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Impact of Neurointensivist Co-Management in a Semiclosed Neurocritical-Care Unit

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Background and Purpose The importance of the specialized management of neurocritical patients is being increasingly recognized. We evaluated the impact of neurointensivist co-management on the clinical outcomes (particularly the mortality rate) of neurocritical patients admitted to a semiclosed neurocritical-care unit (NCU).

Methods We retrospectively included neurocritical patients admitted to the NCU between March 2015 and February 2018. We analyzed the clinical data and compared the outcomes between patients admitted before and after the initiation of neurointensivist co-management in March 2016.

Results There were 1,785 patients admitted to the NCU during the study period. Patients younger than 18 years (n=28) or discharged within 48 hours (n=200) were excluded. The 1,557 remaining patients comprised 590 and 967 who were admitted to the NCU before and after the initiation of co-management, respectively. Patients admitted under neurointensivist co-management were older and had higher Acute Physiologic Assessment and Chronic Health Evaluation II scores. The 30-day mortality rate was significantly lower after neurointensivist co-management (p=0.042). A multivariate logistic regression analysis demonstrated that neurointensivist co-management significantly reduced mortality rates in the NCU and in the hospital overall [odds ratio=0.590 (p=0.002) and 0.585 (p=0.001), respectively].

Conclusions Despite the higher severity of the condition during neurointensivist co-management, co-management significantly improved clinical outcomes (including the mortality rate) in neurocritical patients.

Key Words intensive care unit, critical care, critical care outcomes, mortality.

INTRODUCTION

Critically ill patients with neurologic diseases need to receive medical care for both their primary illnesses and concomitant medical problems, which include comorbidities and complications.[1-3] Neurointensivists are specialists trained in the provision of comprehensive care to neurocritical patients, including for cardiac, pulmonary, renal, and infectious problems.[4] It has been reported that neurointensivist co-management can improve the clinical outcomes in patients with intracerebral hemorrhage, subarachnoid hemorrhage, traumatic brain injuries, spinal injuries, and ischemic stroke.[5-9]

The importance of high-quality neurocritical care being provided by neurointensivists and an organized infrastructure is being increasingly recognized in Korea.[3,10,11] Intensive care units (ICUs) can be classified into open, closed, and semiclosed types based on the intensivist's authority for clinical decision-making in ICU patients.[12] The types of ICUs for neurocritical patients differ among hospitals. There are several reports of a critical-care model with a neurointensivist-led team having positive impacts on patient outcomes in several specific pa-

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tient subpopulations.[5-9] Only a few studies worldwide have evaluated the impact of neurointensivist co-management with a holistic approach in a semiclosed neuroscience ICU.[1] Moreover, no previous Korean study has shown an improvement in mortality rates among patients treated in a semiclosed ICU.[10]

The present study was conducted to comparatively evaluate the impact—especially with regard to mortality rates—of neurointensivist co-management in a semiclosed neurocritical-care unit (NCU) in patients who were admitted before and after the recruitment of a neurointensivist to the NCU.

METHODS

Study design and population

This retrospective observational study was undertaken through chart reviews of the patient electronic medical records from the NCU of the Dong-A University Hospital, which is a tertiary-care center in the region. Data were collected on all patients admitted to the NCU between March 2015 and February 2018. Patients aged 18 or younger or admitted for 2 days or less (e.g., for routine postoperative care) were excluded from the analysis. Neurointensivist co-management began at our study center on March 1, 2016. The study population was stratified into two groups: 1) patients admitted prior to the initiation of co-management (Pre-CM group) and 2) patients admitted after co-management began (Post-CM group).

The institutional ethics committee and Internal Review Board of the Dong-A University Hospital approved the protocol used in this study (DAUHIRB-19-178).

Infrastructure and staffing of the NCU

Differences in NCU infrastructure and practices between before and after the initiation of neurointensivist co-management are presented in Table 1. In the Pre-CM group, patient care was undertaken by the departments of neurology and neurosurgery, which predominantly comprised residents and attending staff, together with elective consultations in other departments such as internal medicine and surgery. In contrast, all patients in the Post-CM group were comanaged by a full-time neurointensivist for both neurocritical and general critical care, including mechanical ventilation, hemodynamic monitoring, renal replacement therapy, and therapeutic temperature management. Bedside procedures such as percutaneous tracheostomy, ultrasound-guided central catheter insertion, and peripherally inserted central venous catheters were directly carried out or supervised by a neurointensivist. The neurointensivist consultations additionally included the management of infectious, cardiac, pulmonary, renal, and gastrointestinal problems as well as providing nutritional support. Some patients were directly admitted or later transferred to the NCU with the neurointensivist as their primary physician. Furthermore, the neurointensivist was responsible for setting up protocols and providing nurse education programs on neurocritical care in the NCU.

