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Current Status of Neurosurgical and Neurointensive Care Units in Korea : A Brief Report on Nationwide Survey Results

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Objective : The purpose of this study is identify the operation status of the neurosurgical care units (NCUs) in neurosurgical residency training hospitals nationwide and determine needed changes by comparing findings with those obtained from the Korean Neurosurgical Society (KNS) and Korean Society of Neurointensive Care Medicine (KNIC) survey of 2010.

Method : This survey was conducted over 1 year in 86 neurosurgical residency training hospitals and two neurosurgery specialist hospitals and focused on the following areas : 1) the current status of the infrastructure and operating systems of NCUs in Korea, 2) barriers to installing neurointensivist team systems, 3) future roles of the KNS and KNIC, and 4) a handbook for physicians and practitioners in NCUs. We compared and analyzed the results of this survey with those from a KNIC survey of 2010.

Results : Seventy seven hospitals (87.5%) participated in the survey. Nineteen hospitals (24.7%) employed a neurointensivist or faculty member; Thirty seven hospitals (48.1%) reported high demand for neurointensivists, and 62 hospitals (80.5%) stated that the mandatory deployment of a neurointensivist improved the quality of patient care. Forty four hospitals (57.1%) believed that hiring neurointensivist would increase hospital costs, and in response to a question on potential earnings declines. In terms of potential solutions to these problems, 70 respondents (90.9%) maintained that additional fees were necessary for neurointensivists' work, and 64 (83.1%) answered that direct support was needed of the personnel expenses for neurointensivists.

Conclusion : We hope the results of this survey will guide successful implementation of neurointensivist systems across Korea.

Key Words : Intensive care units · Neurosurgery · Critical care · Prognosis · Republic of Korea.

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INTRODUCTION

Korean medical policies are currently heading toward emphasizing patient safety and medical expertise; to align with this trend, hospital systems are changing rapidly. In particular, the importance of intensive care units (ICUs) is being highlighted, with particular emphasis on appropriate treatment for patients with brain and spinal cord injuries. This emphasis is because most brain injuries (intracerebral hemorrhage, traumatic brain injury [TBI], cerebral infarction, etc.) can cause irreversible damage if not properly and timely cared for.

Moreover, in the course of neurological treatment, physicians must address neurology-related medical issues such as fluid management, infection (pneumonia, urinary tract infection, sepsis, etc.), blood pressure control, renal injury, and nutritional support. For this reason, neurosurgical and neurointensive care units (NCUs and NICUs, respectively) require highly trained experts, efficient interdisciplinary care, and adequate facilities and equipment and other needs. Many studies have given evidence that well-trained neurointensivists responsible for clinical care in NCUs and NICUs have positive effects on treatment outcomes, and this finding has drawn increasing attention in Korea[11-13]. Neurosurgery departments and NCUs require efficient infrastructures including neurointensivists, operational and quality control guidelines, and medical equipment that are essential for caring for patients affected by neurological and neurosurgical disease.

The Korean Society of Neurointensive Care Medicine (KNIC) was founded in December 2009. In 2010, KNIC affiliated with the Korean Neurosurgical Society (KNS) to address the demands for neurosurgical residency training in the ICUs of teaching hospitals. The work group together investigated hospital patient capacities, facilities, equipment, personnel, and operating systems and presented guidelines at an academic conference[4].

The aim of this study was to identify the operation status of the NCUs in neurosurgical residency training hospitals nationwide and determine needed changes by comparing findings with those obtained from KNS/KNIC survey of 2010. We provide recommendations for the ideal NCU operating model, specifically, the requirements, importance, specialties, and limitations of neurosurgeons as neurointensivists, potential solutions to barriers to using neurointensivists, and requirements for effective education curricula based on our survey findings.

MATERIALS AND METHODS

This survey was approved by our Institutional Review Board (HC20QCDE0023). We conducted a survey in 86 neurosurgical residency training hospitals and two neurosurgery specialist hospitals that operate ICUs in Korea, excluding stroke units and ICUs in regional trauma centers. The survey was conducted over a 12-month period from March 2019 to March 2020.

We administered the survey to the responsible NCU neurosurgeons and neurologists (mostly neurosurgeons) at each teaching hospital via email, phone call, and face-to-face interview. After initial analysis of the responses, we asked follow-up questions for clarification.

The survey questionnaire was divided into four areas : 1) general information about the teaching hospitals, 2) barriers and potential solutions in deploying neurointensivists, 3) future roles of the KNS and KNIC, and 4) opinions about publishing a handbook for physicians and practitioners in NCUs. The questionnaire comprised a total of 31 items, including all sub-items in each section; we investigated hospital equipment separately at each hospital.

First, the general hospital information of consisted of number of beds, location, operating body (national, private, secondary, other), service level (tertiary level or not), independence and affiliated organizations of the NCU, presence of neurointensivists, neurointensivist numbers and qualifications, NCU operating formats, and other elements. We compared our findings from this survey with the results from the now-ten-year-old KNS/KNIC hospital survey.

Second, in regard to barriers and potential solutions in deploying neurointensivists, we asked the respondents about increases in costs, physicians' objections, lower hospital performance, difficulties in recruitment, suggestions for facilitating employment (public reporting of indices such as hospital standardized mortality ratio, legislation for deployment of neurointensivists, and financial support).

