CHAPTER 4

FINDINGS AND DISCUSSION

The purpose of this study was to measure and estimate patient cost and length of stay in adult ICUs in a teaching hospital of Thailand. The specific objectives were to assess health personnel cost per patient day, medical care cost per patient day, nursing personnel cost per patient day, length of ICU stay and to explain the relationship between patient characteristics, types of ICU, day and time of patient admissions, nurse staffing, nursing personnel cost per patient day, medical care cost per patient day and length of ICU stay. Results from the data analyses are presented with the demographic characteristics of the sample followed by the findings of each research question. The discussion part of each objective is presented in the last part of this chapter.

Findings

Demographic Description of the Sample

The demographic characteristics of the study sample are presented in Table 2. Patient age ranged from 15 to 93 with a mean age of 55.7 (*SD* = 20.6) years; 50.8% of patients were 60 years or older. The majority of the 242 patients were males (55.8 %). The most common diagnoses included diseases of respiratory system (28.5%), nervous system (17.8%), digestive system (13.2%), circulatory system (12.8%) and renal failure (9.9%). The data indicated that the patients were frequently transferred from general units in this hospital (37.2%). Only 18.2% were transferred from other hospitals. In terms of day and time of patient admission, the majority of them (63.2%) were admitted to an ICU on a week day and 69% were admitted to an ICU during non-office hours.

Nutrition status of critically ill patients was determined based on the levels of albumin and lymphocyte counts at admission. Of 242 medical records, approximately 32% had albumin levels less than 3.2 grams per liter, and 85.5% had lymphocyte counts less than 2,000 cells per cubic millimeter. The mean first 24 hour severity of illness score was 45 (*SD* = 23.5). This score indicated that the mean predicted risk of death at admission was 36.9 % (*SD* = 31.2). Approximately 58% (140 patients) had severity of illness score less than 40. Only 15% (36 patients) were not ventilated during ICU stay while 85% (206 patients) received mechanical ventilation assistance. There were differences in the durations of mechanical ventilation. Approximately 60% of the sample underwent ventilation for 1 to 3 days, 22% underwent ventilation for 4 to 7 days and 4% underwent ventilation for 7 or more days. The mean duration of mechanical ventilation for these patients was 2.6 (*SD* = 2.2) days. A mean length of ICU stay was 5.2 (*SD* = 2.2) days with ranged from 1 to 21 days. Death rate of all patients in the study was 14%. Transfer to general units was frequent for survival patients. Approximately 17% transferred to sub-ICUs. Only 5% discharged to home and a few non-recovered patients (0.8%) needed to go back home.

Stratified demographic data of the sample by types of ICU indicated the age distribution of patients in both units was concentrated in patients aged more than 60 years. The majority of the surgical ICU patients (62.5%) were male whereas the half of medical ICU patients (50.8 %) was female. Diseases of the nervous system and the digestive system were most prevalent among surgical patients; diseases of the respiratory system diseases and renal failure were most prevalent among medical patients. The majority of patients in both units were transferred from general units in this hospital. Interestingly, nearly 27% of surgical patients were transferred from neighboring hospitals whereas few medical patients

(9.8 %) were transferred from other hospitals. The majority of surgical patients were admitted to the unit on weekdays and non-office hours. This proportion was similar to medical patients.

Approximately 28% and 85% of surgical patients respectively had low levels of albumin and low lymphocyte counts. These proportions were slightly higher in medical patients (36.9% and 86.1%, respectively). The mean severity of illness scores for surgical patients on admission was 28.7 (*SD* = 16.1) and was higher in medical patients (*M* = 50.0, *SD* = 20.7). Approximately 18% of surgical patients were not ventilated during ICU stay while the majority of them (82%) required ventilation assistance with the mean duration of mechanical ventilator of 2.0 (*SD* = 1.7) days, and the longest duration of mechanical ventilation for them was 7 days. For medical patients, approximately 12% were not ventilated during the ICU stay while approximately 88% underwent ventilator with the mean duration of mechanical ventilator of 3.3 (*SD* = 2.4) days. There was approximately 8% of medical patients underwent ventilation more than 7 days. The range of length of ICU stay in the surgical ICU was 1 to 8 days, with a mean of 4.1 (*SD* = 1.0) days. The majority of surgical patients (30.0%) had an ICU LOS of 4 days and 35 patients (29.1%) stayed for more than 4 days. The range of length of ICU stay in the medical ICU was 2 to 21 days. The mean length of ICU stay for the medical ICU was 6.6 (*SD* = 2.9) days. The majority of these patients (31.2%) had an ICU LOS of 6 days and 41 patients (33.6%) had a prolonged ICU stay of more than 6 days. Death rate was 8.3% in surgical ICU and 19.7 % in medical ICUs. No surgical patients were discharged to home, in contrast, nearly 10% of medical patients were.

Table 2

Demographic Characteristics of the Study Sample

Characteristics	Surgical ICU (n = 120) Number (%)	Medical ICU (n = 122) Number (%)	All patients (N = 242) Number (%)
Patient age by stage of development			
Early adulthood (15 through 25 years)	18 (15.0%)	10 (08.2%)	28 (11.6%)
Middle adulthood (26 through 40 years)	16 (13.3%)	13 (10.7%)	29 (12.0%)
Late adulthood (41 through 60 years)	34 (28.3%)	28 (23.0%)	62 (25.6%)
Older adulthood (more than 60 years)	52 (43.4%)	71 (58.1%)	123 (50.8%)
Patient sex			
Male	75 (62.5%)	60 (49.2%)	135 (55.8%)
Female	45 (37.5%)	62 (50.8%)	107 (44.2%)
Patient diagnoses categorized by ICD 10			
Diseases of the respiratory system	10 (08.3%)	59 (48.4%)	69 (28.5%)
Diseases of the nervous system	37 (30.8%)	6 (04.9%)	43 (17.8%)
Diseases of the digestive system	26 (21.7%)	6 (04.9%)	32 (13.2%)
Diseases of the circulatory system	21 (17.5%)	10 (08.2%)	31 (12.8%)
Renal failure	0 (00.0%)	24 (19.7%)	24 (09.9%)
Injury	20 (16.7%)	0 (00.0%)	20 (08.3%)
Infectious and parasitic diseases	2 (01.7%)	8 (06.6%)	10 (04.1%)
Other diseases	4(03.3%)	9 (07.3%)	13 (05.4%)
Location prior to ICU admission			
General units in this hospital	50 (41.7%)	40 (32.8%)	90 (37.2%)
Emergency room in this hospital	12 (10.0%)	36 (29.6%)	48 (19.8%)
Sub-ICU in this hospital	22 (18.3%)	22 (18.0%)	44 (18.2%)
Transfer from other hospital	32 (26.7%)	12 (09.8%)	44 (18.2%)
Other ICU in this hospital	4 (03.3%)	12 (09.8%)	16 (06.6%)
Day of ICU admission			
Weekdays	76 (63.3%)	77 (63.1%)	153 (63.2%)
Weekend days	44 (36.7%)	45 (36.9%)	89 (36.8%)
Time of ICU admission			
Non-office hours	88 (73.3%)	79 (64.8%)	167 (69.0%)
Office hours	32 (26.7%)	43 (35.2%)	75 (31.0%)

Table 2 *(Continued)*

Characteristics	Surgical ICU (n = 120) Number (%)	Medical ICU (n = 122) Number (%)	All patients (N = 242) Number (%)
Level of albumin at admission			
< 3.2 grams per liter (abnormal level)	33 (27.5%)	45 (36.9%)	78 (32.2%)
≥ 3.2 grams per liter (normal level)	66 (55.0%)	73 (59.8%)	139 (57.4%)
No result	21 (17.5%)	4 (03.3%)	25 (10.4%)
Lymphocyte count at admission			
< 2,000 cells/mm^3 (abnormal level)	102 (85.0%)	105 (86.1%)	207 (85.5%)
≥ 2,000 cells/mm^3 (normal level)	18 (15.0%)	17 (13.9%)	35 (14.5%)
Severity of illness scores at first 24 hour admission			
Less than 40 (Predicted risk of death < 25%)	96 (80.0%)	44 (36.1%)	140 (57.9%)
41 to 51(Predicted risk of death = 25% to50%)	13 (10.8%)	27 (22.1%)	40 (16.5%)
52 to 63(Predicted risk of death = 50% to75%)	6 (05.0%)	26 (21.3%)	32 (13.2%)
More than 63 (Predicted risk of death > 75%)	5 (04.2%)	25 (20.5%)	30 (12.4%)
Duration of mechanical ventilator			
No ventilation assistance	22 (18.3%)	14 (11.5%)	36 (14.9%)
Ventilation assistance			
1.0 to 4.0 days	80 (66.7%)	64 (52.5%)	144 (59.5%)
4.1 to 7.0 days	18 (15.0%)	34 (27.9%)	52 (21.5%)
> 7 days	0 (00.0%)	10 (08.1%)	10 (04.1%)
Length of ICU stay			
1 day	5 (04.2%)	0 (00.0%)	5 (02.1%)
2 days	16 (13.3%)	10 (08.2%)	26 (10.7%)
3 days	28 (23.4%)	10 (08.2%)	38 (15.7%)
4 days	36 (30.0%)	6 (04.9%)	42 (17.4%)
5 days	28 (23.3%)	17 (13.9%)	45 (18.6%)
6 days	4 (03.3%)	38 (31.2%)	42 (17.4%)
7 days	0 (00.0%)	10 (08.2%)	10 (04.1%)
more than 7 days	3 (02.5%)	31 (25.4%)	34 (14.0%)
Discharge status			
Non-survival	10 (08.3%)	24 (19.7%)	34 (14.0%)
Survival			
Transfer to general units	88 (73.3%)	64 (52.5%)	152 (62.8%)
Transfer to sub-ICUs	22 (18.4%)	20 (16.4%)	42 (17.4%)
Patients need to go home	0 (00.0%)	2 (01.6%)	2 (00.8%)
Discharge to home	0 (00.0%)	12 (09.8%)	12 (05.0%)

The average ratio of RN to other nursing staff and the ratio of RN to patient categorized by Thai Nursing Council Standard were shown in Table 3. Approximately 60% of the 242 patients were cared for in an ICU with RN to other nursing staff ratios of 1.5:1 to 2:1 while 32 % with RN to other nursing staff had ratios of more than 2:1. The data indicated that the majority of patients (75.6%) were cared for in an ICU with RN to patient ratios of more than 1:1. Approximately 3% were cared with RN to patient ratio of 1:1. The remaining patients (21.5%) were cared with RN to patient ratios of more than 1:1. These proportions were different across surgical and medical ICUs. However, the majority of surgical patients as well as medical ones were cared for in an ICU with RN to other nursing staff ratios of 1.5:1 to 2:1 and with RN to patient ratios of less than 1:1.