Data collection

Data were collected from the medical records of patients admitted to the NCU. Baseline demographics and variables were obtained from admission records. Data on multidisciplinary management in the NCU were collected from the patient progress notes and prescription records. The initial Glasgow Coma Scale (GCS) score was defined as the best GCS score, and the Acute Physiologic Assessment and Chronic Health Evaluation II (APACHE II) score was based on the worst physiologic val-

Table 1. NCU infrastructure and practices Pre-CM and after Post-CM

	Pre-CM group	Post-CM group
Study period	March 01, 2015 to February 28, 2016	March 01, 2016 to February 28, 2018
NCU beds	18	18
Attending physicians	8 neurologists 7 neurosurgeons	8 neurologists 7 neurosurgeons 1 neurointensivist
Treating physician during daytime and weekdays	Neurology/neurosurgery resident	Neurology/neurosurgery resident Neurointensivist
Treating physician during nighttime and weekends	Neurology/neurosurgery resident	Neurology/neurosurgery resident
Organizational structure	Open	Semiclosed
NCU protocol	No	Yes
Nurse education on neurocritical care	No	Regularly, once a month
NCU rounds of attending physicians on weekdays	Irregularly, once or more daily	Regularly, twice or more daily
NCU rounds of attending physicians on weekends	Irregularly, none or once daily	Irregularly, once or more daily
Who undertook bedside procedures in NCU	Resident doctor	Neurointensivist or resident doctor

NCU: neurocritical-care unit, Post-CM: after the initiation of neurointensivist co-management, Pre-CM: before the initiation of neurointensivist co-management.

ues recorded within 24 hours of NCU admission. The predicted mortality was calculated on the basis of the APACHE II score,[13] and we adopted a concept called the "mortality ratio" that was the ratio between the actual NCU mortality rate and the predicted mortality rate as a simplified reference.[3]

Statistical analysis

Categorical variables are presented as numbers and percentages, and continuous variables are presented as mean and standard-deviation values or median and interquartile-range values. The odds ratios (ORs) were summarized with 95% confidence intervals (CIs) and *p* values. Baseline characteristics and clinical outcomes were compared between the two patient groups. We used the chi-square and Fischer's exact tests for categorical variables, and Student's *t*-test and the Mann-Whitney U test for continuous variables. Kaplan-Meier survival analysis and the log-rank test were used for 30-day survival analysis. Multivariate logistic regression analysis was performed to evaluate the association between neurointensivist co-management and mortality rates. We included the demographic data, risk factors, and severity score as variables. All of the data analyses were performed using SPSS (version 21, IBM Corp., Armonk, NY, USA).

RESULTS

Baseline characteristics

During the study period there were 1,785 patients admitted to the NCU. We excluded 228 patients aged 18 or younger (n=28) or who were admitted for 2 days or less (n=200; for routine postoperative care). The 1,557 patients enrolled in the final analysis data set comprised 590 and 967 who were admitted before and after the initiation of neurointensivist co-management, respectively. The baseline characteristics of the study population are listed in Table 2. The mean age of patients in the Pre-CM group was 60.0 years, and 58.8% of them were male, while the mean patient age in the Post-CM group was 62.7 years, and 58.9% of them were male. Traumatic brain injury, stroke (ischemic or hemorrhagic), and brain tumor were the main causes of NCU admission in both groups.

There were some significant between-group differences. Patients in the Post-CM group were on average 2.7 years older than those in the Pre-CM group (p=0.001). Hypertension (37.1% vs. 42.7%, p=0.029) and diabetes mellitus (17.6% vs. 23.4%, p=0.007) were more common in the Post-CM group, in which the initial GCS and APACHE II scores were also significantly higher (p<0.001). In the Post-CM group, 71 (7.3%) patients were admitted directly under the neurointensivist's care after the initial consultation. Larger numbers of patients in the Post-CM group received mechanical ventilation (25.6% vs. 32.1%, p=0.007), vasopressors (18.8% vs. 25.0%, p=0.005), and continuous renal replacement therapy (1.4% vs. 3.6%, p=0.008), whereas arterial line monitoring (10.2% vs. 15.8%, p=0.002) and electroencephalography (EEG; 5.6% vs. 9.6%, p=0.005) were undertaken more frequently in the Post-CM group.