The third category consisted of items on the future roles of the KNS and KNIC. The KNIC is a society affiliated with the KNS. The survey items questioned respondents on competitiveness and future direction of the KNIC which is a similar association to the Korean Neurocritical Care Society (KNCS) led by the neurologist. The fourth subscale comprised items on a potential textbook or handbook for clinical practice

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Table 1. Four survey criteria and 25 core questions

Criteria	Core question
General information on teaching hospitals	Basic information 1. How many beds are there in your hospital? 2. What are the operational entities of your hospital? 3. Is your hospital designated a tertiary hospital? Regarding neurointensivists and NCUs 4. Does your hospital employ a neurointensivist? 5. What is the role of the neurointensivist? 6. How many independent adult ICUs are operated by your hospital? 7. Is the NCU of your hospital operated as an independent department? 8. If not separated, how is it operated? 9. Accessory room for neurosurgery critical patients Hospitalizing disease entities to NCU 10. What is the frequency of hospitalizing disease entities? Demand of neurointensivist and difficulties related with deployment of neurointensivist 11. Is the demand for neurointensivists high? 12. Do you think your hospital is equipped with resources to support a neurointensivist system (human, physical, financial)? 13. Do you think the mandatory deployment of neurointensivists improves the quality of patient care? 14. Have you been through any difficulties (conflicts with the management team, treatment, or work) related to neurointensivist staffing?
Barriers to deploying neurointensivists	Important barriers 15. Do you think the deployment of neurointensivists brings economic problems (increased costs to hospital administration, loss of income to certain physician groups)? 16. Do you have difficulty finding qualified neurointensivists? Potential solutions to barriers 17. Public reporting of hospitals' standardized death rates and corrected severity death rates in NCU 18. Deployment of neurointensivists in adult NCUs (revision of the medical law) 19. Realization of intensive care unit specialist's additional fee Proposal of new model 20. Proposal of a new model based on distinguishing the original ICU medical model from the qualifications needed of a neurosurgeon-operated NCU neurointensivist
Future roles of the KNS and KNIC	21. Do you know that there is the KNIC as a branch of the KNS? 22. Do you know about the KNCS, which is operated by neurologists? 23. Do you think the KNIC is more competitive than the KNCS?
Handbook for physicians and practitioners in NCUs	24. Do you think a handbook is necessary? 25. Are you willing to participate in making a handbook?

NCU : neurosurgical care unit, ICU : intensive care unit, KNS : the Korean Neurosurgical Society, KNIC : the Korean Society of Neurointensive Care Medicine, KNCS : the Korean Neurocritical Care Society

guidelines to standardize medical treatment and maintain medical care quality in the NCU. Table 1 presents the core survey questions; we analyzed the survey responses using descriptive statistics.

Statistical analysis

Survey responses were analyzed using descriptive statistics. Differences in responses by disease category were analyzed using the student t test.

RESULTS

Of all 86 neurosurgical residency training hospitals and two neurosurgery specialist hospitals, respondents from 77 hospitals (87.5%) participated in the survey. By distribution across the country, 35.1% (27/77) of the respondent hospitals were located in Seoul, 26.0% (20/77) were in Incheon and Gyeonggi-do, mostly in the metropolitan area, and, in order, Busan/Gyeongnam, Daejeon/Chungcheong, Gwangju/Jella and Gangwon-do (Table 2).

Table 2. Geographic distributions of the hospitals in this survey compared with those of the 2010 survey

Province	The 2010 survey (total=50)	The 2019 survey (total=77)
Seoul	22	27
Incheon/Gyeonggi	15	20
Gangwon	2	4
Daejeon/Chungcheong	2	5
Daegu/Kyungbok	2	5
Gwangju/Jella	3	5
Busan/Gyeongnam	4	11

Survey results on basic information

Question 1 : How many beds are there in your hospital?; Question 2 : What are the operational entities of your hospital?; Qusetion 3 : Is your hospital designated a tertiary hospital?

For hospital bed counts, there were five hospitals with more than 1500 beds, 12 with 1000–1499, 52 with 500–999, and eight with fewer than 500. There were 52 private university hospitals, 13 national university hospitals, nine secondary hospitals and three other hospitals, one for veterans, one military, and one a national medical center. Forty-three hospitals were tertiary level. For comparison, in the 2010 survey, a total of 50 hospitals (41 university hospitals and nine tertiary hospitals) participated (Table 3).

Question 4 : Does your hospital employ a neurointensivist?; Question 5 : What is the role of the neurointensivist (operating model of ICU)?

Nineteen hospitals (24.7%) employed a neurointensivist or faculty member; two hospitals employed two neurointensivists each, and the other 17 each had one neurointensivist on staff. All hospitals had more than 500 beds, and 16 hospitals (84.2%) were private. Among the neurointensivists, 14 had majored in neurosurgery, four in neurology, two in anesthesiology, and one in cardiothoracic surgery. Fourty seven percent (n=10) had more than 5 years of professional experience, and 47.6% (n=10) had a medical intensivist certificate from the Korean Society of Critical Care Medicine. In terms of ICU operating model, 13 hospitals were open, five were semi-closed, and one hospital were co-management. Tables 3 and 4 list the study ICUs' operating models and the demographic data from this survey.

