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Analysis of the Effect of Conversion From Open to Closed Surgical Intensive Care Unit

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Objective
To compare the effect on clinical outcome of changing a surgical intensive care unit from an open to a closed unit.

Design
The study was carried out at a surgical intensive care unit in a large tertiary care hospital, which was changed on January 1, 1996, from an open unit, where private attending physicians contributed and controlled the care of their patients, to a closed unit, where patients' medical care was provided only by the surgical critical care team (ABS or ABA board-certified intensivists). A retrospective review was undertaken over 6 consecutive months in each system, encompassing 274 patients (125 in the open-unit period, 149 in the closed-unit period). Morbidity and mortality were compared between the two periods, along with length-of-stay (LOS) and number of consults obtained. A set of independent variables was also evaluated, including age, gender, APACHE III scores, the presence of preexisting medical conditions, the use of invasive monitoring (Swan-Ganz catheters, central and arterial lines), and the use of antibiotics, low-dose dopamine (LDD) for renal protection, vasopressors, TPN, and enteral feeding.

Results
Mortality (14.4% *vs.* 6.04%, $p = 0.012$) and the overall complication rate (55.84% *vs.* 44.14%, $p = 0.002$) were higher in the open-unit group *versus* the closed-unit group, respectively. The number of consults obtained was decreased (0.6 *vs.* 0.4 per patient, $p = 0.036$), and the rate of occurrence of renal failure was higher in the open-unit group (12.8% *vs.* 2.67%, $p = 0.001$). The mean age of the patients was similar in both groups (66.48 years *vs.* 66.40, $p = 0.96$). APACHE III scores were slightly higher in the open-unit group but did not reach statistical significance (39.02 *vs.* 36.16, $p = 0.222$). There were more men in the first group (63.2% *vs.* 51.3%). The use of Swan-Ganz catheters or central and arterial lines were identical, as was the use of antibiotics, TPN, and enteral feedings. The use of LDD was higher in the first group, but the LOS was identical.

Conclusions
Conversion of a tertiary care surgical intensive care unit from an open to closed environment reduced dopamine usage and overall complication and mortality rates. These results support the concept that, when possible, patients in surgical intensive care units should be managed by board-certified intensivists in a closed environment.

In 1923, Dr. W. E. Dandy opened a three-bed unit for neurosurgical patients at Johns Hopkins Hospital.[1] Intensive care units (ICU) were first opened in the 1960s with the advent of cardiac surgery where patients were followed postoperatively in the recovery room with special monitoring devices. Soon after, such specialty care was offered in separate units, and the techniques extended to other surgical patients who were severely ill or had complex medical problems.[2] The concept spread to other specialties, creating an array of different ICUs caring for different patient populations. In 1971, the Society of Critical Care Medicine (SCCM) was created, and in the 1970s, critical care became a defined nursing specialty. As populations age in the developed world, the incidence of concomitant medical conditions will also increase. According to the U.S. Census Bureau, there were 25.1 million Americans older than 65 years in 1980, and this number is estimated to rise to 34.9 million by the year 2000.[3] This group forms 13% of the population, but occupies 47% of the ICU beds.[4] ICU use is anticipated to increase in this setting, despite an overall lower hospital occupancy rate with a shift toward outpatient care. According to a study done on 2,876 intensive care units in the United States, about 7% of hospital beds are allocated to critical care, with a three to four times higher cost per day than a regular ward bed.[4]

Many tertiary care hospitals have critical care teams caring for ICU patients in either an open or a closed model. In the open model, private attending physicians are actively involved or actively participate in the care of these patients,

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but in the closed-unit system, it is the critical care team that is directly responsible for patient care. Considering outcome as a major factor in the overall cost of ICUs, few studies have analyzed the value on outcome of using dedicated intensivists in the ICU. To our knowledge, only one study has evaluated the outcome effects of changing an open unit to a closed unit; in that study, outcome in a medical ICU was improved.[5]

Herein we compare effectiveness of open *versus* closed models in a surgical ICU (SICU) setting by retrospectively comparing outcome results before and after the implementation of a closed-unit model at Rhode Island Hospital on January 1, 1996.

METHODS

Setting

Rhode Island Hospital is a 721-bed tertiary care hospital affiliated with Brown University. The Surgical Intensive Care Unit is a 9-bed unit where care is offered to surgical patients from varying specialties (general surgery, neurosurgery, and vascular, orthopedic, and plastic surgery).