Mean daily hours of care to be provided for each patient were shown in Table 4. The 120 patients in the surgical ICU were found to have the following daily hours of care. One patient required an average of 21 hours per day for care in the ICU (*SD* = 8.7). Stratified by types of ICU personnel (expressed as professional nurses, other nursing staff, residents and intensivists or certified critical care physicians), mean daily care hours by professional nurses was 10.2 (*SD* = 3.1), by other nursing staff was 8.2 (*SD* = 6.0), by intensivists was 0.2 (*SD* = 0.2) and by residents was 2.4 (*SD* = 1.6); the percentage ranged from 48.5, 39.1, 11.4 and 1.0 for care hours by professional nurses, other nursing staff, residents and intensivists, respectively. For the medical ICU, one patient required slightly higher daily hours of care than surgical patients (*M* = 23.8; *SD* = 7.8). Daily care hours by professional nurses comprised 50.0% (*M* = 11.9; *SD*=2.7), other nursing staff 38.2% (*M* = 9.1; *SD* = 4.1), intensivists 1.3% (*M* = 0.3; *SD* = 0.2) and residents 10.5% (*M* = 2.5; *SD* = 2.0) of total daily hours of care.

Table 3

Number and Percentage for Nurse Staffing Measures of the Study Sample

Nurse staffing measures	Surgical ICU (n = 120) Number (%)	Medical ICU (n = 122) Number (%)	All patients (N = 242) Number (%)
The average ratio of RN to other nursing staff			
Less than 1.5:1	37 (30.8%)	40 (32.8%)	77 (31.8%)
1.5:1 to 2:1	78 (65.0%)	68 (55.7%)	146 (60.3%)
More than 2:1	5 (04.2%)	14 (11.5%)	19 (07.9%)
The average ratio of RN to patient			
Less than 1:1	99 (82.5%)	84 (68.9%)	183 (75.6%)
1:1	3 (02.5%)	4 (03.3%)	7 (02.9%)
More than 1:1	18 (15.0%)	34 (27.9%)	52 (21.5%)

Table4

Range, Mean and Percentage of ICU Personnel Working Time Allocated to the Sample for One Day (Unit: in hour)

ICU personnel	Surgical ICU patients (n = 120)			Medical ICU patients (n = 122)		
	Min to Max	Mean (± SD)	Percentage of time to total	Min to Max	Mean (± SD)	Percentage of time to total
Professional nurses	4.6-18.4	10.2 (± 3.1)	48.5	4.2-19.1	11.9 (± 2.7)	50.0
Other nursing personnel (Practical nurses or helpers)	0.6-10.1	8.2 (± 6.0)	39.1	0.3-10.2	9.1 (± 4.1)	38.2
Medical personnel						
• Intensivists	0.0 - 0.6	0.2 (± 0.2)	1.0	0.0 - 1.1	0.3 (± 0.2)	1.3
• Residents	0.2 - 9.8	2.4 (± 1.6)	11.4	0.1 - 8.1	2.5 (± 2.0)	10.5
Total	5.4-38.9	21.0 (± 8.7)	100.0	4.6-38.0	23.8 (± 7.8)	100.0

Findings of the Research Questions

Research question 1. What are health personnel cost per patient day and medical care cost per patient day in adult ICUs?

The health personnel cost per patient day ranged from 730.5 to 3,358.8 baht with a mean of 1,699.6 (*SD* = 584.3) baht and a median of 1,680.7 baht (Table 5). This cost represents approximately 30% of total patient cost per patient day. The health personnel cost per patient day in relation to types of ICU personnel was shown in Figure 3. The mean cost of care by RNs was 910.3 (*SD* = 247.3) baht, other nursing staff 566.3 (*SD* = 336.2) baht, residents 178.6 (*SD* = 109.4) baht and intensivists 44.4 (*SD* = 37.2) baht. This figure yields cost of care by RNs making up the largest part of total health personnel cost per patient day, followed by cost of care by other nursing personnel, residents and intensivists, respectively.

Table5

Summary of Patient Costs per Day (Unit: in baht) (N = 242)

Cost categories	Min	Max	Mean (± *SD*)	Median
Medical care cost per patient day	1,639.7	16,533.2	6,864.7 (± 3,810.0)	6,019.5
Health personnel cost per patient day	730.5	3,358.8	1,699.6 (± 584.3)	1,680.7
Total patient cost per patient day	2,833.8	21,014.4	8,564.3 (± 4,007.3)	7,668.0

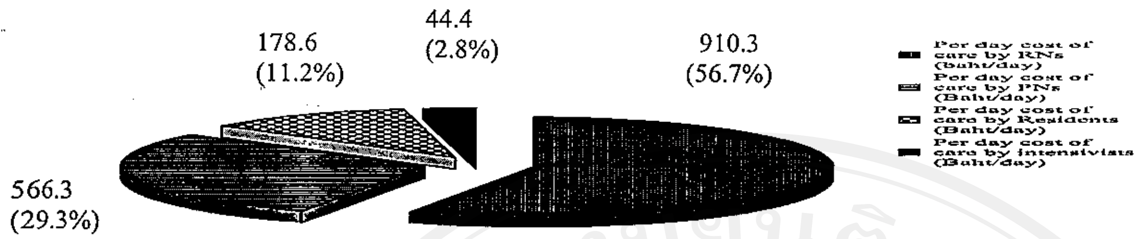
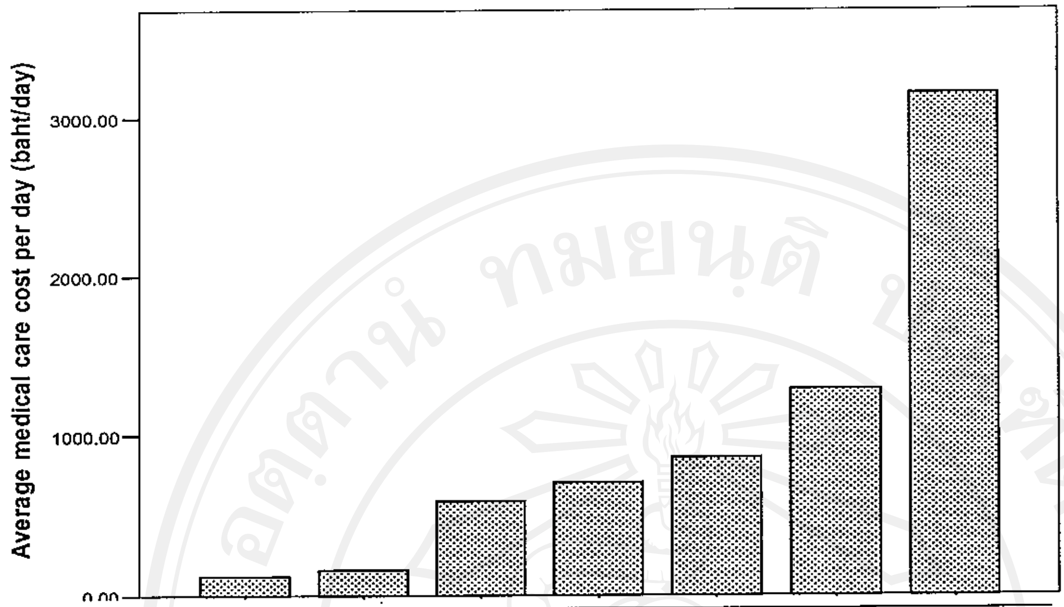


Figure 3. Mean costs (Unit: in baht) and percentage of different components of costs within health personnel costs per day (*N* = 242).

As shown in Table 5, the total patient cost per patient day ranged from 2,833.8 to 21,014.4 baht with a mean of 8,564.3 (*SD* = 4,007.3) baht and a median of 7,668.0 baht. Medical care cost per patient day represents approximately 70% of total patient cost per patient day. The minimum medical care cost per patient day was 1,639.7 baht while the maximum was 16,533.2 baht. The mean medical care cost per patient day was 6,864.7 (*SD* = 3,810.0) baht and the median cost was 6,019.5 baht. The mean medical care cost per patient day included: drugs and medical supplies, 3,152.4 baht or 45.9% of total medical care cost per day; equipment used, 1,284.3 baht or 18.7%; laboratories, 858.1 baht or 12.5%; life support therapies, 702.0 baht or 10.2%; blood products, 588.3 baht or 8.6%; diagnosis, 160.5 baht or 2.3%; and nutrition, 119.1 baht or 1.7% (Figure 4).