Table 3. Survey respondent demographics (77 hospitals)

Respondent characteristic	Value
Number of beds	
≥1500	5 (6.5)
1000–1499	12 (15.6)
500–999	52 (67.5)
300–499	6 (7.8)
Under 300	2 (2.6)
The operational entities	
National university hospital	13 (16.9)
Private university or school/medical corporation	52 (67.5)
Secondary hospital	9 (11.7)
Other	3 (3.9)
The level of the hospitals (tertiary level)	
Yes	43 (55.8)
No	34 (44.2)
Facility has neurocritical care unit or employs neurointensivists	
Yes	19 (24.7)
Beds	
≥1500 beds	4
1000–1499 beds	3
500–999 beds	12
300–499 beds	0
Under 300 beds	0
Operational entitise	
National university hospital	3
Private university or school/medical corporation	16
Secondary hospital	0
Other	0
No	58 (75.3)
Details of neuintensivist in the NCU (19 hospitals, 21 physicians)	
Number of faculty	
1 physician	17* (89.5)
2 physicians	2* (10.5)
Specialty	
Neurosurgery	14†
Neurology	4†
Others (CS 1, AN 2)	3†
Duration of professional experience (years)	
≥5	10 (47.6)
<5	11 (52.4)
Subspecialty for medical intensive care	
Yes	10 (47.6)
No	11 (52.4)
Operating model of NCU with neurointensivist attended	
Open	13 (68.4)
Intensivist co-management	1 (5.3)
Closed	0 (0.0)
Semiclosed	5 (26.3)

Values are presented as number (%). *Number of hospitals. †Number of physicians. NCU : neurosurgical care unit, CS : cardiothoracic surgery, AN : anesthesiologist

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Table 4. ICU models and definitions

Model type	Definition	Intensity
Open ICU model	Clinical decisions made by primary physician, surgeon Intensivist may play a role as a consultant	Low-intensity
Intensivist co-management	Open ICU model + mandatory consultation from an intensivist	High-intensity
Closed ICU model	All patients admitted to the ICU are cared for by an intensivist-led team that is responsible for making clinical decisions.	High-intensity
Semi-closed ICU model	Critical care team provides direct patient care in collaboration with other privileged physicians	High-intensity

ICU : intensive care unit

Table 5. Independence of the NCU and a quarantine zone for infection control : comparison between the 2010 survey and the 2019 survey

	2010 survey (50 hospitals)	2019 survey (77 hospitals)
NCU operation		
Independent	21/50 (42.0)	35/77 (45.5)
Average number of beds	16 (10–30)	13.1 (8–19)
Dependent	29/50 (58.0)	42/77 (54.5)
With exclusive bed	10/29 (34.5)	10/42 (23.8)
Average exclusive bed number of beds	10.3 (4–16)	9.4 (2–20)
Without exclusive bed	19/29 (65.5)	32/42 (76.2)
Independent air ventilation system for infection control	35/50 (70.0)	29/35 (82.9)
A quarantine zone for infection control	39/50 (78.0)	34/35 (97.1)
Average number of beds in quarantine area	2.8 (1–14)	2.35 (1–6)
Accessory room		
On-call room for neurosurgeon	27/50 (54.0)	26/35 (74.3)
Waiting room for guardian	40/50 (80.0)	13/35 (37.1)
Meeting room for guardian	31/50 (62.0)	20/35 (57.1)

Values are presented as number/total number (%) or number (range). NCU : neurosurgical care unit

Question 6 : How many independent adult ICUs are operated by your hospital?; Question 7 : Is the NCU of your hospital operated as an independent department?; Question 8 : If it is not separate, how is it operated?; Question 9 : Accessory room for neurosurgery critical patients

We compared NCU dependency and quarantine zones for infection control between the 2010 survey and our 2019 survey. In 2010, 21 hospitals (42%) operated their NCUs independently, and that increased to 35 hospitals (45.5%) in the current survey; of these, 12 hospitals did not operate NCUs independently from their neurology departments or intensive stroke units. The average number of NCU beds was 13.1 beds (range, 8–19) in this survey. Of the 35 hospitals that operated independent NCUs, 29 (82.9%) had an independent air ventilation system and 34 had a separate quarantine area for infection control; the average number of separated isolation beds was 2.35 (range, 1–6), in contrast with the average of 2.8 beds in a quarantine area in the 2010 survey. Hospitals equipped with an independent air ventilation system for infection control accounted for 70% of all respondent hospitals in the 2010 survey, and 82.9% of hospitals in that survey offered a quarantine area.

In the 2010 survey, 10 hospitals (34.5%) held neurosurgery-exclusive beds in the ICUs of other departments among 29 jointly operated hospitals. According to the findings of the 2019 survey, of the 42 hospitals that were not operating independent NCUs, 10 (23.8%) held an average of 9.4 beds in their surgical or general ICUs exclusively for their neurosurgery departments, and 32 were using nonexclusive beds in their surgical or general medical ICUs. In both surveys, hospital ad-

ministrators used beds in the ICUs of other departments when a quarantine zone was not available. Table 5 gives comparative statistics for the two surveys.

Question 10 : What is the frequency of hospitalizing disease entities?