Most of the patients admitted to this unit are postoperative patients, with a small percentage (2.6%) transferred from the wards or an intermediary unit (Table 1).

Critically ill patients coming through the emergency department usually undergo emergent surgery before being admitted to the SICU. Rarely, patients are transferred directly from another hospital to the SICU (< 1% of total admissions).

Open Unit

Prior to January 1, 1996, SICU patients were cared for by the critical care team, composed of an attending intensivist rotating on a weekly basis who was board-certified in surgical critical care and two surgical residents (PGY-2 and PGY-3) rotating in a 1- or 2-month period, alternating on a 24-hour basis.

Table 1. ICU ADMISSIONS BY SURGICAL SUBSPECIALTY

	Open Unit	Closed Unit	Total
Orthopedics	7	10	17
Gynecology	4	6	10
Neurosurgery	15	8	23
Urology	4	5	9
Thoracic	11	15	26
Vascular	34	34	68
Endocrine	3	3	6
Ear, nose, and throat	1	1	2
Gastrointestinal	46	56	102
Pelvic sarcoma	1	3	4
Floor transfers	3	4	7

The private attending physician and the corresponding service had a direct influence on the management of their particular patients with the ability to write orders. The critical care team functioned primarily in a consulting or advisory capacity.

Closed Unit

After January 1, the SICU was converted to a closed unit where patient management was directly dictated by a surgical ICU team, with patients formally transferred to the ICU attending during their ICU stay. The ICU attending became legally responsible for the medical care of patients while in the ICU. The original operating surgeon for the patient was informed of the patient's progress on a daily basis, and if operative intervention became necessary in these patients, that surgeon performed the surgical procedure(s). The status of the same critical care staff changed from being merely consultants in the open unit to being the only physicians with admitting privileges to the SICU, and therefore the only legally responsible doctors taking care of SICU patients.

Study Period

The study period for the open-unit group (Group I) was from July 1, 1995, to December 31, 1995. The study period for the closed-unit system (Group II) extended from January 1, 1996, to June 30, 1996.

Patient Eligibility and Enrollment

Concomitant with the changed status of the surgical ICU in January 1996, a new Trauma Intensive Care Unit (TICU) was created; trauma patients who needed intensive care were treated in the surgical ICU until December 1995, and in the TICU starting January 1, 1996. Because trauma patients could form a different population, we decided to exclude these patients from the study (we also excluded 64 trauma patients from the period of time when the SICU functioned as an open unit). In the open-unit period, 125 patients were evaluated; 149 patients were evaluated in the closed-unit period. Only the first admission of a patient to the SICU was evaluated to avoid different outcomes for the same patient.

Measurement of Outcome

Severity of illness was measured by the Acute Physiology and Chronic Health Evaluation III (APACHE III) system. We used APACHE III instead of APACHE II because of an increased discriminative power shown in some studies.[6–8] The worst values during the first 24 hours were used and no point was given when laboratory values, which were assumed to be normal, were missing.

Other than the APACHE III score, we evaluated specific

Table 2. PATIENT CHARACTERISTICS AND INTERVENTIONS

	Open Unit	Closed Unit	p Values
Age (mean)	66.48 ± 1.35	66.4 ± 1.23	0.96
Sex (male %)	63%	53.35%	0.049
SG days	1.9 ± 0.33	1.7 ± 0.23	0.62
CL days	1.65 ± 0.33	1.59 ± 0.35	0.91
A-lines days	4.58 ± 0.49	4.189 ± 0.44	0.55
LDD days	1.03 ± 0.26	0.23 ± 0.06	0.001
No. of consults per patient	0.68 ± 0.09	0.432 ± 0.07	0.03
Antibiotics	1.44 ± 0.12	1.18 ± 0.11	0.14
ATB days	3.60 ± 0.49	2.89 ± 0.35	0.23
Precardiology	62.40%	65.10%	0.64
Prepulmonary	29.60%	38.93%	0.10
Prerenal	5.60%	7.38%	0.55
Preimmunologic	2.40%	6.04%	0.14
Diabetes	16.80%	15.44%	0.75
APACHE III score	39.02	36.16	0.22
Total parenteral nutrition	12.80%	15.40%	0.53
Enteral feeding	12.80%	10.10%	0.48
Pressors	12%	13.42%	0.72

