The Impact of Closed ICU Model on Mortality in General Surgical Intensive Care Unit

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Background: *A closed model of ICU (intensive care unit) care is associated with improved outcomes and less resource utilization in mixed medical and surgical ICUs as well as traumatic ICUs. However, most of ICUs in developing countries use an opened model especially in surgical ICUs due to lack of specialized physician. The aims of the present are to compare the effects of closed and opened model on ICU mortality and length of ICU stay.*
Material and Method: *The authors conducted a retrospective study to compare mortality between two periods of time. First period was between July 2002 and June 2004, and used open model. The second period was between July 2004 and June 2006, and followed by closed model. The closed model was defined as an ICU service led and managed by an intensivist. The open model was an ICU service where critically ill surgical patients were managed by host surgeons individually.*
Result: *Two thousand two hundred and sixty nine patients were included in the present (Open vs. Close, 1,038 vs. 1,231). The overall ICU mortality rate was decreased with statistical significance in closed model (27.4% vs. 23.4%; $p = 0.03$). This effect was obvious in patients admitted to ICU longer than 48 hours (22.7% vs. 13.9%; $p < 0.01$). After adjusting for differences in baseline characteristics and case-mix factor, the risk of death in closed ICU model was also statistically significant less than opened model [RR = 0.85 (0.74-0.98); $p = 0.02$]. The effect was explicit in patients admitted to ICU longer than 48 hours [RR = 0.60 (0.47-0.76); $p < 0.01$]. However, risk of death in non-traumatic patients and elderly patients older than 65 years of age tend to be lower in closed model [RR = 0.81 (0.64-1.01); $p = 0.06$ and RR = 0.81 (0.64-1.01); $p = 0.07$ respectively]. In addition, closed model ICU has shorter length of ICU stay (5.4 ± 7.1 vs. 4.6 ± 6.1 days; $p < 0.01$) and adjusted length of ICU stay was lowered about 0.80 day [-0.80 day (-1.34 to -0.25); $p < 0.01$] in closed model with statistical significance when compare to open model.*
Conclusion: *The closed model, led and managed by an intensivist, is associated with reduction in overall ICU mortality and has greatest effect in patients admitted longer than 48 hours. Furthermore, this model shortens ICU length of stay.*

Keywords: *Intensive care unit model, Closed ICU model, Opened ICU model, Intensivist led ICU model, ICU mortality, Organizational innovation, Organization and administration*

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Although no exacted utilization expenses were reported in intensive care patients in Thailand but in the United State of America (US), approximately 1% of the US gross domestic product (GDP) is consumed by the care given in intensive care unit[1]. The effective treatment method and administrative issue are important variables to improve cost and benefit balance[1-4]. An arranging system of intensive care unit (ICU), physician staffing analyzed in meta-analysis and reported that high intensity ICU staffing is associated with reduced hospital and ICU mortality as well as ICU

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length of stay[5-11]. However, there are lacks of physician staffing or intensivists in Thailand. Thus, most of ICU in Thailand especially in general government hospital used opened model of ICU where each patients was admitted to ICU and managed by host physicians liberally. In trauma patients, literature revealed that intensivist model or closed ICU is associated with a large reduction in in-hospital mortality following trauma[12-15]. In the authors' hospital, policy of surgical department transformed ICU service to closed model after June 2004. Due to limitation of supply resources in developing country, results might be altered from those performed in developed countries. Therefore, the aim of the authors' study was to compare mortality and the length of ICU stay obtained from open ended versus close ended ICU model in general surgical ICU.