	Daily cost of nutrition	Daily cost of diagnosis	Daily cost of blood product	Daily cost of life support therapies	Daily cost of lab	Daily cost of equipment used	Daily cost of drugs and supplies
Mean (baht/day)	119.1	160.5	588.3	702.0	858.1	1,284.3	3,152.4
Percentage	1.7	2.3	8.6	10.2	12.5	18.7	45.9

Fig 4. Mean costs (unit: in baht) and percentage of different components of costs within medical care cost per patient day ($N = 242$)

As shown in Table 6, the mean daily cost of care for a survivor was 7,978.2 (*SD* = 3,138.5) baht, whereas the mean daily cost of non survivors was 12,149.8 (*SD* = 4,229.4) baht. Data indicated that a non survivor patient required more expensive treatments than a survivor. Costs of laboratories and drugs of treating of a non survivor patient were nearly twice higher than those of treating a survivor. Also, costs of life support therapies and blood products on a non survivor patient were nearly three times as much as that for a survivor.

Table 6

Patient Costs per Patient Day of Surviving and Non Surviving Patients (Unit: Baht)

Cost categories	Surviving patients ($n = 208$)		Non surviving patients ($n = 34$)	
	Mean	*SD*	Mean	*SD*
Daily cost of laboratories	774.8	545.7	1,367.8	515.9
Daily cost of diagnosis	157.3	328.3	179.9	248.1
Daily cost of equipment used	1,260.2	624.3	1,431.9	517.9
Daily cost of life support therapies	586.5	533.2	1,408.3	954.8
Daily cost of blood products	478.3	160.9	1,261.6	809.7
Daily cost of nutrition	1,31.2	100.4	45.3	43.2
Daily cost of drugs, IV and medical supplies	2,907.8	2,149.6	4,648.8	2,456.8
Health personnel cost per patient day	1,682.2	576.5	1,806.2	628.3
Total cost per patient day	7,978.2	3,138.5	12,149.8	4,229.4

The mean cost of achieving a survivor varied according to diagnoses. Table 7 showed selected diagnoses in which there were top five diseases frequently found in this study. The mean costs per patient day ranged from 6,211.4 to 10,172.4 baht. The cost for patients with renal failure were most expensive with a mean cost of 10,172.4 ($SD = 4,273.0$) baht per day. Interestingly, those renal patients had the lowest percentage of survival compared to the other groups.

Table 7

Patient Cost per Survivor for Top Five Diagnoses (Unit: Baht)

Descriptions	Diagnostic groups				
	Diseases of the respiratory system	Diseases of the nervous system	Diseases of the digestive system	Diseases of the circulatory system	Renal failure
Number of survivors	60	43	27	29	18
Percentage of survival	87.0	95.3	84.4	93.5	75.0
Daily cost of laboratories (baht)	737.7 (± 444.7)	463.9 (± 247.2)	848.2 (± 353.5)	657.6 (± 305.1)	1,528.5 (± 694.8)
Daily cost of diagnosis (baht)	201.3 (± 130.9)	175.6 (± 114.7)	179.5 (± 352.1)	153.2 (± 64.1)	102.7 (± 31.6)
Daily cost of equipment used (baht)	1,354.2 (± 627.0)	1,081.5 (± 469.3)	1,281.9 (± 559.5)	1,049.1 (± 545.2)	1,693.0 (± 811.1)
Daily cost of life support therapy (baht)	682.9 (± 429.1)	519.4 (± 287.4)	493.5 (± 229.2)	359.3 (± 193.4)	849.5 (± 694.7)
Daily cost of blood products (baht)	333.1 (± 246.0)	410.9 (± 383.3)	434.0 (± 233.5)	468.6 (± 169.7)	295.3 (± 190.6)
Daily cost of nutrition (baht)	246.6 (± 155.1)	181.0 (± 98.5)	111.9 (± 42.9)	109.4 (± 96.2)	197.1 (± 153.6)
Daily cost of drugs, IV and medical supplies (baht)	3,069.7 (± 1,663.9)	1,910.0 (± 887.5)	3,131.9 (± 1,078.1)	2,507.3 (± 962.8)	3,434.5 (± 915.7)
Health personnel cost per day (baht)	1,897.5 (± 578.6)	1,569.1 (± 666.6)	1,599.5 (± 315.6)	1,260.7 (± 372.7)	1,754.2 (± 444.2)
Total cost per day (baht)	9,073.7 (± 3,107.4)	6,211.4 (± 2,475.2)	7,967.8 (± 2,790.8)	6,282.6 (± 2,874.3)	10,172.4 (± 4,273.0)

Research question 2. What is nursing personnel cost per patient day in adult ICU?

As shown in Table 8, the minimum nursing personnel cost per patient day was 683.4 baht while the maximum was 2,761.1 baht. The mean nursing personnel cost per patient day was 1,476.6 (*SD* = 466.5) baht and the median cost was 1,443.2 baht. The mean nursing personnel cost per patient day included: cost of care by RNs, 910.3 baht; and cost of care by other nursing personnel, 566.3 baht.

Table8

Summary of Nursing Personnel Costs per Day (Unit: in baht) (N = 242)

Cost categories	Min	Max	Mean (± *SD*)	Median
Cost of care by RNs	350.2	1,537.1	910.3 (± 247.3)	908.3
Cost of care by other nursing personnel	25.8	2,228.4	566.3 (± 511.4)	520.7
Total nursing personnel cost	683.4	2,761.1	1,476.6 (± 466.5)	1,443.2

Research question 3. What is length of ICU stay in adult ICUs?

Length of ICU stay of the 242 sample ranged from 1 to 21 days, with a mean of 5.2 (*SD* = 2.2) days and median of 5 days (Table 9). The range of length of ICU stay in the surgical ICU was 1 to 8 days, with a mean of 4.1 (*SD* = 1.0) days and median of 4 days. The range of length of ICU stay in the medical ICU was 2 to 21 days. The mean length of ICU stay of the medical ICU was 6.6 (*SD* = 2.9) days and median of 6 days.

Table 9

Length of ICU Stay by Types of Patients

Types of Patients	*N*	Min (day)	Max (day)	Mean (± SD) (day)	Median (day)
Medical patients	122	2	21	6.6 (± 2.9)	6.0
Surgical patients	120	1	8	4.1 (± 1.0)	4.0
All patients in the study	242	1	21	5.2 (± 2.2)	5.0

Stratification of length of ICU stay of surviving patients by diagnostic groups (Table 10) indicated that overall mean ICU LOS ranged from 3.8 to 6.6 days and median ranged from 3 to 6 days. Surviving patients with respiratory system diseases as well as those with renal failure had a median ICU LOS of 6 days whereas those with other diseases had a median of less than 6 days. This signifies that patients with respiratory system diseases and renal failure were more likely to have longer stay in an ICU than other groups.

Table 10

Length of ICU Stay for Surviving Patients by Diagnostic groups

Diagnostic groups	*N*	Min (days)	Max (days)	Mean(± SD) (days)	Median (days)
Diseases of respiratory system	60	1	21	6.6 (± 2.9)	6.0
Diseases of digestive system	27	2	7	4.1 (± 1.0)	4.0
Renal failure	18	3	16	6.2 (± 2.2)	6.0
Diseases of circulatory system	29	2	11	4.9 (± 2.2)	4.0
Diseases of nervous system	43	1	9	4.8 (± 2.0)	4.0
Infectious & parasitic diseases	10	2	7	3.8 (± 1.5)	3.0
Injury	13	2	7	4.8 (± 1.9)	4.0
Other diseases	8	2	7	3.8 (± 0.9)	4.0

Research question 4. How much variance of nursing personnel cost per patient day can be explained by patient characteristics (patient age, severity of illness, groups of albumin level, groups of lymphocyte count), types of ICU, day and time of patient admissions, and nurse staffing in adult ICUs?

Stepwise multiple regression analysis was performed to develop a regression model of nursing personnel cost per patient day. The dependent variable was nursing personnel cost per patient day and independent variables included patient age, severity of illness, groups of albumin level, groups of lymphocyte counts, types of ICU, day of patient admission, time of patient admission, the average ratio of RN to patient and the average ratio of RN to other nursing staff. Evaluation of predicted nursing personnel cost model assumptions was displayed in Appendix M, Figure 5 and 6. The assumptions of normality and homoscedasticity of the dependent variable distribution were tested by taking a residual scatter plot and a normal probability plot of residuals. Results showed that residuals were distributed approximately in a rectangular form and the expected normal values of residuals correspond to actual normal values, signifying that the assumptions for multiple regression analysis were met. Multicollinearity was tested by means of the Variance Inflation Factors (*VIF*). Results showed that *VIF* of these included independent variables ranging from 1.01 to 1.24. *VIF* values were less than 10, indicating no problem with multicollinearity for any independent variables in the model (Table 12).

A summary of the regression model was presented in Table 11. In addition, regression coefficients between each predictor and the dependent variable were presented in Table 12. The regression results indicated a model of three predictors (the average ratio of RN to patient, the average ratio of RN to other nursing staff and day of patient admission) that significantly predicted nursing personnel cost per patient day, $R^2 = 0.25$, R^2 *adj*=0.24,

$F(3, 212) = 24.00, p < 0.001$. This model accounted for 25 % of variance in nursing personnel cost per patient day. Data in Table 10 indicated the order of entry of predictor variables. The first independent variable entered in the stepwise regression model is the average ratio of RN to patient, which accounted for 0.13 of R^2. Addition of the average ratio of RN to other nursing staff to the model with the average ratio of RN to patient resulted in a significant increase in R^2 from 0.13 to 0.23. The variables of types of ICU and days of patient admission were entered in two steps, respectively. With day of patient admission created a model that accounted for 0.25 of R^2. The regression equation using these data is shown below

Nursing personnel cost per patient day = 1,657.53 + 8.98 (the average ratio of RN to patient) + 5.17 (the average ratio of RN to other nursing staff) + 134.71 (day of patient admission).