ATB = antibiotics; CL = central lines; LDD = low-dose dopamine; SG = Swan-Ganz catheters.
Results = mean ± SEM.

pre-SICU medical conditions, such as the presence of any cardiac disease (e.g., congestive heart failure, coronary artery disease, myocardial infarction, hypertension, chronic atrial fibrillation), pulmonary disease (e.g., chronic obstructive pulmonary disease as evidenced by O_2 dependency or chronic use of inhaled steroids), renal disease (e.g., chronic renal insufficiency as evidenced by a creatinine level > 1.8 mg/dl or chronic use of dialysis), immunologic disease (e.g., AIDS or use of chronic steroids), or diabetes mellitus. We also evaluated interventions in the ICU by monitoring the use of Swan-Ganz catheters, central and arterial lines, total parenteral nutrition (TPN), enteral feedings, low-dose dopamine (LDD), any vasopressor agents, and antibiotics (cumulative days and number of antibiotics). In addition, we reviewed the number of consults obtained for each patient (Table 2).

Outcome was measured as the occurrence of any complications, the length of stay (LOS), death in the SICU, and 30-day mortality. We divided complications by system and included a miscellaneous category (Table 3). For each system, we included Marshall's organ dysfunction score and the occurrence of any abnormality which deviated from an uncomplicated normal ICU course.[9] For example, cardiac complications were defined as any arrhythmia (supraventricular tachycardia, atrial fibrillation or flutter, ventricular tachycardia or fibrillation, AV bloc), myocardial infarction, congestive heart failure, or cardiogenic shock necessitating the use of vasopressors. Pulmonary complications were categorized as the presence of pneumonia, pneumothorax, respiratory failure (PaO_2/FiO_2 <250) or empyema. Renal insufficiency was identified with a creatinine value of >1.3 mg/dl or a rise of more than 100% if chronic renal insufficiency was already present (creatinine ≥1.8 mg/dl) or urine output was less than 480 cc per day, or both. Hepatic complications were recorded when bilirubin rose above 1.2 mg/dl. Neurologic problems were defined with a Glasgow coma score of less than 13, or the development of seizures, delirium requiring medication, or stroke. Hematologic complications included thrombocytopenia (platelet count < 100,000), consumptive coagulopathy, or disseminated intravascular coagulation. Gastrointestinal complications included gastrointestinal bleeding requiring endoscopic diagnosis or treatment (or both) or transfusions, severe diarrhea (*Clostridium difficile* colitis), or bowel ischemia. Under miscellaneous, we included all infectious complications as well as more benign events. The occurrence of any yeast infection was also evaluated (Table 4). This retrospective study was approved by the Institutional Review Board at Rhode Island Hospital.

Statistical Analysis

Univariate testing (chi-square, Wilcoxon rank sum, and independent sample *t* test) was performed on 14 independent variables against the two principal outcome variables: occurrence of any complication other than death (morbidity) and death (mortality). Variables resulting in univariate probability values of 0.20 or less were entered into an initial multivariate logistic regression model. We then used Wald and the likelihood ratio tests to eliminate noncontributory variables from the model. All statistical analysis was performed using commercially available software (Stata version 5.0, Stata Corporation, College Station, TX).

Table 3. COMPLICATIONS AND OUTCOME IN CLOSED *VERSUS* OPEN SURGICAL INTENSIVE CARE UNITS

	Open Unit	Closed Unit	Total
Pulmonary	14	20	34
Cardiology	14	19	33
Renal	16	4	20
Hepatic	2	2	4
Coagulation	2	4	6
Neurologic	9	8	17
Gastrointestinal	3	4	7
Infectious	31	37	68
Other	3	2	5
Morbidity	55.84%	44.14%	p = 0.002
Length of stay (mean)	5.83	5.51	p = 0.729
Deaths	18 (14.4%)	9 (6.04%)*	p = 0.012