Clinical outcomes

The clinical outcomes for the study periods are presented in Table 3. The NCU mortality rate was lower in the Post-CM than the Pre-CM group (15.4% vs. 13.7%), as was the hospital mortality rate (18.8% vs. 15.9%), but the differences were not statistically significant. Patients in the Post-CM group had longer durations of the NCU stay (6.0 days vs. 7.0 days, p<0.001), hospital stay (21.0 days vs. 25.0 days, p<0.001), and mechanical ventilation (6.0 days vs. 7.5 days, p=0.013). The NCU readmission rates were similar in the Pre-CM and Post-CM groups (5.1% vs. 4.9%). The mortality ratio (actual mortality/predicted mortality) was significantly lower in the Post-CM group (0.81 vs. 0.63), whereas the predicted mortality as calculated using the APACHE II score was significantly higher in the Post-CM group (18.9% vs. 21.9%, p=0.001). Furthermore, the GCS score at ICU discharge improved in the Post-CM group (p=0.030).

We further analyzed the effectiveness of neurointensivist co-management according to the department and admission route (Supplementary Tables 1–4 in the online-only Data Supplement). After neurointensivist co-management, the NCU and hospital mortality rates decreased among the neurosurgical patients and patients admitted via the emergency room. Among neurologic patients and patients admitted via a general ward, the hospital mortality rate decreased after neurointensivist co-management, while the NCU mortality rate was similar. However, the decreases in NCU and hospital mortality rates observed in the subgroup analyses were not statistically significant.

There were significant differences in the baseline characteristics of age, risk factors, GCS score, and APACHE II score between the two groups (Table 2). We evaluated the impact of neurointensivist co-management on patient survival and mortality using Kaplan-Meier survival analysis with the log-rank test and multivariate logistic regression analysis. The Kaplan-Meier 30-day survival curves are shown in Fig. 1, which shows that this outcome was better in the Post-CM group than the Pre-CM group (log-rank test: p=0.042). The results of the multivariate logistic regression analyses are presented in Table 4. Baseline characteristics that differed significantly (p<0.1) between the Pre-CM and Post-CM groups (Table 2) and variables with clinical importance (sex) were

included. After adjusting for age, sex, GCS score, APACHE II score, and comorbidities (hypertension, diabetes mellitus, and smoking), the ORs for the NCU and hospital mortality rates in comparisons between the Pre-CM and Post-CM groups were 0.590 (95% CI=0.420–0.828, p=0.002) and 0.585 (95% CI=0.429–0.798, p=0.001), respectively.

Table 2. Baseline characteristics of the patients admitted to the neurocritical-care unit

Characteristic	Pre-CM group (n=590)	Post-CM group (n=967)	p
Sex, male	347 (58.8)	570 (58.9)	0.959
Age, years	60.0±15.4	62.7±15.7	0.001
Diagnosis at admission			
Traumatic brain injury	181 (30.7)	303 (31.3)	0.786
Ischemic stroke	96 (16.3)	136 (14.1)	0.235
Spontaneous intracerebral hemorrhage	94 (15.9)	141 (14.6)	0.470
Subarachnoid hemorrhage	61 (10.3)	93 (9.6)	0.644
Brain tumor	51 (8.6)	98 (10.1)	0.332
Seizure	21 (3.6)	57 (5.9)	0.040
Central nervous system infection	15 (2.5)	42 (4.3)	0.066
Others (e.g., spine, movement disorder)	71 (12.0)	97 (10.0)	0.217
Risk factors			
Hypertension	219 (37.1)	413 (42.7)	0.029
Diabetes mellitus	104 (17.6)	226 (23.4)	0.007
Coronary heart disease	81 (13.7)	128 (13.2)	0.782
Chronic kidney disease	123 (21.0)	205 (21.2)	0.932
Alcohol consumption	236 (40.0)	365 (37.7)	0.384
Smoking	228 (38.6)	327 (33.8)	0.051
Department			0.908
Neurosurgery	453 (76.8)	740 (76.5)	
Neurology	137 (23.2)	227 (23.5)	
Admission route			
Emergency room	406 (68.8)	541 (55.9)	<0.001
Ward	110 (18.6)	297 (30.7)	<0.001
Operation room*	74 (12.5)	129 (13.3)	<0.001
Initial vital signs			
Systolic BP	126.6±46.8	125.5±23.7	0.532
Diastolic BP	77.5±12.6	77.9±13.0	0.625
Heart rate	89.7±21.4	88.5±20.1	0.274
Respiration rate	19.8±5.6	19.7±7.0	0.730
Glasgow Coma Scale score	5.0 [3.0–9.0]	7.0 [3.0–10.0]	<0.001
Acute physiology and chronic health evaluation II score	14.0 [9.0–19.0]	15.0 [11.0–21.0]	<0.001
Direct admission into neurointensivist care	-	71 (7.3)	-
Emergency operation	226 (38.3)	354 (36.6)	0.502
Vasopressor	111 (18.8)	242 (25.0)	0.005
Mechanical ventilation	151 (25.6)	310 (32.1)	0.007
Tracheostomy	90 (15.3)	177 (18.3)	0.121
Continuous renal replacement therapy	8 (1.4)	35 (3.6)	0.008
Arterial line monitoring	60 (10.2)	153 (15.8)	0.002
Brain CT	464 (78.6)	738 (76.3)	0.289
Brain MRI	36 (6.1)	59 (6.1)	1.000
Electroencephalography	33 (5.6)	93 (9.6)	0.005