Material and Method

Study design and time selection

The authors conducted retrospective study on general intensive care unit (ICU) in university hospital, which is the tertiary referral center in the northern region of Thailand between July 2002 and June 2006. Overall nurse staff to patient ratio and registered nurse staff to patient ratio in the authors' ICU setting were one to one and one to two respectively. The number of beds in ICU were counted depend on the previous ratio and ranged between six to eight bed during these period. The study was divided into before and after intervention. Period of open-ended ICU service was from July 2002 to June 2004 while close ended period was from July 2004 to June 2006 with an aim to reduced possible confounders. There were two reasons for the selection of these periods. Firstly, the equipment; the authors' institute replaced large number of mechanical ventilators at the end of the year 2006 and the authors were concerned about these high technological equipment affecting the results. Thus, patient admitted after the new equipments was installed were excluded of this study. Secondly, there was alteration of service system in surgical department, which was changed from general service to specialized organ oriented service system in second half of year 2006. This may have influenced the treatment and the outcome from surgeon expert.

Model of ICU setting

An open-ICU model was a traditional system in the authors' hospital. The unit had 24 hours ICU on call service, which is rotated by surgical residents. All patients admitted to ICU were managed by individual host general surgical team separately or attending physicians contributed and controlled the care of their patients. The ICU rotated surgical residents had an important role only in emergency conditions. However, most of the treatments were ordered by host team. In this model, all physicians involved in the patient problems could mandate investigation as well as treatments independently.

A closed ICU model was ICU service system where all patients' management and all primary responsibility in term of investigation and critical care management were led only by specific team. In the authors' model, the specific team was led by an intensivist who was defined as a physician board certified in critical care.

Population domain in the study

All the patients admitted to ICU between July 2002 and June 2006 were considered as the study domain population. The authors excluded patients scheduled and admitted to kidneys transplantation without complication, moribund patients, and patients admitted and discharged from ICU less than 1 hour.

Data collection and analysis

The authors collected age, gender, main admission diagnosis, and admission severity of disease, which was measured by APACHE II score. The interested outcomes were intensive care mortality and length of ICU stay in number of day(s). Data was analyzed by STATA 10.1 software. They were analyzed by Pearson's Chi-square for categorical variables, student's t-test for normal distributed continuous variables, and Mann-Whitney U-test for nonparametric continuous variables. Confounding factors were observed from primary analysis variable, which set different significant level at p-value less than 0.05. Those were put together with theoretical factors, which might involve occurrence of outcomes. All of concerned confounders were controlled in analysis model by binary logistic regression analysis for binary outcome variable and linear regression for continuous variable as well as exponential risk regression for relative risk analysis.

The authors designed subgroup analysis in the authors' data to compare patients in each model who was admitted up to 48 hours and longer than 48 hours to exclude extreme prognosis patients. These timing periods were determined based on the authors' institute experience and clinical observation of these groups patient including uncomplicated postoperative patients, high-risk surgical patients admitted for monitoring, and moribund patients who had multi-organ dysfunction, which most of them would be discharged from ICU within 48 hours after admission.

The expected number of patient in the authors' study cohort was calculated from previous studies, which found that opened model had 33% mortality(5). The authors expected closed model might reduce risk of death by about 6%. Of these assumptions, the authors calculated a number of patient to reveal statistical significant at alpha error 5% and power of test 80%. The samples needed for the present study was approximately 950 patients in each groups. The ICU admission rate in the authors' ICU was about 50 patients per month. Thus, the authors collected patient's data for two years in each groups from these background.

Result

After patient selection process from previous inclusion and exclusion criteria, 2,269 patients were included in data analysis. There were some differences in baseline patient characteristics between two models. Male gender proportion was predominant in closed model (65% vs. 59.3%) and female in open (40% vs. 35%). Major admission diagnosis of organ involvements proportion (specialty) was slightly different in these two groups in spite of significant in statistical difference. However, the admission severity score measured by APACHE II score was similar between groups (open vs. close: 20.3 $\pm$ 7.8 vs. 19.9 $\pm$ 7.7; p = 0.2). Admission score was higher in dead group than survival group but was not different between groups of patients (Table 1).