This question was about the diseases that had presented for hospitalization in survey hospitals' NCUs or NICUs over the previous year, and the disease frequencies were in order as follows : internal cerebral hemorrhage (ICH), TBI, subarachnoid hemorrhage, and others; the most common other cause of hospitalization was admission for routine post-operative care. There was no significant difference between the tertiary and non-tertiary hospital in the distribution of diseases categoriese in NCU or NICU under neurosurgery department (Table 6). However, the tertiary hospitals had high admission rates were high for postoperative care after elective surgery for neurosurgical disorders such as brain tumor and unruptured aneurysm, whereas TBI and ICH were the most frequent reasons for admission in the non-tertiary hospitals.

However, there was no statistical difference between tertiary and non-tertiary hospitals. There was also a marked difference in the distribution of disease categories between ICUs under neurosurgery departments and those under neurology. Most of the patients hospitalized in the neurologic ICUs were hospitalized with acute ischemic stroke (AIS) and other brain diseases such as nervous system infection, hypoxic encephalopathy after cardiac arrest, myasthenia gravis and demyelinating disease (Table 6).

Question 11 : Is the demand for neurointensivists high?; Question 12 : Do you think your hospital is equipped for a neurointensivist system (human, physical, financial resources)?; Question 13 : Do you think the mandatory deployment of neurointensivist would improve diagnosis?; Question 14 : Have you been through any difficulties (conflicts with the management team, treatment, or work) related to the deployment of a neurointensivist?

Respondents from 37 hospitals (48.1%) reported high demand for neurointensivists, and respondents from 62 hospitals (80.5%) stated that the mandatory deployment of a neurointensivist improved the quality of patient care (Fig. 1). However, respondents from 38 hospitals (49.4%) gave low ratings for whether their hospitals had adequate human, physical, and financial resources support for installing an intensivist system, and 13 respondents (16.9%) reported difficulties related to deploying a neurointensivist (conflicts with the management team, treatment, or work).

Barriers to implementation of neurointensivists

Question 15 : Do you think that neurointensivists bring economic problems (increased of costs to hospital administration, loss of income to certain physician groups)?; Question 16 : Do you feel difficulty in finding qualified neurointensivists?

Respondents from 44 hospitals (57.1%) believed that hiring neurointensivist would increase hospital costs, and in response to a question on potential earnings declines, 25 respondents (32.5%) anticipated conflicts regarding patients' care between neurosurgeons and neurointensivists. Twenty-three hospital respondents (29.9%) worried about loss of income to certain physician groups, but 69 hospitals of survey respondents (89.6%) observed that the most challenging as-

Table 6. Distribution of disease categories in the NCU or NICU under neurosurgery department compared with neurologic ICU (%)

	Total (74 hospitals)	NCU of tertiary general hospital (41 hospitals)	NCU of non-tertiary hospital (33 hospitals)	*p*-value	Neurologic ICU hospital[9)]
ICH	24.2	23.1	25.5	0.371	5.3
SAH	18.8	18.2	19.5	0.603	5.4
TBI	24.0	21.8	26.7	0.129	0
TSI	3.7	3.3	4.3	0.387	0
AIS	8.9	7.9	10.2	0.336	46.0
Epilepsy	1.4	1.3	1.6	0.546	12.1
Others	17.0	21.3	11.7	0.119	31.3

NCU : neurosurgical care unit, NICU : neurointensive care unit, ICU : intensive care unit, ICH : intracerebral hemorrhage, SAH : subarachnoid hemorrhage, TBI : traumatic brain injury, TSI : traumatic spinal injury, AIS : acute ischemic stroke

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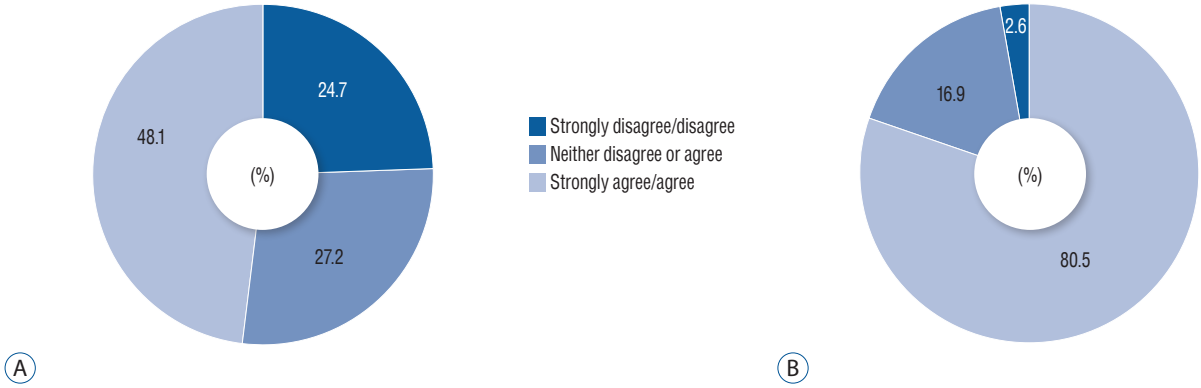

Fig. 1. A : Is the demand for neurointensivists high? B : And do you think the mandatory deployment of neurointensivists improves the quality of patient care?