This equation specifies that nursing personnel cost per patient day can be predicted by adding 1,657.53 to the sum of the raw scores of the four predictors, multiplied by their respective regression coefficients. If a patient has rating of 100%, 200% and 1, respectively, on the average ratio of RN to patient, the average ratio of RN to other nursing staff and dummy coding as defined as a patient who was admitted to an ICU on a weekend day, the predicted rating on nursing personnel cost per patient day is

Nursing personnel cost per patient day = 1,657.53 + 8.98 (the average ratio of RN to patient) + 5.17 (the average ratio of RN to other nursing staff) + 134.71 (day of patient admission).

= 1,657.53 + 8.98 (100) + 5.17 (200) + 134.71 (1)

= 3,724.2 baht

The predicted equation also showed the amount of change in the predicted value of a dependent variable for a specific rate of change in independent variables (IVs). Note in this equation, the regression coefficient for the average ratio of RN to patient was 8.98. This is interpreted that, holding constant the values on the other predictors, nursing personnel cost per patient day is predicted to increase by 8.98 baht for every one percent increase in the average ratio of RN to patient. The regression coefficient for the average ratio of RN to other nursing staff was 5.17, so it was indicated that for every one percent increase in the average ratio of RN to other nursing staff there was an increase of about 5.17 baht in nursing personnel cost per patient day if the values on the other IVs were held constant.

The variable of day of patient admission was transformed to dummy variables coding with 1s and 0s (as shown in Table 1, chapter 3). Regression coefficient on each dummy variable is the estimate of the difference in the nursing personnel cost per patient day between the designed groups. Thus, the regression coefficient for day of patient admission was 134.71. This signified that the mean nursing personnel cost per patient day incurred for each patient admitted to an ICU on a weekend day was higher than that for each patient admitted on a weekday by 134.71 baht.

Table 11

A Summary of the Stepwise Multiple Regression Model of Nursing Personnel Cost per Patient Day (N = 216).

Step predictors	R	R^2	R^2adj	R^2 Change	F Change	P	df_1, df_2
1. The average ratio of RN to Patient (unit: in percent)	0.36	0.13	0.13		32..02	0.00	1, 215
2. The average ratio of RN to other nursing staff (unit: in percent)	0.48	0.24	0.23	0.10	32.81	0.00	2, 214
4. Day of ICU	0.50	0.25	0.24	0.01	23.97	0.00	3, 213

Table 12

A Summary of Regression Coefficients for the Stepwise Multiple Regression Model of Nursing Personnel Cost per Patient Day (N = 216).

Variables	B	*Std. Error*	*Beta*	t	*p-value*	Collinearity Statistic	
						Tolerance	*VIF*
(Constant)	1,657.53	248.14		10.96	0.00		
The average ratio of RN to Patient (unit: in percent)	8.98	1.14	0.52	7.89	0.00	0.80	1.25
The average ratio of RN to other nursing staff (unit: in percent)	5.17	0.92	0.37	5.60	0.00	0.80	1.26
Day of ICU	134.71	59.88	0.13	2.25	0.02	0.99	1.01

Research question 5. How much variance of medical care cost per patient day can be explained by patient characteristics (patient age, severity of illness, groups of albumin level, groups of lymphocyte counts), types of ICU, day and time of patient admissions, and nurse staffing in adult ICUs?

Stepwise multiple regression analysis was employed to determine the regression model of medical care cost per patient day. The variable of medical care cost per patient day was a dependent variable. Independent variables included patient age, severity of illness, groups of albumin level, groups of lymphocyte counts, types of ICU, day of patient admission, time of patient admission, the average ratio of RN to patient and the average ratio of RN to other nursing staff. The assumptions of normality and homoscedasticity of the dependent variable distribution were tested by taking a residual scatter plot and a normal probability plot of residuals. Results illustrated a failure of normality with a skewed distribution of residuals (see in Appendix M, Fig 7 and 8). Since there was evidence that assumptions were violated, it should be possible to omit the problems through transformation of the original values of medical care cost per patient day. A logarithmic transformation was tried and the transformed distributions checked once again for skewness. Results of the residual analysis following regression with the transformed dependent variables indicated that although the residual scatter plots were still not perfectly rectangular, its shape was considerably improved over the previous figure (Appendix M, Figure 9). In addition, the normal probability plot of residuals following regression with the transformed variables showed that the scatter of points was located along the straight line (Appendix M, Figure 10). This signified that the logarithmic transformation could help to stabilize the variance and achieve assumptions of regression.

Results of evaluation of assumptions led to the transformation of the dependent variable to reduce skewness and improve the normality, linearity and homoscedasticity of residuals. Thus, the dependent variable became the logarithmically transformed medical care cost per patient day. In the cases of all IVs, transformation was not undertaken. All these data were rerun to develop the regression model of the logarithmically transformed medical care cost per patient day. Multicollinearity was tested by *VIF*. Results showed that all VIF value of these included independent variables less than 10 with ranging from 1.0 to 1.09. These data indicated that no problem with multicollinearity for any of the independent variables in the model (Table 14).

Table 13 and 14 respectively displayed a summary of stepwise regression model and regression coefficient between each predictors and the logarithmically transformed medical care cost per patient day. Only three independent variables significantly predicted logarithmically transformed medical care cost per patient day, $R^2 = 0.30$, $R^2\ adj = .0.29$, $F(3, 213) = 30.54, p < 0.001$. This model accounted for 30% of variance in logarithmically transformed medical care cost per patient day. The variable of severity of illness was first entered to the regression model, which accounted for 0.23 to R^2. The variable of groups of lymphocyte counts was entered in the model in step 2. This accounted for an increase in R^2 from 0.23 to 0.29. After step 3, the average ratio of RN to patient added to prediction of logarithmically transformed medical care cost per patient day and accounted for a 0.01 increase of R^2 to 0.30.

A summary of the stepwise regression model predicting logarithmically transformed medical care cost per patient day is presented as follows.

Ln(medical care cost per day) = 8.34 + 0.01 (severity of illness) + 0.37 (the groups of lymphocyte count) - 0.003 (the average ratio of RN to patient).

Using the above equation, it is difficult to interpret regression coefficients with logarithmical transformation. Thus, it is necessary to adjust the equation for meaningful interpretation. Following antilogarithmic principle, the final stepwise regression model of medical care cost per patient day is shown as bellow

$$\text{Medical care cost per patient day} = e^{8.34 + 0.01 \text{ (severity of illness)} + 0.37 \text{ (the groups of lymphocyte count)} - 0.003 \text{ (the average ratio of RN to patient)}}$$

$$= \frac{e^{8.34} \text{ X } e^{0.01 \text{ (severity of illness)}} \text{ X } e^{0.37 \text{ (the groups of lymphocyte count)}}}{e^{0.003 \text{ (the average ratio of RN to patient)}}}$$

Note: "e" in the equation is equal to 2.718 ~ 2.72

Medical care cost per patient day can be predicted by substituting the raw scores of three independent variables in the final equation. For instance if a patient has rating of 40, 1 and 100%, respectively, on the severity of illness scores, dummy coding as defined as a patient with abnormal lymphocyte count and the average ratio of RN to patient, the predicted rating on medical care cost per patient day is

$$\text{Medical care cost per patient day} = \frac{e^{8.34} \text{ X } e^{0.01 \text{ (severity of illness)}} \text{ X } e^{0.37 \text{ (the groups of lymphocyte count)}}}{e^{0.003 \text{ (the average ratio of RN to patient)}}}$$

$$= \frac{2.72^{8.34} \text{ X } 2.72^{0.01 (40)} \text{ X } 2.72^{0.37 (1)}}{2.72^{0.003 (100)}}$$

$$= 6{,}700.92 \text{ baht}$$

The final predictive equation also showed the amount of change in the predicted value of medical care cost per patient day for a specific rate of change in independent variables (IVs). For every unit change in each predictor, the amount of change in the predicted value of medical care cost per patient day can be estimated by 2.72 to the power of its regression coefficient. Therefore, when the regression coefficient for the severity of illness was 0.01, this meant that, holding constant the values on the other predictors, medical care cost per patient day increased 1% ($= 2.72^{0.01}$) for every unit increasing in the severity of illness points. When the regression coefficient for the average ratio of RN to patient was 0.003, this signified that for every one percent decrease in the average ratio of RN to patient, medical care cost per patient day increased 0.30% ($= 2.72^{0.003}$) if the values on the other IVs were held constant. In case of groups of lymphocyte count, it is a dummy variable, defining "0" as normal level while "1" as abnormal level, so when the regression coefficient of the variable of groups of lymphocyte count was 0.37, this interpreted that patients who had abnormal level of lymphocyte count were likely to have 1.45 ($= 2.72^{0.37}$) times on medical care cost per patient day relative to those with normal lymphocyte count.

Table 13

A Summary of the Stepwise Multiple Regression Model of Logarithmically Transformed Medical Care Cost per Patient Day (N = 216)

Step predictors	R	R^2	R^2adj	R^2 Change	F Change	p	df_1, df_2
1. Severity of illness (unit: in point)	0.48	0.23	0.23		63.63	0.001	1, 215
2. Groups of lymphocyte counts	0.54	0.29	0.28	0.06	43.00	0.001	2, 214
3. The average ratio of RN to Patient (unit: in percent)	0.55	0.30	0.29	0.01	30.54	0.001	3, 213

Table 14

A Summary of Regression Coefficients for the Stepwise Multiple Regression Model of Logarithmically Transformed Medical Care Cost per Patient Day (N = 216).