Data are n (%), mean±SD, or median [interquartile range] values.
*Operation room: patients admitted after elective surgery.
BP: blood pressure, Post-CM: after the initiation of neurointensivist co-management, Pre-CM: before the initiation of neurointensivist co-management.

Table 3. Clinical outcomes of patients admitted to the NCU

Parameter	Pre-CM group (*n*=590)	Post-CM group (*n*=967)	*p*
NCU mortality	91 (15.4)	132 (13.7)	0.333
Predicted mortality, %	18.9±16.1	21.9±16.7	0.001
Mortality ratio*	0.81	0.63	-
Hospital mortality	111 (18.8)	154 (15.9)	0.141
GCS score at ICU discharge	13.0 [8.0–13.5]	13.0 [9.0–14.0]	0.030
NCU stay, days	6.0 [3.0–11.0]	7.0 [4.0–14.0]	<0.001
Hospital stay, days	21.0 [14.0–32.0]	25.0 [16.0–38.0]	<0.001
MV duration, days	6.0 [2.0–10.0]	7.5 [3.0–14.0]	0.013
NCU readmission rate	30 (5.1)	47 (4.9)	0.843

Data are *n* (%), mean±SD, or median [interquartile range] values.
*Mortality ratio: observed mortality/predicted mortality.
GCS: Glasgow Coma Scale, ICU: intensive care unit, MV: mechanical ventilation, NCU: neurocritical-care unit, Post-CM: after the initiation of neurointensivist co-management, Pre-CM: before the initiation of neurointensivist co-management.

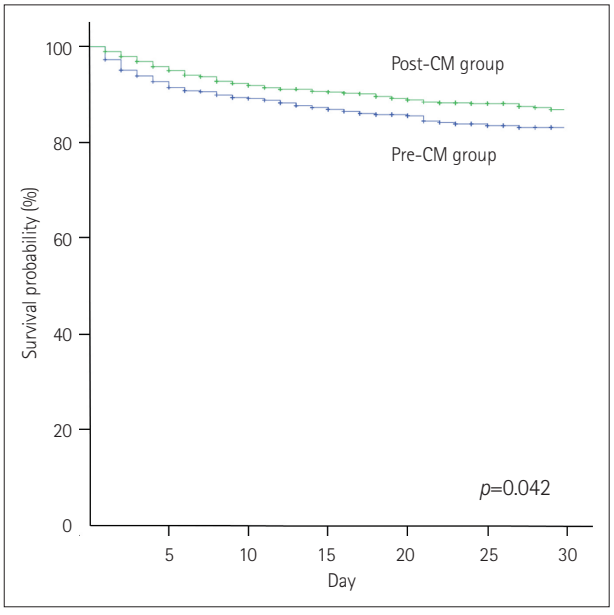

Fig. 1. Kaplan-Meier 30-day survival analysis of the patients Pre-CM and Post-CM groups (log-rank test: p=0.042). Post-CM: after the initiation of neurointensivist co-management, Pre-CM: before the initiation of neurointensivist co-management.

DISCUSSION

The aim of this study was to determine the effectiveness of the neurointensivist co-management of neurocritical patients in a semiclosed neuroscience ICU by comparatively evaluating the clinical outcomes of patients admitted to the NCU before (Pre-CM group) and after (Post-CM group) the initiation of co-management. The ICU and hospital mortality rates improved in the Post-CM group, but this change was not statistically significant. However, we identified significant between-group differences in the following patient baseline characteristics: age, comorbidities (hypertension and diabetes mellitus), initial GCS score, and APACHE II score. We therefore conducted a multivariate analysis that included age, sex, risk factors, GCS score, and APACHE II score, which showed that the ICU and hospital mortality rates were significantly improved in the semiclosed NCU after the initiation of neurointensivist co-management. These observations demonstrate that neurointensivist co-management can improve the clinical outcomes of patients in a semiclosed NCU.

