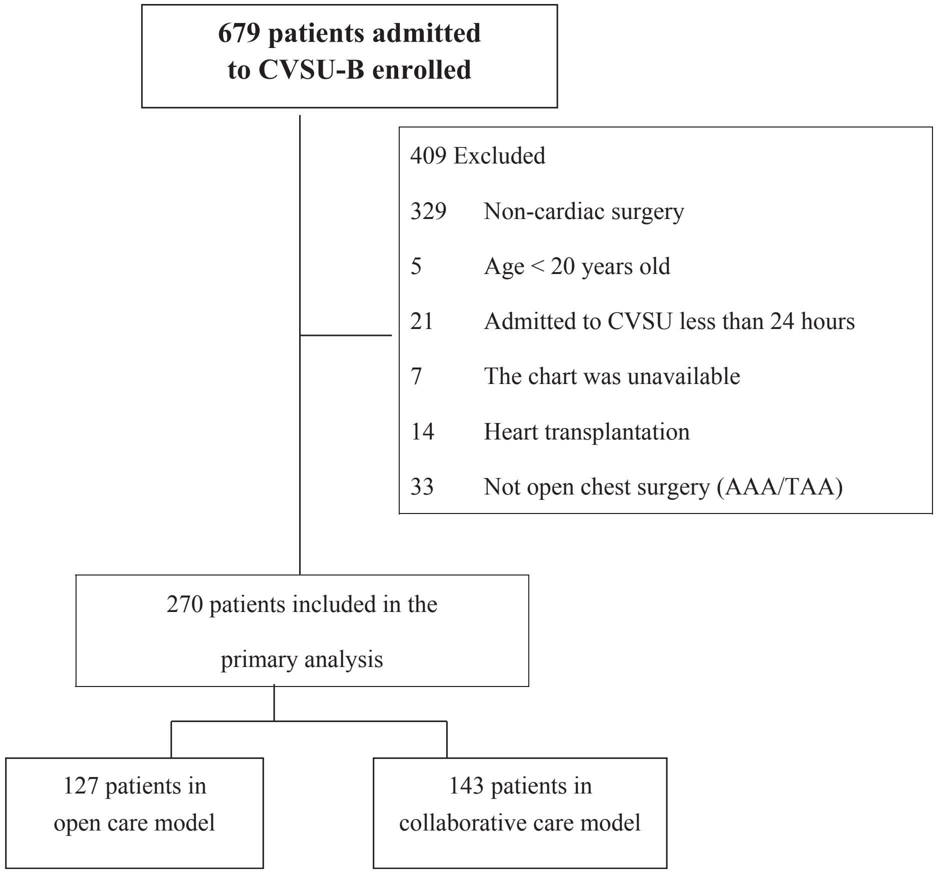

Fig. 1. Flow of patients in this study.

Table 1
Demographic data of patients admitted to CVSB in an open and a collaborative ICU care model.

Variables	Open (n = 127)	Collaborative (n = 143)	*p*
Age (years)	66.30 ± 13.5	66.3 ± 14.0	0.84
Male, n (%)	88 (69.3%)	93 (65.0%)	0.52
Height (cm)	162.30 ± 8.856	160.90 ± 9.104	0.20
BW, kg − when OP	64.33 ± 14.033	63.88 ± 12.775	0.77
BMI, kg/m^2	24.0 ± 4.3	24.0 ± 4.1	0.93
Smoking			0.50
None, n (%)	79 (62.2%)	84 (58.7%)	
Quit, n (%)	30 (23.6%)	31 (21.7%)	
Smoker, n (%)	18 (14.2%)	28 (19.6%)	
APACHE II	19.0 ± 5.3	18.0 ± 4.6	0.11
CCI	2.1 ± 1.8	1.9 ± 1.7	0.16
Status of OP			0.39
Emergency, n (%)	31 (24.4%)	25 (17.5%)	
Urgent, n (%)	11 (8.7%)	13 (9.1%)	
Elective, n (%)	85 (66.9%)	105 (73.4%)	
OP type			1.0
CABG, n (%)	48 (37.8%)	53 (37.1%)	
Other[a] (non-CABG), n (%)	79 (62.2%)	90 (62.9%)	