The crude overall mortality rate in closed model (23.4%) was significantly lower when compared with opened model (27.36%), yielding an unadjusted relative risk of death of 0.86 (0.74-0.98; p = 0.03). Interestingly, although the closed model did not affect crude mortality and relative risk of death in patients whose admission to ICU was shorter than 48 hours, the closed model revealed an obvious significant

Table 1. Demographic data of patients in an opened and a closed ICU model

	Open (n = 1,038)	Close (n = 1,231)	p-value
Age	54.46 $\pm$ 20.09	54.79 $\pm$ 19.8	0.70
Gender female:male (%)	422 (40.7):616 (59.3)	431 (35.0):800 (65.0)	<0.01
APACHE II score			
Total	20.3 $\pm$ 7.8	19.9 $\pm$ 7.7	0.20
Dead group	29.8 $\pm$ 6.8	30.1 $\pm$ 7.0	0.6
Survive group	16.7 $\pm$ 4.8	16.8 $\pm$ 4.5	0.87
Diagnosis			
Non trauma (%)	795 (76.6)	947 (76.9)	0.77
Trauma (%)	245 (23.6)	284 (23.1)	
Advance age			
Age $\leq$ 65 yrs (%)	648 (62.4)	779 (63.3)	0.68
Age > 65 yrs (%)	390 (37.6)	452 (36.7)	
Specialty(%)			
Trauma	245 (23.6)	284 (23.1)	0.02
Gastrointestinal	282 (27.2)	311 (25.3)	
Vascular	147 (14.2)	237 (19.3)	
surgery	153 (14.7)	143 (11.6)	
HBP*	38 (3.7)	71 (5.8)	
HNB**	54 (5.2)	51 (4.1)	
Urosurgery	109 (10.5)	123 (10.0)	
Chest	10 (1.0)	11 (0.9)	
Neurosurgery			
Admission			
$\leq$ 48 hr (%)	460 (44.3)	575 (46.8)	0.24
> 48 hr (%)	578 (55.7)	654 (53.2)	

* HBP = hepato-biliary and pancreas, **HNB = head neck and breast

Table 2. Demonstrate crude overall mortality, subgroup analysis of mortality and length of ICU stay in each model

	Open (n = 1,038)	Close (n = 1,231)	p-value
Overall mortality(%)	284 (27.36)	288 (23.4)	0.03
Mortality by time			
$\leq$ 48hr (%)	153 (33.3)	197 (34.3)	0.74
> 48hr (%)	131 (22.7)	91 (13.9)	<0.01
Mortality by cause			
Non-trauma(%)	204 (25.7)	207 (21.9)	0.06
Trauma(%)	80 (32.65)	81 (28.5)	0.30
Mortality by age			
Age $\leq$ 65 yrs	171 (26.4)	182 (23.4)	0.19
Age > 65 yrs	113 (29.0)	106 (23.5)	0.07
Length of ICU stay (day)	5.4 $\pm$ 7.1	4.6 $\pm$ 6.1	<0.01

different in both crude mortality and relative risk in patients who had ICU length of stay longer than 48 hours [Open vs. Close: 22.7% vs. 13.9%; p < 0.01; RR 0.61 (0.48-0.78); p < 0.01] (Table 2 and Fig. 1). Furthermore, closed model could significantly decrease ICU length of stay (open vs. close: 5.4 $\pm$ 7.1 vs. 4.6 $\pm$ 6.1; p < 0.01). In spite of an indifference in crude mortality in patient less than 65 years old, older patients had tendency for a significantly lower mortality in closed model (open vs. close: 29% vs. 23.5%; p = 0.07). In subgroup of traumatic and non traumatic patients, closed model ICU also had tendency to decrease mortality only in a group of non-traumatic patient (open vs. close: 25.7% vs. 21.9%; p = 0.06). However, it was not different in traumatic patients when compared to open model.