Table 4. COMPLICATIONS

	Open Unit	Closed Unit	Total
Cardiac			
Arrhythmias	7	10	17
Infarction	5	6	11
Pulmonary edema	2	0	2
Pulmonary			
Pneumonia	8	10	18
Acute respiratory distress syndrome	2	4	6
Bronchospam	0	1	1
Lung collapse	1	3	4
Empyema	0	1	1
Pneumothorax	3	0	3
Renal			
Renal failure	16	4	20
Coagulopathy			
Consumptive coagulopathy	2	4	6
Hepatic			
Cholestasis	2	2	4
Neurologic			
Delirium	8	4	12
Seizures	0	2	2
Stroke	1	2	3
Gastrointestinal			
GI bleed	1	2	3
GI perforation	1	0	1
Clostridium difficile colitis	1	2	3
Infectious			
Wound infection	2	5	7
Abdominal abscess	2	2	4
Urinary infection	9	5	14
Yeast infection	12	16	28
Bacteremia	4	6	10
Line sepsis	3	2	5
Miscellaneous			
Radial artery thrombosis	2	0	2
Lower extremity ischemia	1	1	2

Each patient might have developed more than one complication. Complications occurring in patients who died were not included.

RESULTS

Comparison of Independent Factors Between the Open-Unit and Closed-Unit Groups

Patients in both groups were of similar ages (66.48 years *vs.* 66.40, p = 0.96; Table 2). There were more men in Group I (63% *vs.* 51.35%, p = 0.049). The APACHE III score was slightly worse in Group I but the difference did not reach statistical significance (39.02 *vs.* 36.16, p = 0.222). Most of the patients were postoperative patients; only 7 were transferred either from another unit or from an intermediate surgical care unit. The two populations were identical concerning the presence of preadmission medical conditions (Table 2). The use of Swan-Ganz catheters, central and arterial lines, total parenteral or enteral feedings, and antibiotics were similar in both groups (Table 2). As expected, there was a positive association between APACHE III score and both the complication and death rate. (mean APACHE III = 34.54 for patients who did not die *vs.* 64.4 for those who did, p = 0.0001, and mean APACHE III = 32.38 *vs.* 44.48, when complications occurred, p = 0.0001.)

Comparison of Outcome Variables Between the Open-Unit and Closed-Unit Groups

Overall morbidity was higher in Group I (55.84% *vs.* 44.14%, p = 0.002), as was mortality (14.4% *vs.* 6%; Fig. 1). These results were independent of the APACHE III score. Male gender did not carry a higher morbidity, but a higher mortality (14.8% *vs.* 6.3%) which approached statistical significance (p = 0.056). The presence of renal insufficiency was the only independent medical condition which correlated with a higher mortality (33% *vs.* 8.2%, p = 0.014). This observation was found in both groups. The complication rate as well as mortality was also increased with the use

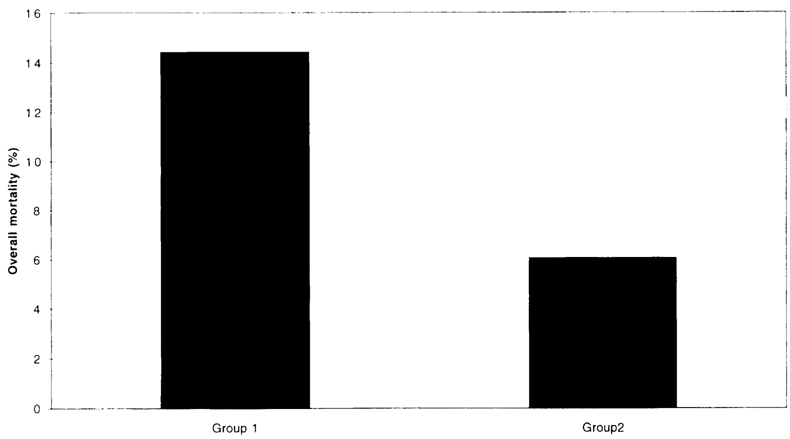

Figure 1. Effect of conversion of open to closed ICU on overall mortality. Mortality decreased from 14.4% to 6.04% by converting the SICU from an open (Group I) to a closed (Group II) unit, despite similar patient characteristics (p = 0.012).