Variables	B	*Std. Error*	*Beta*	t	*p-value*	Collinearity Statistic	
						Tolerance	*VIF*
(Constant)	8.43	0.11		75.51	0.00		
Severity of illness (unit: in point)	0.01	0.01	0.45	7.47	0.00	0.92	1.09
Groups of lymphocyte counts	0.37	0.09	0.24	4.10	0.00	1.00	1.00
The average ratio of RN to Patient (unit: in percent)	-0.003	0.001	-0.10	-2.07	0.00	0.92	1.09

Research question 6. How much variance of length of ICU stay can be explained by patient characteristics (patient age, severity of illness, groups of albumin level and groups of lymphocyte count), types of ICU, day and time of patient admissions and nurse staffing in adult ICUs?

Stepwise multiple regression analysis was conducted to determine the variance of length of ICU stay explained by patient age, severity of illness, groups of albumin level, groups of lymphocyte counts, types of ICU, day of patient admission, time of patient admission, the average ratio of RN to patient and the average ratio of RN to other nursing staff. Data were first evaluated for the regression model assumptions. The residual analysis illustrated the problem of non-normality and non-homoscedasticity of the variable of length of ICU stay (Appendix M, Fig 11 and 12). The evaluation of normality and homoscedasticity led to natural log transformation of the variable of length of ICU stay. Residual analysis following regression with the transformed dependent variables indicated that residual distribution was considerably improved over the previous figure (Appendix M, Figure 13). In addition, the normal probability plot of residuals following regression with the transformed variables showed that the scatter of points was located along the straight line (Appendix M, Figure 14). This signified that the logarithmic transformation could help to stabilize the variance and achieve assumptions of regression.

The replication of stepwise regression analysis was conducted to determine which independent variables (patient age, severity of illness, groups of albumin level, groups of lymphocyte counts, types of ICU, day of patient admission, time of patient admission, the average ratio of RN to patient and the average ratio of RN to other staff) were the predictors of logarithmically transformed length of ICU stay. Regression results indicated that an overall model of seven predictors (severity of illness, the groups of albumin level, the groups of lymphocyte counts, types of ICU, day of patient admission, time of patient admission, the average ratio of RN to patient) that significantly predicted logarithmically transformed length of ICU stay, $R^2 = 0.31$, $R^2adj = 0.29$, $F(7, 209)=13.35$, $p < 0.001$. This model accounted for 31% of variance in logarithmically transformed length of ICU stay (Table 15). Considering the order of entry of predictor variables, the first independent variable entered in the stepwise regression was ICU types, which accounted for 0.12 of R^2. Addition of the variable severity of illness to the regression model with ICU types resulted in a significant increase in R^2 from 0.12 to 0.19. The variable of the average ratio of RN to patient was entered in step 3, R^2 increased by 0.04 to 0.23. Addition of the variable of groups of albumin level created a regression model that accounted for 0.26 of R^2 after step 4. After step 5, with the variable of groups of lymphocyte count added to the model, R^2 increased by 0.02 to 0.28. The variable of time of patient admission and day of patient admission were entered in two steps, respectively. With time of patient admission, R^2 increased by 0.02 to 0.30, and the addition of day of patient admission created a model that accounted for 0.31of R^2.

A summary of the stepwise regression model predicting logarithmically transformed length of ICU stay is presented as follow.

Ln (length of ICU stay) = 1.95 + 0.60 (types of ICU) - 0.01 (severity of illness) - 0.005 (the average ratio of RN to patient)+ 0.18 (the groups of albumin level) + 0.24 (the groups of lymphocyte count) + 0.14 (time of patient admission) + 0.13 (day of patient admission)

Due to the difficulty in interpreting regression coefficients with logarithimically transformed variable of length of ICU stay (in Table 15), an antilogarithmic equation was performed. The final stepwise regression model of length of ICU stay is shown as follow.

$$\text{Length of ICU stay} = e^{\{1.95 + 0.60\text{ (types of ICU)} - 0.01\text{ (severity of illness)} - 0.005\text{ (the average ratio of RN to patient)} + 0.18\text{ (the groups of albumin level)} + 0.24\text{ (the groups of lymphocyte count)} + 0.14\text{ (time of patient admission)} + 0.13\text{ (day of patient admission)}\}}$$

$$= \left\{ \frac{e^{1.95} \text{ X } e^{0.60\text{ (types of ICU)}} \text{ X } e^{0.18\text{ (the groups of albumin level)}} \text{ X } e^{0.24\text{ (the groups of lymphocyte count)}} \text{ X } e^{0.14\text{ (time of patient admission)}} \text{ X } e^{0.13\text{ (day of patient admission)}}}{e^{0.01\text{ (severity of illness)}} \text{ X } e^{0.005\text{ (the average ratio of RN to patient)}}} \right\}$$

Note: "e" in the equation is equal to 2.718 ~ 2.72

Length of ICU stay can be predicted by substituting the raw scores of seven independent variables in the anti-logarithmical equation. For instance if a patient has rating of 0 or dummy coding as defined as a surgical patient, 40 points of severity of illness measure, 100% of the average ratio of RN to patient, 1 or dummy coding as defined as a patient with abnormal albumin level, 1 or dummy coding as defined as a patient with abnormal lymphocyte count, 1 or dummy coding as defined as a patient with non-office hour admission and 1 or dummy coding as defined as a patient who admitted to an ICU on a weekend day, the predicted rating on length of ICU stay is

$$\text{Length of ICU stay} = \left\{ \frac{e^{1.95} \text{ X } e^{0.60\text{ (types of ICU)}} \text{ X } e^{0.18\text{ (the groups of albumin level)}} \text{ X } e^{0.24\text{ (the groups of lymphocyte count)}} \text{ X } e^{0.14\text{ (time of patient admission)}} \text{ X } e^{0.13\text{ (day of patient admission)}}}{e^{0.01\text{ (severity of illness)}} \text{ X } e^{0.005\text{ (the average ratio of RN to patient)}}} \right\}$$

$$= \frac{e^{1.95} \text{ X } e^{0.60(0)} \text{ X } e^{0.18(1)} \text{ X } e^{0.24(1)} \text{ X } e^{0.14(1)} \text{ X } e^{0.13(1)}}{e^{0.01(40)} \text{ X } e^{0.005(100)}}$$

= 5.70 days

The predicted equation of length of ICU stay also showed the amount of change in the predicted value of length of ICU stay for a specific rate of change in independent variables (IVs). For every unit change in each predictor, the amount of change in the predicted value of length of ICU stay can be estimated by 2.72 to the power of its regression coefficient. Thus, the regression coefficient for the severity of illness was 0.01; this indicated that, holding constant the values on the other predictors, lengths of ICU stay increased 1 % ($= 2.72^{0.01}$) for every unit decreasing in the severity of illness point. The regression coefficient for the average ratio of RN to patient was 0.005, meaning that for every one percent decrease in the average ratio of RN to patient, length of ICU stay increased 0.5% ($= 2.72^{0.005}$) if the values on the other IVs were held constant.

In case of dummy variables which consisted of types of ICU, the groups of albumin level, the groups of lymphocyte count, time and day of patient admission, their regression coefficients were interpreted as follows. The regression coefficient of the variable of types of ICU was 0.06. This meant that length of ICU stay for medical patients was 1.06 ($= 2.72^{0.06}$) times longer than those of surgical patients. For the variables of groups of albumin level and groups of lymphocyte count, the regression coefficient was 0.18, 0.24, respectively. This signified that length of ICU stay for the patients who had an abnormal level of albumin was 1.20 ($= 2.72^{0.18}$) times longer than those with a normal albumin level. Patients with an abnormal level of lymphocyte were likely to have 1.27 ($= 2.72^{0.24}$) times the length of ICU stay compared to those with a normal level. The regression coefficient of the variable of time and day of patient admission was 0.14 and 0.13, respectively. This meant that patients who admitted to an ICU on non-office hour were likely to have 1.15 ($= 2.72^{0.14}$) times the length of ICU stay relative to those with office hour admission. Patients admitted on a weekend day increased length of ICU stay to 1.14 ($= 2.72^{0.13}$) times longer than those who were admitted on a weekday.

Table 15

A Summary of the Stepwise Multiple Regression Model of Logarithmically Transformed Length of ICU Stay (N = 216).

Step predictors	R	R^2	R^2adj	R^2 *Change*	F *Change*	P	df_1, df_2
1. Types of ICU	0.35	0.12	0.12		29.61	0.00	1, 215
2. Severity of illness (unit: in point)	0.44	0.19	0.18	0.07	24.97	0.00	2, 214
3. The average ratio of RN to Patient (unit: in percent)	0.48	0.23	0.22	0.04	21.06	0.00	3, 213
4. Groups of albumin levels	0.51	0.26	0.24	0.03	18.19	0.00	4, 212
5. Groups of lymphocyte counts	0.53	0.28	0.26	0.02	16.45	0.00	5, 211
6. Time of patient admission	0.54	0.30	0.28	0.02	14.69	0.00	6, 210
7. Day of patient admission	0.56	0.31	0.29	0.01	13.35	0.00	7, 209

Table 16

A Summary of Regression Coefficients for the Stepwise Multiple Regression Model of Logarithmically Transformed Length of ICU Stay (N = 216).