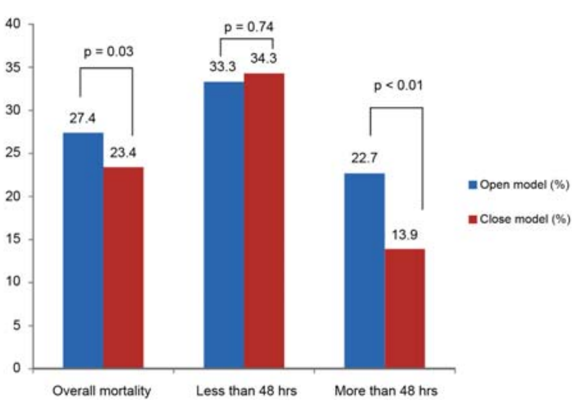

Fig. 1 Demonstrate percentage of overall mortality, less than and more than 48 hours admission between opened and closed model

To control the potential confounder effects due to baseline differences and theoretical clinical variable affected outcomes, the regression models were used to determine effect size of relation by risk ratio to compare outcomes of closed model with opened model by controlling for confounding variable included age, gender, APACHE II score, diagnosis, and specialty. By these models, the adjusted risk ratio or multivariate risk ratio also had the same direction as univariate analysis. Overall mortality and mortality among patients who were admitted to ICU longer than 48 hours significantly decreased by 15% and 40% orderly [RR (95% confidence interval): 0.85 (0.74-0.98); p = 0.02 and 0.60 (0.47-0.76); p < 0.01 respectively]. Length of ICU stay significantly decreased in closed model about 0.77 day in univariate analysis and 0.80 day in adjusted model (Table 3). Subgroup analysis of non-traumatic patients as well as elderly patient with age more than 65 years had trend to decrease of mortality about 19% (Table 3).

Discussion

From the authors' results of study, the authors have demonstrated an adjusted risk reduction in overall mortality about 15% in closed model when compare to opened model. Although the authors' series had higher overall mortality rate about 25% when compare to the other series in Lertakyamanee and et al performed study in large tertiary teaching hospital closed ICU in Bangkok which reported only 10.6%[16]. In one hand, the causes of this difference might be difference in patient characters because the authors' hospital had no limitation of critically ill referral patients from northern region primary and secondary general hospital of Thailand and this might create

Table 3. Demonstrate relative risk ratio and the length of ICU stay comparing a closed model and an opened model using univariate and multivariate analysis

Main outcomes	Univariate	p-value	Multivariate[a]	p-value
Overall mortality [RR (95% CI)]	0.86 (0.74-0.98)	0.03	0.85(0.74-0.98)	0.02
Mortality [RR (95% CI)]				
$\leq$ 48 hr admission	1.03 (0.86-1.22)	0.76	1.02(0.87-1.21)	0.78
> 48 hr admission	0.61 (0.48 – 0.78)	<0.01	0.60(0.47-0.76)	<0.01
Mortality [RR (95% CI)]				
Non-trauma	0.81 (0.65-1.01)	0.06	0.81 (0.64-1.01)	0.06
Trauma	0.82 (0.57-1.19)	0.30	0.84 (0.57-1.25)	0.41
Mortality [RR (95% CI)]				
Age $\leq$ 65 yrs	0.88 (0.74-1.06)	0.12	0.88 (0.73-1.05)	0.15
Age > 65 yrs	0.81 (0.64-1.02)	0.07	0.81 (0.64-1.01)	0.07
Length of ICU stay [day (95% CI)][b]	-0.77 (-1.32 to -0.23)	<0.01	-0.80 (-1.34 to -0.25)	<0.01

[a] = Adjusted for age, gender, APACHE II score, diagnosis and specialty
[b] = mean difference in days with 95% CI closed model vs. opened model
CI = confidence interval

selection bias between series of study. On the other hand, the characteristics of the latter ICU were closed model, which might alter positive outcomes. However, when the authors compared admission APACHE II in the authors' series to Khwannimit et al series(17) demonstrated comparable of severity score in non-survival patients (The authors' series vs. Khwannimit series 29.9 $\pm$ 6.9 vs. 30.5 $\pm$ 28.2 respectively). In addition, the authors' mortality rate was closely comparable to Baldock et al series, which reported crude mortality between 20% and 28%(2).