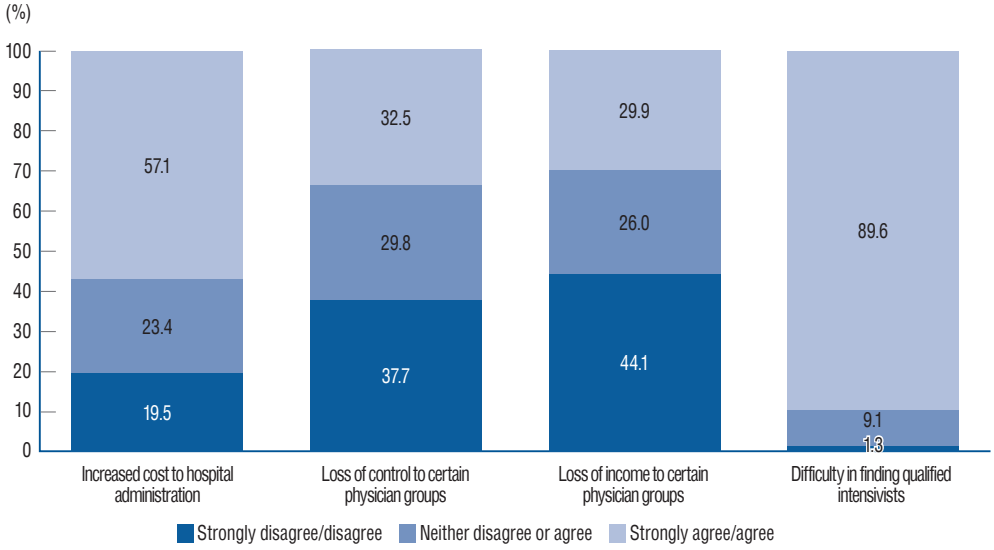

Fig. 2. Survey respondents' opinions on barriers to impelementing neurointensivists.

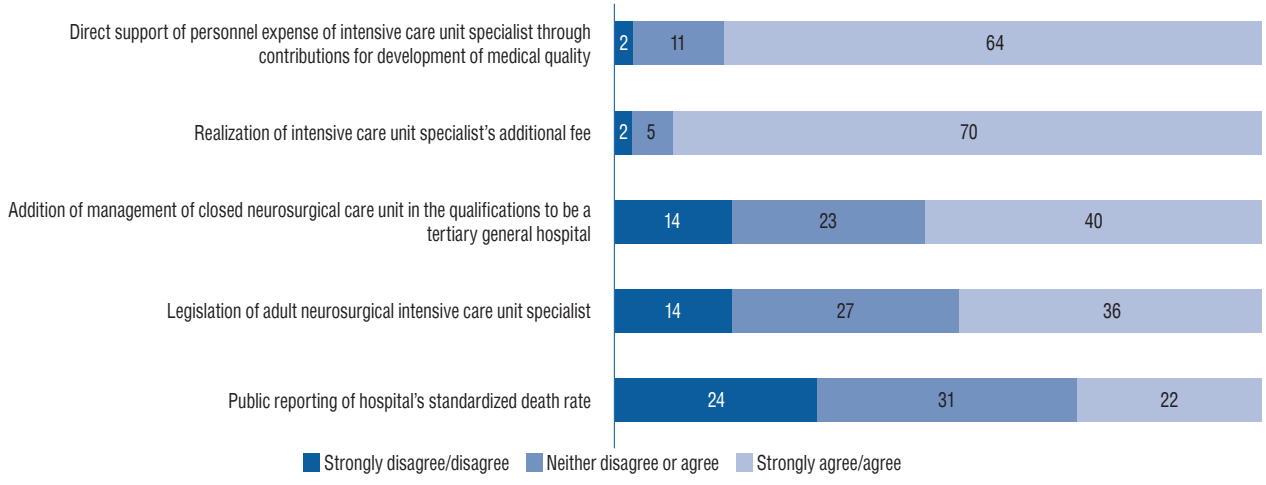

Fig. 3. Potential solutions to barriers. Values are presented as number of hospitals.

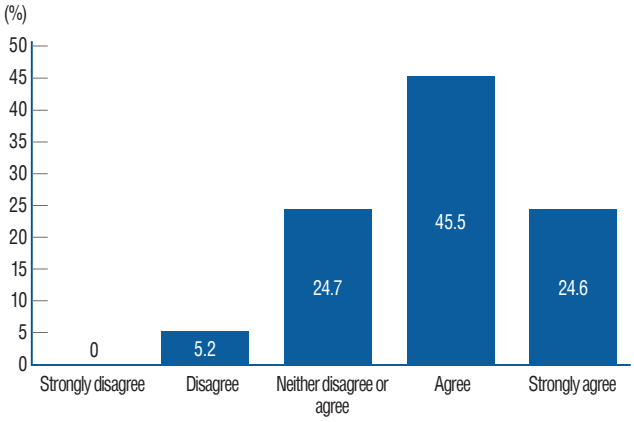

Fig. 4. Proposal of a new model based on distinguishing the original medical intensive care model from the qualifications needed of a neurosurgeon-operated neurosurgical care unit as a neurointensivist.