BW = body weight; BMI = body mass index; APACHE II score = Acute Physiology and Chronic Health Evaluation II score; CCI = Charlson Comorbidity index; OP = operation; CABG = coronary artery bypass grafting.
[a] Other includes = valve, >2 cardiac procedures (CABG + valve), >3 cardiac procedures (CABG + valve + AAA).

Table 2
Patient outcomes in an open and a collaborative ICU care model.

Variables	Open (n = 130)	Collaborative (n = 143)	*p*
Return to CVSU in 14 days	12 (9.4%)	9 (6.3%)	0.37
Operation complications, n (%)	23 (18.1%)	19 (13.3%)	0.31
CVSU length of stay	15.8 ± 15.7	10.6 ± 10.0	0.001
Hospital length of stay	48.2 ± 40.0	38.6 ± 28.6	0.051
Duration of MV	9.4 ± 13.4	7.0 ± 8.1	0.26
CVSU weaning rate of MV	108 (85.0%)	132 (92.3%)	0.08
CVSU-free days	17.20 ± 9.9	20.7 ± 8.8	0.0008
Ventilator-free days	21.5 ± 9.1	23.0 ± 7.6	0.21
Mortality rate of CVSU	14 (11%)	7 (5%)	0.069
Mortality rate of hospital	24 (18.9%)	16 (11.2%)	0.087
Mortality rate of 30 days	4 (3.1%)	4 (2.8%)	1.00

MV = mechanical ventilation.

Most of the studies evaluating the role of intensivists in ICU care took place in general surgical ICUs, medical ICUs and mixed ICUs. Few were conducted in specialized trauma centers.[10,24,25] A recent article reported that intensivist-directed model might reduce mortality after cardiac surgery.[28] To our knowledge, our study is the first focusing on the benefit of collaborative model in a highly specialized ICU, the cardiovascular surgical unit. Patients in the CVSU

Table 3
Poisson model for CVSU-free days.

	Dependent variables			
	CVSU days	MV days	30 days ICU free day	30 days MV free day
Age	0.96*** (0.95,0.97)	0.96*** (0.94,0.97)	1.02** (1.01,1.03)	1.01 (1.00,1.02)
BMI	0.99** (0.98,1.00)	0.99* (0.98,1.00)	1.00 (1.00,1.01)	1.00 (0.99,1.01)
APACHE II	1.11*** (1.10,1.12)	1.14*** (1.13,1.15)	0.94*** (0.93,0.94)	0.96*** (0.95,0.96)
CCI	1.02 (1.00,1.04)	0.99 (0.97,1.02)	0.99 (0.97,1.01)	1.00 (0.98,1.01)
Sex (Male)	1.21*** (1.13,1.29)	1.11* (1.01,1.22)	0.94 (0.87,1.01)	0.98 (0.92,1.05)
Smoke-Quit	1.02 (0.93,1.11)	0.97 (0.86,1.08)	0.99 (0.91,1.07)	1.04 (0.97,1.10)
Smoke-Smoker	1.09 (0.99,1.19)	1.14* (1.01,1.26)	0.91* (0.83,1.00)	0.96 (0.88,1.04)
OP-Emergency	1.18*** (1.09,1.26)	1.42*** (1.31,1.53)	0.86*** (0.78,0.95)	0.83*** (0.79,0.99)
OP-Urgency	1.21** (1.09,1.32)	1.47*** (1.33,1.61)	0.98 (0.88,1.09)	0.89* (0.79,0.99)
Op type-CABG	0.90** (0.83,0.98)	0.91 (0.81,1.01)	1.01 (0.95,1.07)	1.01 (0.95,1.07)
Hypertension	0.82*** (0.75,0.89)	0.81*** (0.72,0.90)	1.10** (1.04,1.16)	1.04 (0.99,1.10)
Care model	0.79*** (0.73,0.86)	0.93 (0.84,1.02)	1.13*** (1.08,1.19)	1.02 (0.97,1.07)

