Consultation Patterns of Neursurgical Patients Admitted to Intensive Care Units Vary with Neurointensivist Co-management

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Objective
To evaluate the consultation patterns in the neurosurgical intensive care unit (ICU) and the neurointensivist factors that may influence consultations.

Methods
This was a retrospective, single-center, observational study of neurosurgical patients admitted to ICU from January 2013 to December 2019. In this study, only formal consultation was defined as the consultation, but curbside consultation was excluded.

Results
A total of 12,743 patients were analyzed in this study. Malignancy (54.6%) and hypertension (30.6%) were the most common comorbidities. Brain tumor (43.0%) and microvascular decompression (17.6%) were the most common reasons for ICU admission. Among total neurosurgical patients, 3,056 (24.0%) patients had 8,789 consultations during their ICU stay. The departments of Infectious disease (27.9%), Pediatrics (9.6%) and Rehabilitation (9.6%) were the three most frequently consulted specialties, accounting for up to 47.1% of all the consultations. The frequency of the consultations involving infectious disease and pediatric services except for permission to use restricted antibiotics, and consultation services involving neurology, pulmonology and respiratory care by respiratory therapists were reduced compared to levels before neurointensivist co-management. However, the consultations with otorhinolaryngologists, radiologists and endocrinologists were increased compared to levels after neurointensivist co-management. Consultations replied within 24h before initiation of neurointensivist co-management were increased.

Conclusion
In this study, we were able to identify an interesting consultation patterns of neurosurgical and neurocritically ill patients. Neurointensivist co-management may have an impact on the consultation under general and neurocritical management.

Keywords: Referral and consultation; Neurosurgery; Intensive care units
INTRODUCTION

Neurosurgical and neurocritically ill patients admitted to the intensive care unit (ICU) may have other medical and surgical problems as well as neurosurgical issues. Neurocritically ill patients and old neurosurgical patients often exhibit various comorbidities. Therefore, they may frequently manifest various ailments during their ICU stay. The timely evaluation of heart diseases and airway or pulmonary complaints is critical. Therefore, consultation with different medical and surgical subspecialists is an important strategy to manage the care of these patients. However, there is limited data regarding the consultation patterns of neurosurgical patients in the ICU.

Neurointensivists are specialists equipped with skills and expertise to manage various aspects of neurosurgical and neurocritically ill patients admitted to the ICU. They focus on the management of patients with acute neurological conditions including traumatic brain injury, stroke, status epilepticus, and neuromuscular respiratory failure as well as general critical care. Therefore, neurointensivist co-management may affect the consultation patterns of these patients.

We conducted a retrospective observational study of neurosurgical and neurocritically ill patients who were admitted to the ICU. The objective of this study was to evaluate the consultation patterns in the neurosurgical ICU and identify the neurointensivist factors that may influence the consultations of these patients under the care of general and neurocritical managements.

MATERIALS AND METHODS

Study population and design

This was a retrospective, single-center, observational study of neurosurgical patients admitted to the ICU at Samsung Medical Center from January 2013 to December 2019. This study was approved by the Institutional Review Board of Samsung Medical Center (approval number: SMC 2020-09-082). The requirement for informed consent was waived due to its retrospective nature. We included neurosurgical patients admitted to the ICU during the study period. We excluded patients who had insufficient medical records.

Definitions and outcomes

All consecutive neurosurgical and neurocritically ill patients admitted to the ICU were evaluated in this study. The following data were extracted from Clinical Data Warehouse on ICU admission: age, sex, comorbidity, severity score, and reasons for ICU admission. Data regarding consultations of neurosurgical patients were also obtained through the Clinical Data Warehouse. The initial Glasgow Coma Scale (GCS) was defined as the best GCS within 24 h of ICU admission. The severity of illness was assessed by the Acute Physiology and Chronic Health Evaluation II (APACHE II) scores. In this study, only formal consultation was defined as the consultation, whereas curbside consultation was excluded.

Neurointensivist co-management was initiated on October 1, 2014. During the co-management period, the neurointensivist worked for 6 days per week during the daytime. The neurointensivist was involved in various aspects of care, such as general critical care, neurocritical care and post-operative management, including hemodynamic monitoring, nutritional support, and use of mechanical ventilation and renal replacement therapy, neuro-monitoring, and control of malignant intracranial hypertension. The neurocritical care team consisted of an attending neurointensivist, neurosurgical resident, critical care dietitian and pharmacist.