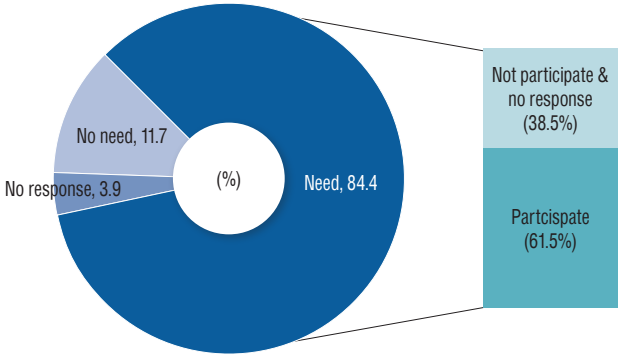

Fig. 5. Do you think a handbook is necessary and are you willing to participate in making a handbook?

pect of recruiting neurointensivists was that they had no applicants for the position (Fig. 2).

Potential solutions to barrier

Question 17 : Public reporting of hospital's standardized death rate and corrected severity death rate in NCU; Question 18 : Deployment of neurointensivist in adult NCU (revision of the medical law); Question 19 : Realization of intensive care unit specialist's additional fee

Question 17 asked whether disclosing medical records such as hospital standardized mortality ratios and risk adjusted morality rates of ICUs was a barrier hiring neurointensivists, only 22 hospital respondents (28.6%) agreed or strongly agreed. Thirty-six respondents (46.8%) supported legislation for deployment of neurointensivists. In terms of potential solutions to these problems, 70 respondents (90.9%) maintained that additional fees were necessary for neurointensivists' work, and 64 (83.1%) answered that direct support was needed of the personnel expenses for neurointensivists (Fig. 3).

Proposal of new model

Question 20 : Proposal of a new model based on distinguishing the original ICU medical model from the qualifications needed of a neurosurgeon-operated NCU neurointensivist

Fifty-three hospital respondents (70.1%) agreed with the need for a new neurosurgeon-oriented NCU model; there was little negative response (strongly disagree/disagree) to this question (n=4, 5.2%) (Fig. 4).

Future roles of the KNS and the KNIC

Question 21 : Do you know that there is the KNIC as a branch of the KNS?; Question 22 : Do you know there is the KNCS which is operated by neurologists?; Question 23 : Do you think the KNIC is more competitive than the KNCS?

For the survey questions related to the societies, most neurosurgeons (n=73, 94.8%) were well aware of the KNIC; 20.8% (n=16) felt that the KNIC was less competitive than the neurologist-driven KNCS.

Handbook for clinical practice in the NCU and current status of hospital equipment

Question 24 : Do you think a handbook is necessary?; Question 25 : Are you willing to participate in making a handbook?

In this survey, 65 hospital survey respondents (84.4%) believed a neurointensivist handbook was necessary. However, only 40 (61.5%) expressed willingness to participate in developing such a handbook (Fig. 5).

Current status of hospital equipment

One survey question related to the survey respondents' possessed NCU equipment at their hospitals, including intracranial pressure (ICP) monitors, tools for measuring cerebral blood flow velocity, transcranial Doppler, equipment for hypothermia treatment, etc., and compared their responses with data obtained from the 2010 survey. Sixty-one respondents (61/70, 87.1%) said their hospitals were equipped with ICP

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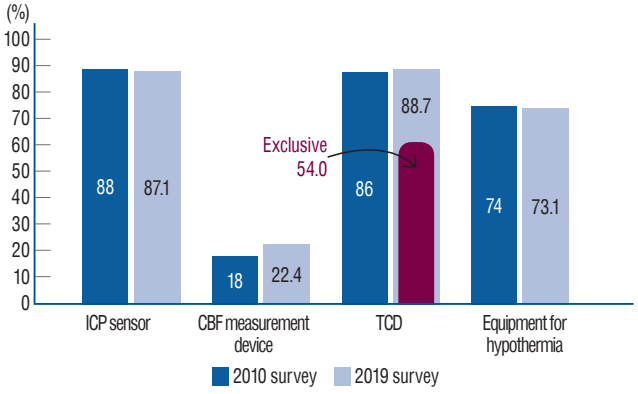

Fig. 6. Hospital equipment status comparison between the 2010 and 2019 surveys. ICP : intracranial pressure, CBF : cerebral blood flow, TCD : transcranial Doppler.

monitors, either Camino, Spiegelburg, or LiquidGard. Of the 62 survey respondents who answered the question, 15 (15/67, 22.4%) worked at hospitals that had devices for measuring central blood flow velocity, and of 63 respondents to a different question, 63 (63/71, 88.7%) had transcranial doppler equipment; at 34 of those hospitals, this was operated exclusively as neurologic equipment. Sixty-seven doctors responded to a question about hypothermia treatment, and 49 survey respondents (73.1%) did treat hypothermia. Fig. 6 presents these data as percentages. We found insignificant differences in the possessed equipment at survey respondents' hospitals over the last decade.

DISCUSSION

The survey for this study was the first nationwide survey in Korea on identifying appropriate methods of operating NCU and NICUs. In 2010, the KNIC conducted a similar survey and presented the results at its first spring meeting, in 2010. Our survey included the same questions from 2010 to compare changes in NCUs and NICUs in Korea over the past 10 years.