Table 5. ETIOLOGY OF PATIENT MORTALITY

Patients	Diagnosis	Etiology of Death
Open Unit		
1	Necrotizing fascitis	MSOF
2	Bleeding duodenal ulcer	Duodenal leak, MSOF
3	Ruptured abdominal aneurysm	DIC, MSOF
4	Toxic megacolon	MSOF
5	Ischemic lower extremity	Renal failure, made CMO
6	Subdural hematoma	Brain death
7	Subdural hematoma	Brain death
8	Abdominal aneurysm	Ventricular fibrillation
9	Bleeding duodenal ulcer	Stroke
10	Ampullary carcinoma	Liver necrosis
11	Subdural hematoma	Brain death
12	Necrotizing fascitis	MSOF
13	Abdominal aneurysm	MSOF
14	Exploratory laparotomy	GI bleed, coagulopathy
15	Obstruct cholecystocolic fistula	MSOF
16	Sigmoid volvulus	MSOF
17	Ruptured abdominal aneurysm	MSOF
18	Lymphoma	MSOF
Closed Unit		
1	Ischemic lower extremity	MSOF
2	Ruptured abdominal aneurysm	Ischemic colitis, asystole
3	Mesenteric ischemia	Asystole
4	Intraventricular hemorrhage	Brain death
5	Esophageal carcinoma	Ventricular fibrillation
6	Bleeding duodenal ulcer	MSOF
7	Perforated duodenal ulcer	Pulmonary failure
8	Metastic Schwannoma	MSOF
9	Rebleeding after nephrectomy	DIC, MSOF

CMO = comfort-measures-only; DIC = disseminated intravascular coagulation; MSOF = multiple organ system failure.

of Swan-Ganz catheters and arterial lines, but these patients were also sicker, as evidenced by a higher APACHE III score. When taking the APACHE III score into account, this observation did not independently reach statistical significance. Length of stay in the intensive care unit was identical in both groups (5.83 days *vs.* 5.51, p = 0.72).

The occurrence of yeast infection was correlated with the presence of renal insufficiency or the use of Swan-Ganz catheters. The complication rate also increased when yeast infection occurred (35% *vs.* 75.86%, p = 0.0001). This was seen in both groups. The number of outside consults obtained decreased in Group II (0.8 per patient *vs.* 0.43, p = 0.036). The most common complications were infectious and cardiopulmonary in nature, without any significant difference between the two groups. Arrhythmias and pneumonia were the leading cardiopulmonary complications. For infectious complications, 11 patients in Group I and 16 patients in Group II developed yeast infections; urinary tract infections occurred in 9 patients in Group I and 5 patients in Group II. Most of the yeast infections occurred in the urine. Renal failure was more prevalent in Group I (12.8% *vs.* 2.67%, p = 0.001; Table 5). This occurred despite a higher and longer use of LDD by patients in this group. Low-dose dopamine was used more frequently in Group I (21.6% *vs.* 10.7%, p = 0.014) and for longer periods (1.03 days *vs.* 0.23, p = 0.0015; Figs. 2 and 3).

Eighteen patients died in Group I and nine patients in Group II (14.4% *vs.* 6.04%, p = 0.012). Nine patients in Group I and four patients in Group II (p = NS) died from multiple system organ failure (MSOF). Mortality from MSOF was 90% in Group I and 57% in Group II (p = 0.25). When the factor Group I *versus* Group II was taken alone, there was a 0.38 odds ratio of decreasing mortality in Group II with a p = 0.025 (95% confidence interval: 0.165–0.884).

Seven more patients died in Group I in the hospital after discharge from the ICU, compared to six patients in Group II, for a 30-day mortality of 20% and 9.3%, respectively (p = 0.02). Of the 13 patients who died after discharge from the ICU, five died after reaching comfort-measures-only (CMO) status, with a mean of 6.6 days after discharge from the ICU *versus* 9 days if they were not CMO (p = NS).

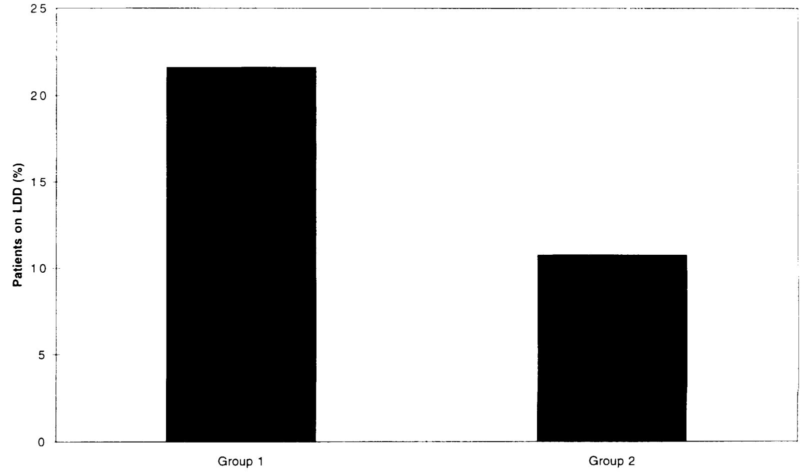

Figure 2. Effect of conversion of open to closed ICU on the percentage of patients receiving low-dose dopamine (LDD). Low-dose dopamine was used more frequently in the open-unit period (Group I) than the closed-unit period (Group II) (p = 0.014).