Variables	B	*Std. Error*	*Beta*	t	*p-value*	Collinearity Statistic	
						Tolerance	*VIF*
(Constant)	1.95	0.13		14.76	0.00		
Types of ICU	0.60	0.07	0.57	8.19	0.00	0.69	1.44
Severity of illness (unit: in point)	-0.01	0.00	-0.28	-4.15	0.00	0.73	1.36
The average ratio of RN to Patient (unit: in percent)	-0.005	0.001	-0.30	-4.13	0.00	0.82	1.23
Groups of albumin levels	0.18	0.07	0.16	2.59	0.01	0.89	1.13
Groups of lymphocyte counts	0.24	0.09	0.16	2.74	0.01	0.99	1.01
Time of patient admission	0.14	0.07	0.12	2.13	0.03	0.99	1.02
Day of patient admission	0.13	0.07	0.12	2.01	0.04	0.95	1.06

Discussion

Findings of the study are discussed in relation to the objectives of the research. This part provides the discussion of patient cost per patient day, length of ICU stay and factors influencing nursing personnel cost per patient day, medical care cost per patient day and length of stay in adult ICUs.

1. Patient cost in adult ICUs

Patient cost is defined as the average value of resource consumption spent directly on a patient per day. It can be determined by the summation of health personnel cost per day and medical care costs per day. Findings of the study indicated that the mean medical care cost per patient day was 6,864.7 baht and the mean health personnel cost per patient day was 1,699.6 baht, giving a total patient cost per patient day of 8,564.3 baht. Comparing this total cost to a fixed reimbursement of 1,659 baht for one patient who has insurance coverage under the 30-baht health scheme in FY2005, the five fold higher cost in patient care supports a tenet that care for a patient in adult ICU in this hospital was considerably more expensive and consumed more resources than a fixed reimbursement for a 30-baht health insured patient.

In this study, health personnel cost per patient day represents approximately 30% of the total cost per patient day. The proportion of health personnel cost found in this study was similar to that described by Gilberton et al. (1991), being 28%. The reasons for such high cost for provision of health personnel may be due to the fact that critically ill patients require 24-hour nursing care for close monitoring and prompt interventions. The care of these patients relies upon the use of skilled personnel with the expenditure of large amounts of time and money. The average ratio of nurses deemed necessary to care for these patients is high. In this study the ratio is normally one RN to two patients on day shifts and 1:3 for evening and night shifts. The results also indicated that approximately half of health personnel cost per day (56.7%) was for the provision of RNs. When costs of care by other nursing staff were added, the cost of care by total nursing personnel as a proportion of the total health personnel cost per patient day increased to 85.0%. This may be due to the fact that the patients will require full attention of nursing personnel, especially RNs, during most days of their stay. RNs will need to spend considerable time with unstable patients to respond to emergency situations. If patients are dependent on inotropic drugs, on mechanical ventilators or on haemofiltration, they will require nurses to detect and prevent possible life-threatening complications. Even if the patient's dependency needs are minimal following the death of patients, nurses will need to spend a long time to provide nursing support for their families.

Medical care cost per patient day of this study comprised nearly 70% of the total patient cost per patient day with cost of drugs at 32.2% and cost of sophisticated equipment used at 13.1%. The relatively large portion of medical care cost per patient day is not surprising since drugs frequently used in ICUs, such as antibiotic and vasoactive drugs, and parenteral nutrition are expensive. In addition, due to severity of illness, the critically ill patients often require a higher level of complex and expensive technology involved in intensive care.

Results of this study demonstrated that daily cost of care for a non survivor was nearly twice as high as that of a survivor (12,149.8 vs. 7,978.2 baht). Costs of laboratories and drugs of treating a non survivor were nearly twice as high as those of treating a survivor. In addition, costs of life support therapies and blood products on a non survival patient were nearly three times as much as those of a survivor (Table 6). This may be due to the fact that non survivors use increased resources in an attempt to reverse the expected fatal outcomes.

This increased effort will occur over time periods in ICU and account for higher daily costs of care in non survivors. The findings of this study are consistent with findings in previous studies. Early work by Detsky (1981), who studied 1,831 patients, found a significantly higher mean expenditure (approximately 30%) on non-survivors than survivors. This is confirmed in a small sample of 120 critically ill patients (Ridley et al., 1991), indicating that a mean daily cost of care for non survivors was 48% higher than those for survivors.

An important aim of the ICU is to provide organ system support until such time as a potentially remedial condition can be corrected. Results in this study showed that approximately 86% of patients in this study were survivors and required continuous treatments on general units and intermediate care units, such as sub-ICUs, of this hospital (Table 2). A daily cost of achieving a survivor in ICU was found to be most expensive for renal failure patients whose percentage of survival was lowest (Table7). The reasons for such high cost to treat renal failure patients may be that the patients have multiple organ failure and required expensive treatments such as multiple vasoactive drugs and antibiotics, invasive monitoring and dialysis. In this study, total cost of laboratories on renal failure patients was twice as much of that of non-renal failure patients. The renal failure patients also required 25% more total costs on drugs and life support therapies than non-renal failure patients. Furthermore, the most significant cost of treating renal failure patients is the nurse requirement. This involves two nurses with special training, including one with renal experience and the other with intensive care training. Since renal failure patients have higher costs as well as the expected high death rate, it seems highly desirable that such referral units should have both experienced personnel and the special equipment necessary for the management of dialysed patients.

2. Length of stay in adult ICUs

A mean length of ICU stay of patients in this study was 5.2 (*SD* = 2.2) days. The mean length of ICU stay of the medical ICUs was 6.6 (*SD* = 2.9) days whereas in surgical ICUs, the mean length of ICU stay was 4.1(*SD* = 1.0) days (Table 8). When comparing this finding to mean lengths of ICU stays of previous studies, the mean lengths of ICU stay of previous studies ranged from 4.7 days to 6.7 days (Arabi et al., 2002; Moerer et al, 2002; Wong et al, 1999). However, Bunburaphong et al. (2001) indicated that the mean length of ICU stay was approximately three days among patients admitted to a surgical ICU in a general hospital in Thailand. The differences in the clinical characteristics of ICU patients in the present study and those who participated in the study of Bunburaphong and colleagues could account for the difference of the mean length of ICU stay. All surgical patients in the previous study were directly admitted to the ICUs of the general hospital whereas these in the present study were admitted to ones of the tertiary hospital that cares for patients with complex or severe illness, many of whom, approximately 27%, were transferred from another hospital (Table 2). Transferred patients in this study were frequently admitted with conditions that complicated their care such as upper gastrointestinal bleeding and brain damage and had mean length of ICU stay was 5.8 days or 1.4 times as long as patients directly admitted to the surgical ICU. Potentially, a large number of transferred patients in this study may contribute to be difference in the mean length of ICU stay between the present study and the report of the study by Bunburaphong and colleagues.

Data in the present study also found that there were 34 (14%) patients staying in an ICU for more than one week. Of 34 patients, approximately 90% were cared for in the medical ICU. Nearly 10% were cared for in the surgical ICU (Table 2). This finding may be due to the underlying diseases, in which the majority groups of medical patients were patients with respiratory diseases. It is well recognized that respiratory patients have impaired lung functions especially the limited ability to restore oxygen (Cohen et al., 1991). Therefore, respiratory patients whose conditions are severe require ventilation for a long period of time in an attempt to reverse lung functions. Prolonged mechanical ventilator patients have to stay in the ICU until they are weaned or died, reflected by the approximately 10% of medical patients undergoing a ventilator more than 7 days (Table 2).

Data of this study demonstrated that surviving patients with respiratory and renal diseases were more likely to have prolonged stays in ICU and utilized more resources. These long-stay patients filled the expensive ICU beds, consumed the precious resources and often blocked other patients who could have been in greater need of the critical care resources. Potential strategies to improve resource utilization should target those patients who are more likely to have prolonged ICU stay. As mentioned previously, the study found that patients with respiratory diseases were more likely to have an increased risk of prolonged ICU stays; probably they underwent long ventilation periods. Therefore, protocols that accelerate weaning are likely to improve resource utilization. Additionally, increasing intermediate care beds for patient whose ICU care is of intermediate duration has been proposed as possible alternative means of effective resource utilization in the ICU. The success of intermediate care units in maintaining quality of care at a substantial cost saving and decreasing length of ICU stay was confirmed by the study of Junker et al. (2002). An intermediate care unit could be equipped to handle monitoring needs and to provide necessary treatment with less resource utilization. For example, one nurse could be taken care for every three patients, instead of one nurse for every one or two patients as in the typical intensive care unit. In order for the intermediate care units to make an impact on ICU resource utilization, the units must have the capacity of caring for stable mechanically ventilated patients and renal patients. In addition, nurses recruited for these areas must have the proper background to care for renal and ventilated patients.

3. Factors influencing nursing personnel cost per patient day, medical care cost per patient day and length of stay in adult ICUs.

Stepwise multiple regression analysis was used to predict factors influencing nursing personnel cost and medical care cost per patient day as well as length of ICU stay in a teaching hospital in Thailand. The factors included in the regression analysis were patient age, severity of illness, groups of albumin levels, groups of lymphocyte counts, types of ICU, day of patient admission, time of patient admission, the average ratio of RN to patient and the average ratio of RN to other nursing staff. The regression was substantially successful in explaining variance for all three dependent variables with R^2_{adj} ranging from 0.23 to 0.30. In all cases, the overall regression was statistically significant beyond the 0.001 level (Table 10 to 15). This study is the first study examining the factors influencing nursing personnel cost and medical care cost per day as well as length of ICU stay in Thailand. The discussion of each factor affecting the costs and length of ICU stay of this study, therefore, uses findings from other studies from different countries for comparisons.