Basic information

We received responses from 77 hospitals (75 of 86 neurosurgical residency training hospitals and two neurosurgery specialist hospitals). Table 4 summarizes the demographic data from the survey. In 2010, there were 50 respondent hospitals, 41 university hospitals and nine tertiary facilities; in addition to there being more respondents to our survey, the mix of hospital types was broader. Nineteen hospitals employed a total of 21 neurointensivists (two hospitals had two each) in our survey; all of these were large hospitals with more than 500 beds, and 16 of the 19 were private. In 2010, 21 hospitals operated independent NCUs, and that increased to 35 hospitals (45.5%) in the current survey.

As shown in Table 5, there were no significant changes in independent operation of NCU and facilities such as air ventilation system for infection control, quarantined hospital beds and others over the last decade. There was no inconvenience about no facilities progression and indepent operation of NCU. Many patients with AIS and TBI admitted to stroke unit, trauma center and ICUs in emergency centers.

Demand for neurointensivists, barriers to their deployment in hospitals, and potential solutions to barriers

Although most hospital respondents to our survey reported that neurointensivists help improve the quality of patient care, only 37 reported high demand for neurointensivists at their hospitals. Our survey findings align with those from many previous studies that neurocritical care by neurointensivists contributed to quality improvement by reducing mortality and length of hospital stay[10]. In some studies, a mandatory operation of a closed neurological ICU shortened the length of hospital stay and was beneficial in patient care[6,10], but few of the respondent hospitals in this survey had NCUs or NICUs staffed with neurointensivists. However, most respondents did report that they had difficulties hiring neurointensivists primarily because they had no applicants for the role.

We consider a number of reasons for the absence of applicants. First, neurointensivists perform only limited surgery and outpatient care, whereas most neurosurgeons want to use the full range of their skills; as such, many neurosurgeons do not find the neurointensivist role appealing. Second, neurointensive care is not recognized as an area of neurosurgery because critically ill patients are already treated in different neurosurgery sub-departments. Third, neurosurgeons tend to be unfamiliar with internal medicine-related knowledge and have difficulties interpreting neurophysiological tests such as electroencephalograms and electromyograms.

Markandaya et al.[2] proposed that neurologists are suitable for providing comprehensive neurological treatment as neuro-

intensivists, but we have a different opinion. Many of the respondents to our survey thought that a new, neurosurgery-oriented model of intensive care, primarily because of the characteristics of patients hospitalized in NCUs. As shown in Table 6, the characteristics of patients hospitalized in NCUs differ entirely from the features of patients admitted to neurology ICUs[9]. Most patients will require surgery or have been admitted to an NCU after surgery; for this reason, neurointensivists in NCUs and NICUs under neurosurgery must have extensive knowledge of neurosurgical treatments, including being able to perform immediate surgical treatment if required including invasive procedures. Therefore, without education on pre- and postoperative management of neurosurgery-related treatments, neurointensivists may not be ideal for running independent NCUs.

Instead, we consider the ideal to be neurosurgery-led multidisciplinary care with teams from departments such as internal medicine, neurology, pharmacy, and rehabilitation[7,11]. We do acknowledge that neurosurgery-led multidisciplinary care may not be possible for many reasons such as economic problems and difficulties in staffing. When such a team approach is not an option for a hospital, we consider appropriate a semi-closed ICU or intensivist co-management model with neurosurgeons. In findings from a previous study, good teamwork and adequate communication between intensivists and surgeons contributed to improving the quality of perioperative care[3]. To increase support for neurosurgeons as neurointensivists, neurointensivists could be authorized to provide certain outpatient clinic and neurosurgical treatments. However, neurointensivists cannot perform all operations, and it is best if they are limited to providing surgery only in emergencies.

In terms of barriers to staffing hospital ICUs with neurointensivists, over half of respondents reported that their hospitals did not have the human, physical, and financial resource support for a neurointensivist system; a small number reported conflicts with hospital executives on the subject of neurointensivists, and more than half were concerned about the increased financial burden of hiring full-time neurointensivists (Fig. 2). The 19 hospitals in this survey that operated under a neurointensivist system were all large hospitals with more than 500 beds and most could financially support the cost of the position (Table 3). For other cases, most respondents to our survey proposed charging patients fees for critical care services by neurointensivists or providing financial support for ICU intensivist employment costs of ICU intensivists. Nearly half of respondents supported legislation on neurointensivists, but less than a third supported attracting social attention to neurology-related care by publicly reporting hospital standardized mortality ratios and risk-adjusted NCU mortality rates (Fig. 3).

Future roles of the KNS and KNIC

Sixteen respondents felt that the KNIC was less competitive than the KNCS, which is mainly run by neurology departments, for a number of reasons such as lack of active participation by and interest from neurosurgeons, lack of good educational programs for fellowships, lack of publicity, and lack of a neurosurgery orientation. Duplicate academic interest and education also leads to a lack of professionalism. For example, basic knowledge such as ICP management considerably overlaps with clinical practice during residency and education programs of the Korean Neurotraumatology Society. To overcome this shortcoming, the KNIC needs to open up for collaborative practice by encouraging the involvement of neurologists, internal medicine specialists, and anesthesiologists.