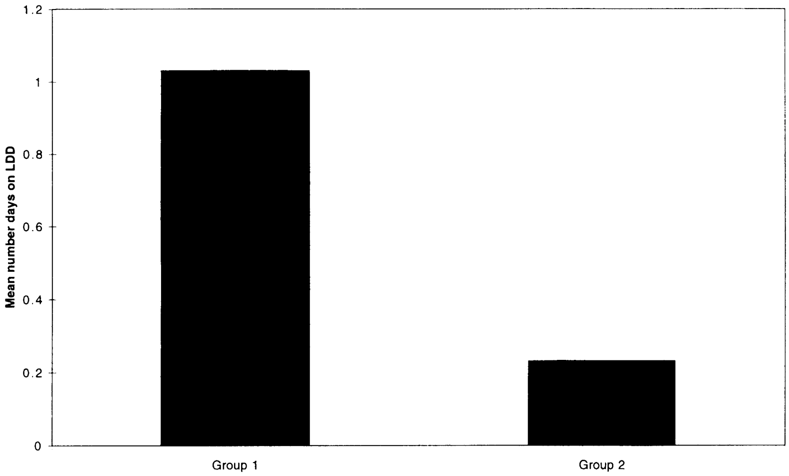

Figure 3. Effect of open to closed ICU on the mean number of days on low-dose dopamine (LDD). Low-dose dopamine was used for longer periods of time in the open unit (Group I) compared to the closed unit (Group II) (p = 0.001).

Results of Logistic Regression Analysis

Results of the logistic regression analysis are presented in Tables 6 and 7 for morbidity and mortality, respectively. The model on morbidity (chi-square = 52.98, $p < 0.00005$, log likelihood = −55.197) retained two variables, ICU group (open *vs.* closed) and APACHE III score. Results show that the odds of morbidity (occurrence of at least one complication) for a closed-unit patient are one half that of an open-unit subject (while adjusting for APACHE score). The odds of morbidity increased by 1.04 for every one-unit increase in APACHE score (Table 6).

Three variables were retained in the mortality mode (chi-square = 34.27, $p < 0.00005$, log likelihood = −155.762). (We retained the ICU group variable even though its p value was not significant at 0.005). These results demonstrate that a prerenal condition results in nearly four times greater odds of death, while adjusting for ICU group and APACHE score. The odds of mortality for a closed-unit patient are 0.44 > than that of an open-subject patient (note, however, that 1.0 is bounded by the 95% CI). The odds of mortality increased by 1.07 for every one-unit increase in APACHE score (Table 7).

DISCUSSION

In the present cost containment environment, intensive care units have been relatively less influenced by the changes affecting the medical community, often providing the last resort for treatment of severely ill patients or patients with complicated medical problems.

There have been ongoing debates about the futility of the care given to a subset of severely ill patients, and scores have been created to try to predict the survival of patients upon initial admission to the ICU with a certain degree of accuracy. Deciding whether to care for these patients, or when to stop treatment, leads to difficult ethical decisions that many physicians find hard to resolve.

Intensive care units are among the costliest units in any hospital setting, carrying the highest cost per patient per day.[4] Efforts have been made to control these costs by evaluating different treatments given in the ICU (e.g., medications, length of stay), the presence of an intensivist,[10,11] and following particular outcomes. In a university hospital pediatric ICU, the presence of an intensivist seems to have increased the therapeutic interventions but decreased mortality.[10] Few studies to date have reviewed the medical management of ICUs and its effect on outcome. A survey in 1991 done by the American Hospital Association showed that 22% of ICUs used a closed system.[4] Larger hospitals, more specialized units, and medical school affiliation had the greatest influence on the presence or absence of closed units. In one study, all patients with septic shock were