Structure of critical care unit service model and organization of ICU are important variables of treatment outcomes. Hanson et al performed cohort study in surgical ICU compared between supervise based intensivist and supervise based by general surgeon. The study reported intensivist based spent less patients' time in surgical ICU, used fewer resources, had fewer complications as well as had lower total hospital charges(4). Ghorra et al reported before and after conversion from open unit to closed unit in tertiary care surgical intensive care unit that closed unit which managed by board certified intensivists could reduced inotropic usage, overall complications and mortality rates. Of these results, they suggested patients in surgical ICU should be managed by board certified intensivists in closed environment if it was possible(3). In the different limited resource utilization in developing country, the authors wondered the results might be altered. However, the results in the authors' study also had the same direction of overall mortality, the same as the previous studies.

In subgroup of patients who admitted to ICU more than 48 hours, the authors found the significant decrease relative risk of death in closed model about 40%, after adjusting for potential confounding factors despite no different in less than 48 hours admission. These phenomena could be explained by different spectrum of disease severities. Those, who were discharged from ICU before 48 hours, had extreme prognosis that meant excellent or poorest prognosis. Stratification to two separate groups could screen for spectrum bias prevention. Closed model that led service team by intensivist might be easier to implement guidelines and had unity of treatment in critically ill patients. The better outcomes in closed model might be affected from these appropriate guidelines. During those period, the authors implemented many guidelines in the period of closed model. Those were surviving septic campaign guidelines for management of severe sepsis and septic shock(18), early goal directed therapy in the treatment of severe sepsis and septic shock(19), and the use insulin protocol to control blood sugar less than 150 mg/dL, which could improve outcome in surgical patient(20). In addition to more than 48 hours admission subgroup, these guidelines might mediate effects to subgroup of patients older than 65 year old and non-traumatic patient. Those subgroup patients had trend to decrease risk ratio of mortality as shown in Table 3.

Adjusted length of ICU stay significantly decreased about 0.8 day (1.34 to 0.25) in closed model. This effect might occurred from the used of weaning protocol for liberal patients from mechanical ventilator which the authors implemented to ICU after altered to closed ICU model[21,22]. In the authors' series of weaning protocol compare to standard care, the authors could decrease median of ventilator day and length of ICU stay[22].

Although the authors attempted to decrease confounder effects by regression multivariate analysis and stratification of affected outcome variables, there were some inevitable limitations in the present study due to nature of retrospective study before and after intervention study. Firstly, although the authors tried equipments control by selecting time to collect patients'data, the authors could not control the advance and progression in pharmaceutical aspects that might give better outcomes such as new antibiotics, use of norepinephrine, and new colloidal fluids. In the present study, those factors were not controlled in the analysis. Secondly, despite an equal proportion of nurse to patient ratio, paramedical and nurse experience increases overtime thus, could improve outcome. Therefore, the result of the present study may be jeopardized from maturity bias. Finally, the authors' study did not collect effective drug usage and all cost of admission. Thus, the authors could not conclude the cost saving and economic aspect from the authors' study.

Conclusion

The closed model was led and managed by an intensivist and is associated with reduction in overall ICU mortality. It had positive effects on patients admitted more than 48 hours. Furthermore, this model decreases ICU length of stay.

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ผลของการบริหารหอผู้ป่วยเวชบำบัดวิกฤตศัลยกรรมทั่วไปแบบปิดต่ออัตราการเสียชีวิต

กวีศักดิ์ จิตตวัฒนรัตน์, ฐิติ ภมรศิลปะธรรม

วัตถุประสงค์: *การบริหารหอผู้ป่วยเวชบำบัดวิกฤตแบบปิดเพิ่มผลการรักษา และลดค่าใช้จ่ายได้ในหอผู้ป่วยเวชบำบัดวิกฤตทั่วไปรวมถึงอุบัติเหตุ อย่างไรก็ตามหอผู้ป่วยเวชบำบัดวิกฤตส่วนใหญ่ในประเทศกำลังพัฒนามีการบริหารแบบเปิดโดยเฉพาะในไอซียูศัลยกรรม วัตถุประสงค์ของการศึกษานี้ เพื่อศึกษาผลของการบริหารหอผู้ป่วยเวชบำบัดวิกฤตศัลยกรรมทั่วไป แบบปิดเปรียบเทียบกับการบริหารแบบเปิดต่ออัตราการเสียชีวิต และระยะเวลาการครองเตียงในไอซียู*