We evaluated the overall consultation patterns of the neurosurgical patients in the ICU and compared the consultation patterns before and after initiation of mandatory neurointensivist co-management.

Statistical analyses

Our center has constructed the “Clinical Data Warehouse Darwin-C” designed for investigators to search and retrieve de-identified medical records from the electronic archive system. After finalizing the patient list for this study, the clinical data and laboratory data were extracted from the Clinical Data Warehouse Darwin-C. All data are presented as means ± standard deviations for continuous variables and numbers (percentages) for categorical variables. Data were compared using Student’s t-test for continuous variables and the chi-square test or Fisher’s exact test for categorical variables. All tests were two-sided and p values of less than 0.05 were considered statistically significant. All data were analyzed using R Statistical Software (version 4.0.2; R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Baseline characteristics

A total of 12,743 patients were analyzed. Among these patients, a quarter of patients (3,353) were admitted to an ICU other than the neurosurgery ICU. The mean age of all patients was 48.8 ± 19.8 years. The study included 5,630 (44.2%) male patients. Malignancy (54.6%) and hypertension (30.6%) were the most common comorbidities. Brain tumors (43.0%) and microvascular decompressions (17.6%) were the most common reasons for ICU admission. GCS and APACHE II scores on ICU admission were
higher in patients compared with levels before initiation of neurointensivist co-management (both p < 0.001) (Table 1).

**Consultations patterns before and after neurointensivist co-management**

Among 12,743 neurosurgical patients, 3,056 (24.0%) had 8,789 consultations during their ICU stay. Half of all the consulted patients (1,337) needed two and more consultations (Table 2).

Among the departments consulted, Infectious diseases (27.9%), Pediatrics (9.6%) and Rehabilitation (9.6%) were the three most frequently consulted specialties (Fig. 1). These services constituted 47.1% of the total consultations. Routine and emergent consultations (64.4%) and permission to use restricted antibiotics (21.5%) were the most common types of consultations. Half of all the emergent consultations were determined by a surgeon.

The routine and emergent consultations with Infectious disease

**Table 1. Demographics and clinical factor of patients in neurointensive care unit who had elevated pancreatic enzymes**

|                      | Before (N=3,457) | After (N=9,286) | Total (N=12,743) | p-value |
|----------------------|------------------|-----------------|------------------|---------|
| Age (yr) — mean ± SD | 47.6 ± 20.4      | 49.3 ± 19.5     | 48.8 ± 19.8      | < 0.001 |
| Gender, male — no. of patients (%) | 1,579 (45.7) | 4,051 (43.6) | 5,630 (44.2) | 0.04 |
| Comorbidities — no. of patients (%) |                  |                 |                  |         |
| Malignancy            | 1,844 (53.3)     | 5,108 (55.0)    | 6,952 (54.6)     | 0.097   |
| Hypertension          | 972 (28.1)       | 2,927 (31.5)    | 3,899 (30.6)     | < 0.001 |
| Dyslipidemia          | 572 (16.5)       | 1,745 (18.8)    | 2,317 (18.2)     | 0.004   |
| Diabetes mellitus     | 475 (13.7)       | 1,309 (14.1)    | 1,784 (14.0)     | 0.627   |
| Chronic kidney disease| 104 (3.0)        | 252 (2.7)       | 356 (2.8)        | 0.403   |
| Chronic liver disease | 65 (1.9)         | 155 (1.7)       | 220 (1.7)        | 0.461   |
| Cardiovascular disease| 61 (1.8)         | 159 (1.7)       | 220 (1.7)        | 0.901   |
| Cause of ICU admission — no. of patients (%) |                  |                 |                  | < 0.001 |
| Brain tumor           | 1,402 (40.6)     | 4,081 (43.9)    | 5,483 (43.0)     |         |
| Microvascular decompression | 575 (16.6) | 1,664 (17.9) | 2,239 (17.6) |         |
| Elective vascular surgery | 522 (15.1)   | 1,464 (15.8)    | 1,986 (15.6)     |         |
| Intracranial hemorrhage| 177 (5.1)       | 380 (4.1)       | 557 (4.4)        |         |
| Traumatic brain injury | 175 (5.1)       | 339 (3.7)       | 514 (4.0)        |         |
| Subarachnoid hemorrhage| 132 (3.8)       | 332 (3.6)       | 464 (3.6)        |         |
| Spinal surgery        | 114 (3.3)        | 236 (2.5)       | 350 (2.7)        |         |
| Congenital anomaly    | 38 (1.1)         | 108 (1.2)       | 146 (1.1)        |         |
| Central nerve system infection | 35 (1.0) | 80 (0.9) | 115 (0.9) |         |
| Cerebral infarction   | 34 (1.0)         | 39 (0.4)        | 73 (0.6)         |         |
| Others                | 253 (7.3)        | 563 (6.1)       | 816 (6.4)        |         |
| Initially admitted ICU— no. of patients (%) |                  |                 |                  | < 0.001 |
| Neurosurgical ICU     | 2,317 (67.0)     | 7,073 (76.2)    | 9,390 (73.7)     |         |
| Other ICUs            | 1,140 (33.0)     | 2,213 (23.8)    | 3,353 (26.3)     |         |
| GCS on ICU admission — mean ± SD | 14.3 ± 2.2 | 14.7 ± 1.5 | 14.6 ± 1.7 | < 0.001 |
| APACHE II score on ICU admission — mean ± SD | 4.3 ± 5.2 | 3.3 ± 4.4 | 3.6 ± 4.6 | < 0.001 |