Table 6. MULTIVARIANT LOGISTIC REGRESSION ANALYSIS OF FACTORS AFFECTING MORBIDITY

Morbidity Variable	Odds Ratio	P < z
Group (I or II patients)	0.4994	0.012
Sex	0.8481	0.556
Age	0.9939	0.564
APACHE III	1.0415	0.0001
Prerenal	1.5834	0.403

Table 7. LOGISTIC REGRESSION ANALYSIS OF FACTORS AFFECTING MORTALITY

DTS	Odds Ratio	P > z
Sex	0.3805	0.098
Group (I vs. II)	0.614	0.37
APACHE III	1.08	0.0001
Prerenal	3.63	0.068

DTS = factor analyzed for impact on mortality.
Prerenal refers to any patient admitted to ICU with creatinine level ≥ 1.8 mg/dl or on dialysis.

investigated after the formal organization of a critical care service. This change generated higher cost but again led to a better outcome.[12] In another study in Brazil, 1,734 patients were studied in ten combined medical-surgical ICUs. The ability to decrease mortality was associated with the amount of technology available in those units.[13]

To our knowledge, there has been only one study reviewing outcome when an ICU was changed from an open to a closed unit. This was a prospective study in a medical ICU that reviewed 245 patients.[5] The patients in the closed unit had a higher APACHE II score (20.6 *vs.* 15.4), but the outcome seemed to have improved. It was also found that nurses were the most supportive of the change. (We did not evaluate hospital charges, nor did we evaluate nurse or house staff satisfaction, because our study was retrospective in nature.)

In our ICU, the team caring for patients was identical in both groups, formed by one attending (with board certification in critical care) rotating on a weekly basis, and two surgical residents (PGY-2 and PGY-3) alternating 24 hours on call. In the closed unit, the ICU physician was the admitting attending and patient care was solely by the ICU team, with orders carried out only if they were written by members of the ICU team. Outside consults were obtained as indicated by the complexity of the medical problems. There was a small but statistically significant decrease in the use of outside consults in the closed-unit period. The majority of our consults were from the nutritional service to institute TPN.

The populations in both study periods were identical as to age, APACHE III score, and preexisting medical conditions, but there was a higher percentage of men in the open-unit group. Male patients showed a trend of increasing mortality that approached statistical significance. However, in our multiple logistic regression analysis, male gender did not independently carry an increased risk of mortality (Table 7). Humoral and cell-mediated immune responses to antigen challenge seem to be enhanced in women compared to men in other studies.[14] It has become recently apparent that sex-linked hormones may affect the immune response and modify the expression of autoimmunity in animals as well as in humans.[15] Our study showing a trend toward increasing mortality in men would support these observations. It is still unclear, however, if women in the postmenopausal age range would have improved outcome, having different hormonal levels than premenopausal women. With a mean patient age of 66 years in both study periods, most of our female population in the ICU would have been postmenopausal.

The use of invasive monitoring devices and antibiotics was similar in both groups. Low-dose dopamine was used less frequently in the closed-unit period and there were fewer renal complications as well. The ICU team's use of LDD was random and did not follow a particular protocol. It is still unclear if patients benefit from LDD for renal protection, which patients will respond to it, and if any extrapolation could be proposed about the use of LDD. We also compared the use of LDD with the severity of renal insufficiency in both groups. The patients who received LDD had a similar degree of renal insufficiency, as 78% of patients in the open-unit group who received LDD had a serum creatinine level of less than 2 mg/dl, compared to 87% in the closed-unit group. In clinical studies, dopamine, although it increased urine output, did not change creatinine values or creatinine clearance.[16,17] Because renal failure was diagnosed as oliguria (<480 cc urine/day) or a rise in creatinine (>50% in patients with normal values and >100% in patients with chronic renal insufficiency, i.e., creatinine >1.8 mg/dl), the occurrence of renal failure would not have been affected by the use of LDD because creatinine clearance would not have changed. A prospective study examining this issue by carefully evaluating all the parameters and concomitant treatments would seem to be appropriate. Renal failure in the ICU still carries a high mortality[18–20] despite recent improvements[21]; evaluating methods to decrease the occurrence of this complication should therefore improve survival.