Table 4. Results from the multivariate logistic regression analysis of the association between neurointensivist co-management and mortality rates

	Odds ratio	95% confidence interval	*p*
NCU mortality	0.590	0.420–0.828	0.002
Hospital mortality	0.585	0.429–0.798	0.001

The analysis was adjusted for age, sex, Glasgow Coma Scale score at admission, Acute Physiology and Chronic Health Evaluation II score, hypertension, diabetes mellitus, and smoking.
NCU: neurocritical-care unit.

The monitoring of neurocritical patients occurred more frequently and was more active after the initiation of co-management, such as through arterial blood pressure monitoring and EEG. Moreover, NCU rounds, mechanical ventilation, vasopressor, and continuous renal replacement therapy were undertaken more often. In addition, specific NCU protocols for neurocritical patients were established and regular nurse education programs on neurocritical care were conducted by the neurointensivist. It is likely that these changes after the initiation of co-management contributed to the improved mortality rates.

In patients with severe neurologic illness, the impaired nervous system (primary injury) is greatly influenced by systemic alterations that may adversely affect its functions (secondary injury). Neurointensivists are specialist practitioners trained to recognize and treat such injuries.[14] The main role of the neurointensivist is to manage secondary injuries, with a focus on aspects of multidisciplinary care, including the treatment of neurologic and general medical problems.

The role of the neurointensivist varies with the type of ICU.[12] In an open ICU, patients are admitted under the care of primary attending physicians, and the intensivist plays a clinical role through elective consultation without actual authority over patient care, with admissions and discharges being controlled by the primary attending physician. In a closed ICU, all patients are admitted directly under the intensivist, and the intensivist-led team is responsible for all decisions related to patient care. In a semiclosed ICU, an intensivist-led team directly provides patient care in collaboration with

primary physicians.

The NCU at our institution has been operated as a semiclosed ICU following the involvement of a neurointensivist. Neurologists and neurosurgeons collaborate with the neurointensivist regarding general care as well as the management of systemic problems in order to reduce the risk of secondary injuries in patients admitted to the NCU. Several previous studies have found that a neurointensivist-led team model was associated with lower mortality, shorter length of hospital stay, better neurologic outcomes, lower cost of care, and greater satisfaction among the families of patients.[1-3,5-9,15] However, these results were obtained mostly in specific patient subpopulations, and few studies have been conducted in a semiclosed ICU.

It is particularly interesting that previous evaluations of the impact of neurointensivist co-management in Korea have not found improvements in mortality rates in the general population, although there have been some reports involving specific subpopulations.[10,11] We consider that these differences in results between the previous studies and the present study are attributable to differences in the patient demographics. Our patients had much higher APACHE II scores and mortality rates and much lower GCS scores than the patients in the previous studies, which indicates that the illness severity was greater in our study population. We therefore suggest that neurointensivist co-management will result in greater improvements in the mortality rates of neurocritical patients with greater illness severity. Nonetheless, there were several aggravated indicators in Post-CM group, such as longer NCU stay, hospital stay, and duration of ventilation. We attribute these results to the worse general clinical condition (higher APACHE II score) rather than the neurologic status (higher GCS score) of the patients in the Post-CM group. The higher APACHE II score in the Post-CM group is presumably attributable to the general worsening of vital signs and laboratory results with increasing age and comorbidities.

Our study had some limitations. First, given its retrospective, observational design at a single center, there is a possibility of selection bias. Second, other environmental factors such as technical developments in procedures or medical advances during the study period might have improved patient outcomes independently of the investigated intervention. Third, our institution had a single neurointensivist whose skill in recognizing and managing the NCU patients inevitably affected their clinical outcomes. Fourth, functional outcomes are a better objective indicator of clinical outcomes in neurocritical patients, and they did not form part of this study. Fifth, it is possible that therapeutic decision-making was considerably influenced by decisions made by the patient or their family members, such as making a living will or refusing life-prolonging treatment, which could have introduced information bias. Lastly, the design of our study meant that we could not conclusively identify which of the changes undertaken after the implementation of co-management significantly contributed to the improved mortality rates. Further research in a controlled and multicenter study is therefore needed to validate the preliminary findings of this study.

In conclusion, neurointensivist co-management was found to significantly improve the ICU, 30-day, and overall hospital mortality rates of neurocritical patients in a semiclosed NCU. We suggest that neurointensivist co-management in a dedicated facility is a better option for the management of neurocritical patients.

Supplementary Materials

The online-only Data Supplement is available with this article at https://doi.org/10.3988/jcn.2020.16.4.681.

Author Contributions

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Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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