ICU: intensive care unit; SD: standard deviation; GCS: Glasgow Coma Scale; APACHE: Acute Physiology and Chronic Health Evaluation.

**Table 2. Demographics and clinical factor of patients in neurointensive care unit who had elevated pancreatic enzymes**

| Number of consultation — no. of patients (%) | Before (N=3,457) | After (N=9,286) | Total (N=12,743) | p-value |
|----------------------------------------------|------------------|-----------------|------------------|---------|
| 0                                            | 2,557 (74.0)     | 7,130 (76.8)    | 9,687 (76.0)     | 0.003   |
| 1                                            | 472 (13.7)       | 1,207 (13.0)    | 1,679 (13.2)     |         |
| 2                                            | 158 (4.6)        | 391 (4.2)       | 549 (4.3)        |         |
| 3                                            | 83 (2.4)         | 170 (1.8)       | 253 (2.0)        |         |
| 4                                            | 45 (1.3)         | 110 (1.2)       | 155 (1.2)        |         |
| 5 and more                                    | 142 (4.1)        | 278 (3.0)       | 420 (3.3)        |         |
DISCUSSION

In this study, we investigated the consultation patterns and the neurointensivist factors that may influence the consultations of neurosurgical and neurocritically ill patients under the care of general and neurocritical managements. The major findings are as follows. First, a quarter of patients admitted to the ICUs needed consultations for medical or other surgical supports, and a half of them needed two or more consultations. Second, Infectious disease, Pediatrics and Rehabilitation were the three most frequently consulted specialty services. Third, consultations with Infectious disease and Pediatrics experts except for permission to use restricted antibiotics and those involving Neurology, Pulmonology and Respiratory Care by a respiratory therapist were significantly decreased compared to the levels before neurointensivist co-management. However, the consultations with Otorhinolaryngology, Radiology and Endocrinology departments were increased compared to the levels after initiation of neurointensivist co-management. The consultations replied within 24h were also increased after compared to the levels before initiation of neurointensivist co-management (Table 3).

CONCLUSION

In this study, we were able to identify an interesting consultation patterns.
Table 3. Distribution of consultations before and after neurointensivist co-management