3.1 Patient characteristics. The variables of patient characteristics, including patient age, severity of illness and nutritional status, were entered into the model in a series of steps to explain variances in nursing personnel cost per patient day, medical care cost per patient day and length of ICU stay. The effect of each variable on the costs per patient day and length of ICU stay was discussed as follows.

3.1.1. Patient age. Data in the study showed that patient age was not significantly associated with ICU care costs per patient day and length of ICU stay when differences in severity of illness, nutritional status, nurse staffing, and day and time of patient admissions were controlled. This finding is consistent with the study of Keenan et al. (2003); Somme et al. (2003) which found that length of ICU did not differ by age; and the study of Fedullo et al. (1983), indicating that patient age did not affect costs of care in the ICU. One possible explanation for the absence of the relationship between patient age, length of ICU stay and ICU care costs per patient day in this study might be that patient age did not independently lead to changes in the costs and length of ICU stay when other factors, particularly severity of illness and comorbidity status, were controlled. There was evidence to show that increasing age was associated with high severity of illness (Knaus et al., 1985) and to be associated with increasing risk of acquiring nosocomial infections (Emori et al., 1991; Smith, 1989; Saviteer et al.,1988). Additionally, older patients require more time for functional recovery (Brosseau et al, 1996). These factors may contribute to prolong lengths of ICU stay and increased costs of intensive care rather than patient age itself, per se.

3.1.2 Severity of illness. Severity of illness is defined as the degree and impact of change in health status of an individual as a result of illness or injury (Kreitzer et al., 1982). In everyday practice, physicians and nurses make judgments about the severity and stability of patients' conditions and use this information to make decisions about nursing care and therapeutic interventions. Several studies found the effect of the severity of illness scores measured at 24 hour after admission on cost of care in ICUs (Edbrooke et al., 1997; Ridley et al., 1991; Stevens et al, 1998) and the effect on length of ICU stay (Arabi et al., 2002; Kanus et al., 1993). Results of the present study revealed that severity of illness scores at admission could be a determinant of medical care costs per patient day as well as length of ICU stay when controlling the effect of other influencing factors. This may be due to the fact that factors that comprise the severity score e.g., heart rate, PaO_2, represent the significant indicators of physiological equilibrium and are known to influence the medical staff or nurses' decisions. Patients who have high severity of illness scores possibly require more intensive treatments, monitoring equipment and expensive drugs for recovery and as a result in higher medical care cost per patient day and prolonged length of ICU stay, which are comparable to patients with lower severity of illness.

3.1.3 Nutritional status. Results of the current study showed the prevalence of malnourished patients in Thailand compared to those of other studies. In different published studies, the observed frequency of malnutrition on admission in critically ill patients varied from 40 to 90% (Huang et al., 2000; Giner et al, 1996). In this study, the frequency of malnutrition on admission varied from 57.4%, as assessed by serum albumin levels, to 85.5% with lymphocyte counts (Table 2). The difference in the reported prevalence of malnourished patients between the present study and the report of other investigators could be due to the difference in the definition of malnourished patients. Both of the previous studies defined malnutrition based on serum albumin levels and body weight. In the present study, malnutrition was determined based on serum albumin levels and lymphocyte counts. The reported high prevalence of malnutrition in this study confirmed that malnutrition has been a serious problem for critically ill patients in this hospital and reinforced the argument that nutritional status should be evaluated at ICU admission in an attempt to reduce nutrition related complications.

Assessment of nutrition status is recognized as the first step in the treatment of malnutrition (Rocandio Pablo, Arroyo Izaga, & Ansotegui Alday, 2003). Data obtained in the present study indicated that serum albumin levels and lymphocyte counts on admission constitute useful criteria for identifying patients who are malnourished. Physicians, nurses and other healthcare providers are able to use these variables to correctly identify all admitted patients who are at nutritional risk. Re-screening at regular intervals using these variables should be performed to identify whether the admitted patients require nutritional interventions. This may assist to reduce disease complications and has economic implications in terms of possibly reducing length of ICU stay and cost of care in ICUs.

The effect of nutritional status on length of stay and cost of care has been studied in critically ill patients and difference were found regarding length of ICU stay and cost of care between well nourished and malnourished patients (Epstein et al., 1987; Giner et al.,1996; Murray et al., 1988). In this study, the presence of abnormal albumin levels at admission was significantly associated with increased length of ICU stays, but not associated with medical care cost per patient day. In terms of the lymphocyte count, it was found that having abnormal lymphocyte counts at admission was associated with increased medical care cost per patient day as well as longer stays in ICUs. A potential explanation for this finding may be due to malnutrition leading to a catabolic state. There is evidence that malnutrition interferes with organs and systems of the human body and causes patients to present with impaired immune function, digestion and absorption (Bower, 1990). Malnutrition may contribute to prolonging mechanical ventilation. It decreases the regeneration of respiratory epithelium, and reduces the efficiency of respiratory muscle strength and ability to restore oxygen (Christman & McCain, 1993). Moreover, thoracic muscle dysfunction due to malnutrition may cause a higher incidence of pneumonia (Rochester & Esau, 1984).

Another interesting finding from this study is that there was no relationship between patient characteristics and nursing personnel cost per patient day. This indicated that share of nursing care times were equal across critically ill patients although they had differences in characteristics. One explanation for this finding may be that each critically ill patient is physiologically unstable whilst being cared for in an ICU, due to the use of vasodilator drugs and a mechanical ventilator. Thus, even though the patients do not have severe conditions, the ICU personnel, especially RNs, have to maintain these patients for long periods of time in order to closely observe them.

3.1.4 Types of ICU. The variable of types of ICU is a dummy variable in the regression analysis, which coded "*1*" as medical ICU and "*0*" as surgical ICU. The variable of types of ICU made a modest contribution to explaining variances for only two out of three dependent variables, including nursing personnel cost per patient day and length of ICU stay. Results of this study demonstrated that patients who were admitted for care in surgical ICU had shorter ICU stays than medical patients when differences in severity of illness, nutrition status, nurse staffing and day and time of patient admissions were controlled. Such differences may be explained by both a different patient mix and different diagnostic or therapeutic approaches. It can be seen that the majority of patients admitted to medical ICUs in this study had chronic illness diseases. Approximately 50% of medical patients were respiratory patients who required respiratory care. About 20% were renal patients who required mechanical ventilation and renal dysfunction therapy. Patients with these diagnoses make it possible to have high average length of ICU stay due to their critical illness associated with a poor prognosis and prolonged ICU stay. Compared to surgical patients, most patients were transferred from operating theater or recovery rooms after receiving elective or scheduled surgery. They required intensive care for a short period and were then discharged from the surgical ICU. Some patients were directly transferred from the emergency room in this hospital. They were unscheduled surgical patients and might have longer periods of critical care than scheduled patients. However, data of this study showed that there were only six percent of surgical patients staying more than five days (Table 2).

This data suggest that most surgical patients, including unscheduled surgical patients, have short ICU lengths of stay compared to medical patients.

Univariate analysis of the relationship between types of ICU and medical care cost per patient day showed that there was a statistically significant association with a coefficient $(r) = 0.16, p < 0.05$, coefficient correlation between types of ICU and nurse staffing variables ranged from 0.14 to 0.37, $p < 0.05$ (Appendix L). This signified that the mean nursing personnel cost and medical care cost per patient day incurred for each patient admitted to a medical ICU was higher than that of each surgical patient. However, there were no significant association between types of ICU with medical care cost per patient day as well as the relationship with nursing personnel cost per patient day when other factors, particularly severity of illness, were controlled. This may be due to the fact that severity of illness may contribute to the change in critical care treatments and the requirement of daily nursing care hours rather than types of ICU itself, per se, reflected by the higher mean severity of illness scores for medical patients than those for surgical patients ($M = 50.0$ vs 28.7).

3.2 Day and time of patient admission. Day and time of patient admission are defined as any day and time that a patient is admitted to an ICU. In this study, day of patient admission was divided into weekends and weekdays. A weekday is any day except Saturday and Sunday whereas a weekend day is either Saturday or Sunday. Times of admission were divided into office hours and non-office hours. Office hours are defined as the period from 8.00 a.m. to 4.00 p.m. All other time is considered to be non-office hours. These day and time cut-offs were chosen to reflect general working schedules in the ICUs and hospitals in Thailand with regard to periods of different staffing and availability of hospital services. Results of this study found that there were almost twice as many admissions on any given weekday compared with any weekend day. Interestingly, more samples of this study were admitted during non-office hours than office hours (Table 2). This finding may come from the fact that decisions in discharges of patients to other units usually occur during day shifts but ICU beds are available for new admissions in the following shifts.

The variables of day and time of patient admission were two dummy variables used to predict nursing personnel cost per patient day, medical care cost per patient day and length of ICU stay. Data from this study demonstrated that the inclusion of the variables of day of patient admission greatly improved the explanatory variances for only nursing personnel cost per patient day and length of ICU stay with R^2 increments by 0.01 (Table 11 and 15). The findings showed that patients who were admitted on Saturday or Sunday were more likely to have longer ICU stays than those with weekday admission and also showed that patients admitted during 4.00 p.m. one day to 8.00 a.m. the following day tend to have longer stays than those admitted during all other periods. One explanation for the effect of day and time of patient admission on length of ICU stay in this study may be related to personnel and procedural issues. Although ICUs are organized with continuous coverage by physicians and a very high nurse to patient ratio, the reduction of the numbers of medical staff and the availability of laboratory and diagnostic tests is a real situation found in ICUs on weekends and after office hours. In addition, people who work in ICUs during these times often have less seniority and experience. The reduction of service capacity over the weekend and non-office hours might result in prolong lengths of ICU stays through delays in obtaining the necessary initial work-up for newly admitted cases.