Mutual exchange among relevant domestic and international medical societies is also crucial. Additionally, academic programs to share knowledge with other departments and learn from other specialists in treating critical neurosurgical patients are warranted, and there should be greater effort toward promoting these programs. Furthermore, the KNIC should establish training programs and qualification standards for neurointensivists because neurointensivists must have knowledge of all internal/surgical conditions and surgical treatment. For example, the Korean Society of Critical Care Medicine had the primary role in initiating subspecialities for managing critically ill patients.

Handbook for clinical practice in the NCU

We believe that an evidence-based manual or handbook related to NCUs' clinical practice guidelines is essential for education and care quality control in institutions without sufficient certified specialists or neurosurgeons[8]. In the survey for this study, 65 hospital respondents thought such a handbook was necessary, but only 40 respondents expressed willingness to participate in producing such a handbook. The KNS and KNIC need to make efforts to update the published manual. Respondents to our survey had many opinions on making the

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Table 7. SWOT analysis of neurosurgeons in neurointensive care units

	Opinion
Strength	A large number of patients require neurosurgical care KNS has well-organized residency education and training programs Sufficient experience and knowledge of medical and surgical management about most of neurosurgical disease Surgical decision and management can be done independently by neurosurgeon Many neurosurgical societies associated with neurointensive care
Weakness	Lack of knowledge and education about internal medicine-related treatment (mechanical ventilator, continuous renal replacement treatment, ECMO, etc.) Unfamiliar with neurological disorders and neurological monitoring equipment (EMG, ultrasonography, EEG, etc.)
Opportunity	Korean medical policies are currently heading toward emphasizing patient safety and medical expertise Financial support is increasing for intensive care There is as yet no system of subspecialities for managing critically ill neurology patients The need of neurointensive care will be increasing
Threat	Lack of appropriate working hours and education time during residency The system of subspecialities for managing critically ill patients Competition of the KNIC with many similar societies (KNIC, KSCCM, etc.) Few applications from neurosurgeons due to limited surgical opportunities Lack of publicity

SWOT : strength/weakness/threat/opportunity, KNS : the Korean Neurosurgical Society, ECMO : extracorporeal membrane oxygenation, EMG : electromyography, EEG : electroencephalogram, KNIC : the Korean Society of Neurointensive Care Medicine, KSCCM : the Korean Society of Critical Care Medicine

handbook functional, and there were some opinions on developing mobile phone applications. However, there were some respondents who argued that a separate handbook is unnecessary because critical care guidelines by disease are already described in the textbooks of each specialty.

Current status of hospital equipment

We compared four equipment retention rates with data from 10 years ago (Fig. 6) and found that despite a slight decrease in overall numbers, there were no significant changes in possessed equipment in departments of neurosurgery over the last decade. The reason may be that some hospitals were considering introducing more advanced monitoring equipment in the ICU such as near infrared spectroscopy, pupillometer, bispectral index, and minimal invasive hemodynamic monitoring system. Along with recent advances, a portable computed tomography (CT) or ultrasound scanner has been introduced because patients have difficulties moving frequently for CT or magnetic resonance imaging scans. Furthermore, monitoring equipment that can directly examine the brain is being used, and studies have verified its effectiveness[1,5].

Limitations and further research

This survey has several limitations that might affect interpretation of the data. First, the accuracy of equipment counts, facilities, and disease distributions is questionable, because some hospitals do not want to release these informations. To expand the availability of these data, we believe it is necessary for the KNS to conduct annual training hospital evaluations to obtain data. Second, selection bias may have occurred; most of the survey participants were neurosurgeons, and only two were neurologists. Thus, many responses heavily reflect the opinions of chief NCU managers, limiting the generalizability of these respondents' opinions. Additionally, we did not solicit data for this survey from other NCU stakeholders such as hospital administrators, non-intensivist physicians, and policymakers. Third, implementation of full-time neurointensivist team systems will depend on many factors including individual NCU or NICU characteristics of each hospital. Considering strengths,weaknesses,threats and opportunities of neurosurgeons as neurointensivists (Table 7), we need to develop the appropriate education, training programs and optimum model for each hospital through further research.

CONCLUSION

The NCU is becoming an essential part of neurosurgery for improving patient safety and the quality of patient care. Neurointensive care by a full-time neurointensive team is effective in reducing hospital mortality and length of hospital stay. KNS and KNIC are making continuous efforts toward the successful implementation and the evolution of the neurointensive care team system in Korea, but we need to understand the importance, specialties, and limitations of the role of neurosurgeons in NCUs compared with those of intensivists in medical and neurological ICUs.

CONFLICTS OF INTEREST

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

INFORMED CONSENT

This type of study does not require informed consent.

AUTHOR CONTRIBUTIONS

Conceptualization : KWJ, DSY
Data curation : KWJ, HK, DSY, DKH, JHC, HKP, BJP, BMC, YWK, THK, IH, SWL, THK
Formal analysis : BJP
Funding acquisition : KWJ, HK, DSY, DKH, JHC, HKP, BJP, BMC, YWK, THK, IH, SWL, THK
Methodology : KWJ, HK
Project administration : KWJ, HK, DSY, DKH, JHC, HKP, BJP, BMC, YWK, THK, IH, SWL, THK
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