Tilney, Bailey, and Morgan identified MSOF as a distinct entity in 1973, when they described the progressive failure of organ systems after repair of ruptured abdominal aortic aneurysms (AAA).[22] Two patterns of MSOF have been described.[23] A "one-hit model" postulates that massive tissue injury or shock combine to produce intense systemic inflammation that results in early (within 72 hours) MSOF. An example of this model would be a ruptured AAA. The more common pattern is the "two-hit model," which seems to involve multiple sequential insults. Less severely injured patients enter a less intense state of the systemic inflammatory response syndrome (SIRS), but are vulnerable to a second inflammatory insult that amplifies SIRS to precipitate late (after 72 hours) MSOF. One can then easily imagine the occurrence of MSOF in patients with delayed or inadequate resuscitation.

Mortality of MSOF is high, varying between 40% and 100%, and is related to the number of organ failures.[24,25] In our study, the mortality of patients who went into MSOF fall within this range, although it seemed to have decreased after converting the SICU to a closed unit (57% *vs.* 90%), but this did not reach statistical significance. The respiratory system was found to be the first to fail in trauma patients developing MSOF,[26,27] and it was also the system affected with the highest mortality. The liver was the last organ to deteriorate. Renal failure was rarely found to occur in trauma patients, but if present it developed early.[27] In another study, 3,611 blunt-trauma patients were evaluated, and a 27% mortality rate was found for early MSOF (<72 hours) *versus* 49% for late MSOF (>72 hours).[28] The occurrence of ARDS and renal failure were both found to carry independent risk factors for increasing mortality. The presence of renal failure was associated with a 6.69 odds ratio of dying. Two other studies showed renal failure to have a high mortality and was associated with MSOF in trauma patients.[29,30] In our patients who developed MSOF, eight out of 17 (47%) experienced renal failure within 48 hours of their admission to the SICU, and two more developed renal failure after 72 hours. Lower renal failure rates in MSOF occurred in the studies mentioned above, but these studies mainly involved trauma patients. Trauma patients could form a different population group than other surgical patients requiring ICU care, and were excluded in Group I from our study to minimize any discrepancy in the population being studied. Nonetheless, it is possible that the decreased rate of renal failure in Group II contributed to the trend toward a decreased rate of MSOF in this same group. At the same time, we acknowledge that the change in the rate of MSOF did not reach statistical significance and that the number of patients with MSOF was too small to show any difference. As for the occurrence of yeast infections, our study showed a higher complication rate when it occurred equally in both groups, and the presence of renal insufficiency increased the risk of yeast infection 6 times, the use of Swan-Ganz catheters 2.6 times, and the use of antibiotics 8 times.

The incidence of brain pathology was higher in the open-unit group (15% *vs.* 5%), as was the incidence of ruptured AAA (4.8% *vs.* 1.3%). This could have accounted partly for the improved outcome in the closed-unit group. More importantly, the mortality of patients with brain pathology was lower in the closed-unit group (12.5% *vs.* 26%). It is unclear if the severity of brain pathology was responsible for this finding. The mortality of ruptured AAA was equally high as expected in both groups (50%). Therefore, the more than two-fold decrease in mortality between the open- and closed-unit groups cannot be accounted for simply by differences in the incidence of ruptured AAA or brain pathology or both. With an improved morbidity and a decreased mortality despite similar interventions, it would seem that the improved outcome by converting the SICU to a closed unit was probably the result of better step-by-step and day-to-day decision-making by expert physicians in critical care. This could have contributed to the decreased rate of renal failure which independently carried a worse outcome. Avoiding diuretic use in inappropriate situations or better initial resuscitation might have also made a difference in these cases. Changing to a closed unit by itself was a factor in improving morbidity and improved survival when analyzed in an independent fashion without confounding variables (i.e., renal failure, APACHE III scores). The improvement in mortality probably is multifactorial in nature, partially accounted for by a decreased rate of occurrence of renal failure and a trend toward a decreased rate of MSOF both of which have a higher mortality. The limitations of this study include its retrospective nature where complications were identified by chart review. Also, the satisfaction of nurse and house officers was not evaluated, although we presume that satisfaction would be higher in a closed unit, having a smaller number of physicians to answer to, reducing confusion and enhanced information exchange.

CONCLUSION

To the best of our knowledge, this study represents the first detailed evaluation of the medical impact of converting a surgical ICU from an open to a closed unit. The change of our unit from an open to a closed system improved both morbidity and mortality irrespective of the severity of illness and interventions used. Our data supports the use of a closed unit in an academic center where the staffing of critical care physicians is adequate.

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