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
BMI = body mass index; APACHE ll score = Acute Physiology and Chronic Health Evaluation II score; CCI = Charlson Comorbidity index; OP-Emergency and OP-Urgency were compared to elective surgery. BW = bodyweight; OP = operation.

are unique in several ways. First, they receives cardiopulmonary bypass (CPB) during the major operation. The CPB alters the circulation flow and produces many pathophysiological changes in many aspects,[29] even after the surgery. It complicates post-operation care. Second, those patients are hemodynamically unstable throughout the operation period and peri-operation period, even for a successful surgery. They need various kinds of inotropes. They may also be connected to various kinds of life-supportive devices, such as intra-aortic balloon pump (IABP), ventricular assist devices (VAD), extracorporeal membrane oxygenation (ECMO), continuous renal replacement therapy (CVVH) and mechanical ventilator. Those devices make patient care more difficult. The patients in this article were even more complicated. They were unable to recover soon after surgery and had prolonged stay in ICU, ie, in our CVSB. We didn't include those who were only admitted to our CVSA and used it as a recovery room. Third, common ICU scores such as APACHE II and Glasgow coma scales (GCS) may not suitable in such patients for outcome prediction. Their usefulness in measuring the benefit of therapy should be further evaluated. Our data showed a collaborative care model was associated with a reduction in CVSU length of stay and increased ICU-free days. It also demonstrated trends toward reduced total hospital days and increased CVSU weaning rate (Table 2). Although the length of time spent on mechanical ventilation in the CVSU was reduced by 7% in the case of the hybrid care model, statistical analysis did not indicate that the hybrid care model had significant influence on either reduction or increase of the ventilation period.

In our assessment of the overall effect, we analyzed using a Poisson regression model when the distribution of variables was not a normal distribution. Only for CVSU length of stay and ICU-free days and the care model effect have statistically significant contributions when all other adjusted covariates were held constant. The reduced ICU stay would relate to the cost reduction, consuming fewer hospital resources and require smaller workforce. There also may be less chance of acquiring an infection in ICU. Most of all, in such setting, we could feel the reduced tension of the working environment and increase in the sense of connection between ICU staff. Both improved patient safety. Those were immeasurable advantages. We think the collaborative ICU care model had better outcome than the open care model. With the collaborative care model, we emphasize the importance of continuing to provide critical care in the cardiovascular surgical care unit.

The effect of introducing intensivists into CVSU has its limits. First, this study was observational only. It is very hard to design a head-to-head, randomized control trial comparing different care models. Second, we didn't have an intensivist-only period. We can't provide data for comparing collaborative and close care models. Third, since our intensivists specialized in chest medicine, some benefit for the infection control and post-operative respiratory care may have been added, especially open chest surgery. Intensivists' background other than chest medicine may not have the same results. Fourth, the collaborative model didn't reduce the complication rate further. Our explanation is that most of the complications related to the particular risks of cardiovascular surgery itself and the preoperative condition of patients themselves. Post-operative care plays little role in those aspects. However, with prompt investigation by intensivists of all patient events, handling complications will be easier and earlier.

In conclusion, the collaborative care model is a good choice in ICU care. Our data showed various outcome improvements in our highly specialized cardiovascular surgical unit compared with the old open care model. In addition, cooperation between surgeons and intensivists in surgical ICUs can provide timely, seamless and continuous surgical patient service and provide safer working atmosphere. And, although those advantages can't be measured directly, our nursing staff loves working with intensivists.

Ethics approval and consent to participate

This study was approved by the institutional review board of Taipei Veterans General Hospital, No. 2011-07-001IC, and the informed consent was waived.

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