The significant association between day and time of patient admission and length of stay in the present study is consistent with the following previous studies. A study based on chest pain patients showed that patients with late-week admissions had a 19% greater length of stay than did patients admitted earlier in the week, after adjusting for severity of illness (Sheng et al., 1993). Another study based on patients with acute exacerbation of COPD also reported a significantly increased length of hospital stay for weekend compared with weekday admission, after adjusting potential confounders (de la Iglesia et al., 2002). A recent study in Singapore showed that weekend admission was associated with a prolonged hospital stay (Earnest et al., 2006). However, these studies have looked only at the effect of weekend admission on length of hospital stay. None have attempted to explore the association of time and day of patient admission with length of ICU stay. On the other hand, the present study found that patients who were admitted to an ICU on a weekend day were likely to have longer length of ICU stay relative to those with a weekday admission (4.5 vs 3.9 days).

Regarding the association between day and time of patient admissions with nursing personnel cost per patient day, the results from this study support a hypothesis that patients admitted on week days have lower nursing personnel cost per patient day than those with weekend day admissions. This may be due to the fact that unlimited access to medical care services with higher levels of staffing by physicians, nurses and other personnel on weekdays could improve patient recovery from serious conditions with high associated mortality rates to stable conditions for short periods, resulting in the great benefits to not only reduce the requirement of daily nursing care hours but nursing personnel cost per patient day as well.

A significant association between day and time of patient admission with medical care cost per patient day was not found in this study. This indicated that despite delays in obtaining the necessary initial work-up for newly admitted cases over weekends, there was no difference in the average medical care cost per patient day between patients with weekend admission and those with weekday admission. A possible explanation for this finding may be due to the effect of care on other subsequent days. Patients admitted on weekends may receive benefit from the following weekday care, while patients admitted on weekdays may also be subject to deleterious effects of weekend care. The effects of care on other days made it possible to equalize average medical care cost per day for patients with weekend and weekday admissions.

3.3 Nurse staffing. Nurse staffing is defined as the number and mix of nurses that are necessary to meet workload demands for care in an ICU. In this study the variable of nursing staff was measured by the average ratio of RN to patient and the average ratio of RN to other nursing staff. Using RN to patient ratios provides information about the appropriate utilization of nurse staffing in terms of number of RNs per patient day. The average ratio of RNs to other nursing staff provides information about the appropriate utilization of nurse staffing in terms of workloads shared between professional nurses and other nursing personnel. The average ratio of RNs deemed necessary to care for critically ill patients varies around the world. In Australia and the United Kingdom the ratio is normally one nurse to one patient in ICU and 1:2 in high dependency units (Ball, 2001). In Thailand, the ratio of one nurse to one patient is the gold standard based on Thailand Nursing Council Standard (2005). However, data in this study revealed that the ratios of RN to patient varied, but frequently a nurse was required to care for more than one patient (Table 3). This indicated that nursing manpower resources in ICU in this hospital were more likely to be over-utilized. On the other hand, this study found that approximately 22% of study sample were cared with RN to patient ratios of more than 1:1. The number of RNs tended to increase due to the necessary for supervising junior critical care nurses and for providing nursing care to patients with a dialysis machine.

It is well recognized that either ratios of two RNs to one other nursing staff or three RNs to two other nursing has been accepted for allocating nursing staff in a university hospital of Thailand (Thailand Nursing Council, 2005). However, the results of this study revealed that approximately 60% of the 242 patients were cared for in an ICU with the Thailand Nursing Council Standard of RN to other nursing staff ratio while 32 % with below the standard. The great use of non-RNs may be explained in part by insufficient number of RNs. In actual practice, in addition to the RNs in charge and those providing direct patient care at the ratio of one nurse to more than one patient, approximately four other nursing staff were required to adequate care for eight patients in day shift and four other ones diving evening and night shifts equally.

The effect of nurse staffing variables on patient costs and length of ICU stay was found in this study. The results indicated that the average ratio of RN to patient was significantly associated with nursing personnel cost per patient day, medical care cost per patient day and length of ICU stay. Possible underlying factors resulting in this finding may be due to an efficient utilization of nurse staffing in ICUs. There was evidence of adequate RN staffing, better patient monitoring and surveillance as nurses were prepared to detect and treat complications (Schultz et al., 1998; Amaravadi et al., 2000; Pronovost et al., 1999). In addition, RNs were more effective in preventing adverse events such as nosocomial infections and pressure sores than other nursing staff. Adequate RN staffing produced quality infection control practices permitting them to adhere to aseptic techniques and high standards of care as these principles and techniques require a higher knowledge and skills level (Cho et al., 2003).

The results also demonstrated that the average ratio of RN to patient had a negatively significant association with medical care cost per patient day but was positively significant in association with nursing personnel cost per patient day. This indicated that although increasing the number of RNs would contribute to increasing personal costs, the great availability of RNs was of great benefit to reduce cost of therapeutic interventions. This finding is congruent with the study of Amaravadi et al., 2000; Behner et al., 1990; Bloom, 1997; Cho et al., 2003; Dimick et al., 2001; McGillis et al., 2004; Schultz et al., 1998, which indicated that cost reductions were possible through increasing the caring activities of RNs.

The lower medical care cost in this study may be explained in part by the high efficiency of professional nurses. Professional nurses in the ICU frequently reviewed and altered planned interventions in response to the patient's condition. There was evidence that educational preparation and clinical experiences of RNs could enhance the nurses' ability to judge actual situations, and detect changes in patient status as well as facilitate lower consumption of resources (Behner et al., 1990; Bloom et al., 1997). Furthermore, professional nurses could improve patient recovery by using proactive management, weaning from ventilation, coping with unpredictable events and prompt interventions in the event of sudden deterioration (Archibald et al., 1997; Kovner et al., 2002; Thorens et al., 1995). Despite the advances in technological expertise in ICUs, there was still no substitute for properly trained professionals providing direct patient care (Beckmann et al., 1996; Buckley et al., 1997). This evidence suggests that ICUs can benefit greatly from using the full potential of RNs.

Regarding the average ratio of RN to other nursing staff, there was a positively significant relationship with nursing personnel cost per day after adjusting for types of ICU and the average ratio of RN to patient. It was not surprising why higher RN-to-other nursing staff ratios contributed to increasing nursing personnel cost per patient day in this study. This result may be due to the high differences between the mean hourly money allowance for RNs and those for other nursing staff. The present study indicated that the mean hourly money allowance for RNs was approximately one and a half times as much as those for other nursing staff. This factor could lead to a positive association between the average ratio of RN to other nursing staff and nursing personnel cost per day.

Although increasing the number of RNs led to increased nursing personnel cost per day, but the decreased medical care cost per patient day decreased by 0.3% when increasing one percent of RN to patient ratios (β = -0.003, $p < 0.001$), suggesting that cost savings appear to be balanced by RNs providing more efficient and effective health services as well as lower consumption of resources. Therefore, the investigator suggests that decisions about nurse staffing levels should be based on sound evidence to ensure that an appropriate number of skilled nursing staff is available to achieve safety standards and optimum patient outcomes.

The data of this study identified that higher RN-to-other nursing staff ratios were not related to medical care cost per patient day as well as length of ICU stay, when severity of illness, nutrition status and the average ratio of RN to patient were constant. This finding was consistent with the analysis of 583 hospitals using nursing personnel study data file that found that higher percentages of RNs were not related to hospital costs (Bloom et al., 1997). From these results, one can infer that increasing other nursing staff will not affect medical care costs and lengths of ICU stay whenever an adequate number of RNs is maintained. The above observation may be due to the fact that although other nursing staff, including PNs or HPs, have been employed within critical care environments to assist RNs in performing non-nursing duties, the majority of direct patient care activities remained within the remit of the RNs. Therefore, greater use of other nursing staff does not reduce the amount of time which the different RNs spend performing ICU related activities. In contrast, there was evidence that the workload of RNs tended to increase with the employment of unlicensed assistive staff due to the requirement for supervision and correction of errors (Mackinnon et al., 1998).

Thus, the investigator suggests that within ICUs RNs are more productive than unlicensed assistive staff because they can perform the entire range of nursing tasks without supervision. However, the assistive staff are needed because hospital policy frequently requires an extra nurse to assist with ICU nursing procedures. Examples of these procedures included tube care, tube suction, tuning of patients, nasogatric feeding, bed bathing and housekeeping in the bed area. Further continuity in patient care and safety will be compromised if there are sufficient numbers of non-RNs to cover for the movement of RNs away from the bedside.

In conclusion, results of the study indicated the importance of certain non-modifiable variables such as patient age, severity of illness and malnutrition. It also identified certain modifiable predictors of patient cost and length of ICU stay. Understanding some of these predictors can help plan strategies to improve resource utilization. The study confirmed that the presence of malnutrition at admission was significantly associated with increased length of ICU stay and high daily medical care cost. The reduction of service capacity over the weekend-days and non-office hours were associated with high daily medical care cost and prolonged-stay in the ICU. The findings suggest that significant reductions in cost and length of stay may be possible with higher ratios of nursing personnel in the ICUs. Reasons for better outcomes with sufficient number of RNs may be related to the immediate availability of a RN to evaluate and care for patients. Although increasing the number of RNs led to increase the nursing personnel cost, but the additional costs of having more licensed nurses would be offset to some extent by the monetary benefit of reducing cost of therapeutic interventions. Many of these results will be helpful for nursing practices and improving the quality of care, furthermore, they also contribute to nurse administrator's decisions on cost containment strategies for providing care in an ICU.