| Consulted department — no. of patients (%) | Before (N=2,963) | After (N=5,826) | Total (N=8,789) | p-value |
|-------------------------------------------|------------------|------------------|------------------|---------|
| **Infectious disease total**              |                  |                  |                  |         |
| Routine consultation                      | 326 (11.0)       | 457 (7.8)        | 783 (8.9)        | < 0.001 |
| Permission to use restricted antibiotic   | 514 (17.3)       | 1,158 (19.9)     | 1,672 (19.0)     | 0.005   |
| **Pediatrics total**                      |                  |                  |                  |         |
| Routine consultation                      | 236 (8.0)        | 386 (6.6)        | 622 (7.1)        | 0.023   |
| Permission to use restricted antibiotic   | 80 (2.7)         | 142 (2.4)        | 222 (2.5)        | 0.503   |
| **Rehabilitation**                        |                  |                  |                  |         |
|                                          | 302 (10.2)       | 541 (9.3)        | 843 (9.6)        | 0.185   |
| **Otorhinolaryngology**                   |                  |                  |                  | < 0.001 |
|                                          | 201 (6.8)        | 583 (10.0)       | 784 (8.9)        | < 0.001 |
| **Radiology**                             |                  |                  |                  |         |
|                                          | 181 (6.1)        | 455 (7.8)        | 636 (7.2)        | 0.004   |
| **Cardiology**                            |                  |                  |                  |         |
|                                          | 144 (4.9)        | 318 (5.5)        | 462 (5.3)        | 0.255   |
| **General surgery**                       |                  |                  |                  |         |
|                                          | 81 (2.7)         | 173 (3.0)        | 254 (2.9)        | 0.578   |
| **Oncology**                              |                  |                  |                  |         |
|                                          | 76 (2.6)         | 151 (2.6)        | 227 (2.6)        | 0.997   |
| **Neurology**                             |                  |                  |                  |         |
|                                          | 92 (3.1)         | 134 (2.3)        | 226 (2.6)        | 0.029   |
| **Pulmonology**                           |                  |                  |                  |         |
|                                          | 92 (3.1)         | 123 (2.1)        | 215 (2.4)        | 0.005   |
| **Gastroenterology**                      |                  |                  |                  |         |
|                                          | 73 (2.5)         | 141 (2.4)        | 214 (2.4)        | 0.959   |
| **Pharmacology**                          |                  |                  |                  |         |
|                                          | 55 (1.9)         | 132 (2.3)        | 187 (2.1)        | 0.238   |
| **Endocrinology**                         |                  |                  |                  |         |
|                                          | 41 (1.4)         | 138 (2.4)        | 179 (2.0)        | 0.003   |
| **Nephrology**                            |                  |                  |                  |         |
|                                          | 67 (2.3)         | 99 (1.7)         | 166 (1.9)        | 0.081   |
| **Respiratory care by respiratory therapist** |            |                  |                  |         |
|                                          | 35 (1.2)         | 35 (0.6)         | 70 (0.8)         | 0.006   |
| **Nutritional support**                   |                  |                  |                  |         |
|                                          | 16 (0.5)         | 46 (0.8)         | 62 (0.7)         | 0.235   |
| **Others**                                |                  |                  |                  |         |
|                                          | 351 (11.8)       | 614 (10.5)       | 965 (11.0)       | 0.069   |
| **Type of consultation — no. of patients (%)** |          |                  |                  | 0.001   |
| Routine and emergent consultation         | 1,996 (67.4)     | 3,661 (62.8)     | 5,657 (64.4)     |         |
| Permission to use restricted antibiotic   | 594 (20.0)       | 1,300 (22.3)     | 1,894 (21.5)     |         |
| Request for examination                   | 302 (10.2)       | 687 (11.8)       | 989 (11.3)       |         |
| Pill identification                       | 55 (1.9)         | 132 (2.3)        | 187 (2.1)        |         |
| Nutrition support                         | 16 (0.5)         | 46 (0.8)         | 62 (0.7)         |         |
| Consultation replied within 24h — no. of patients (%) | 1,476 (49.8) | 3,838 (65.9) | 5,314 (60.5) | < 0.001 |
| Emergent consultation — no. of patients (%) | 218 (7.4) | 471 (8.1) | 689 (7.8) | 0.247   |
| Reasons of emergent consultation — no. of patients (%) |          |                  |                  | 0.556   |
| Judgement of surgeon                      | 124 (57.4)       | 264 (55.3)       | 388 (56.0)       |         |
| Acute deterioration of disease            | 53 (24.5)        | 114 (23.9)       | 167 (24.1)       |         |
| Instability of patients’ vital signs      | 17 (7.9)         | 52 (10.9)        | 69 (10.0)        |         |
| For emergent operation                    | 22 (10.2)        | 44 (9.2)         | 66 (9.5)         |         |
| Others                                    | 0 (0)            | 3 (0.6)          | 3 (0.4)          |         |

patterns of neurosurgical and neurocritically ill patients. Neurointensivist co-management may affect the consultation patterns of these patients under the care of general and neurocritical management.

NOTES

**Conflict of interest**

No potential conflict of interest relevant to this article was reported.

**Informed Consent**

The requirement for informed consent was waived due to its retrospective nature in this study.

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