วัสดุและวิธีการ: *เก็บรวบรวมแบบย้อนกลับระหว่าง กรกฎาคม พ.ศ. 2545 ถึง มิถุนายน พ.ศ. 2549 โดยแยกเป็น 2 ช่วงเวลา โดยช่วงแรกเป็นช่วงบริหารแบบเปิดในช่วง กรกฎาคม พ.ศ.2545 ถึง มิถุนายน พ.ศ.2547 และ ช่วงที่สองเป็นช่วงบริหารแบบปิดระหว่าง กรกฎาคม พ.ศ. 2547 ถึง มิถุนายน พ.ศ. 2549 โดยการบริหารหอผู้ป่วยเวชบำบัดวิกฤตแบบปิดหมายถึงการบริหารจัดการในหอผู้ป่วยเวชบำบัดวิกฤตโดยทีมแพทย์ของหอผู้ป่วยเวชบำบัดวิกฤตซึ่งนำทีมโดยผู้เชี่ยวชาญทางเวชบำบัดวิกฤต และการบริหารหอผู้ป่วยเวชบำบัดวิกฤตแบบเปิดหมายถึงการบริหารจัดการในหอผู้ป่วยเวชบำบัดวิกฤตโดยทีมแพทย์ผู้ผ่าตัด*

ผลการศึกษา: *ผู้ป่วยจำนวน 2260 คน นำเข้าสู่การศึกษา โดยระยะเวลาการบริหารแบบเปิดจำนวน 1038 คน และแบบปิดจำนวน 1231 คน อัตราการเสียชีวิตลดลงอย่างมีนัยสำคัญทางสถิติในแบบปิด (27.4% และ 23.4%; $p = 0.03$) ผลของอัตราการเสียชีวิตจะเด่นชัดขึ้นในผู้ป่วยที่นอนในหอผู้ป่วยมากกว่า 48 ชั่วโมง (22.7% และ 13.9%; $p < 0.01$) ภายหลังจากทำการควบคุมหลายตัวแปรพบว่าการบริหารแบบปิดมีความเสี่ยงสัมพัทธ์ลดลงอย่างมีนัยสำคัญ [RR = 0.85 (0.74-0.98); $p = 0.02$] และเป็นดังกล่าวเด่นชัดในผู้ป่วยที่นอนในหอผู้ป่วยที่นานกว่า 48 ชั่วโมง [RR = 0.60 (0.47-0.76); $p < 0.01$] อย่างไรก็ตาม ในผู้ป่วยที่รับเข้ารักษาในหอผู้ป่วยเวชบำบัดวิกฤตด้วยสาเหตุอื่น ๆ ที่ไม่ใช่จากอุบัติเหตุ และผู้ป่วยที่อายุมากกว่า 65 ปี มีแนวโน้มว่าอัตราการตายลดลงแต่ไม่มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ [RR = 0.81 (0.64-1.01); $p = 0.06$ และ RR = 0.81 (0.64-1.01); $p = 0.07$ ตามลำดับ] สำหรับระยะเวลาการครองเตียง ในหอผู้ป่วยเวชบำบัดวิกฤตพบว่า การบริหารแบบปิดสามารถลดระยะเวลาการนอนในหอผู้ป่วยประมาณ 0.80 วัน [-0.80 วัน (-1.34 to -0.25); $p < 0.01$]*

สรุป: *การบริหารหอผู้ป่วยเวชบำบัดวิกฤต แบบปิดสามารถลดอัตราการเสียชีวิต และระยะเวลาการครองเตียงในหอผู้ป่วยผลดังกล่าว จะเห็นได้ชัดมากขึ้นในผู้ป่วยที่นอนในหอผู้ป่วยมากกว่า 48 ชั่วโมง อีกทั้ง การบริหารแบบปิดยังลดระยะเวลาการครองเตียงในหอผู้ป่วยเวชบำบัดวิกฤตด้วย*