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The development of the neurocritical care specialty in China based on the analysis of neurocritical care unit volume and quality

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Abstract:

PURPOSE: Through three neurocritical care unit (NCCU) surveys in China, we tried to understand the development status of neurocritical care and clarify its future development.

METHODS: Using a cross-sectional survey method and self-report questionnaires, the number and quality of NCCUs were investigated through three steps: administering the questionnaire, sorting the survey data, and analyzing the survey data.

RESULTS: At the second and third surveys, the number of NCCUs (76/112/206) increased by 47% and 84%, respectively. The NCCUs were located in tertiary grade A hospitals or teaching hospitals (65/100/181) in most provinces (24/28/29). The numbers of full-time doctors (359/668/1337) and full-time nurses (904/1623/207) in the NCCUs increased, but the doctor–bed ratio and nurse–bed ratio were still insufficient (0.4:1 and 1.3:1).

CONCLUSION: In the past 20 years, the growth rate of NCCUs in China has accelerated, while the allocation of medical staff has been insufficient. Although most NCCU hospital bed facilities and instruments and equipment tend to be adequate, there are obvious defects in some aspects of NCCUs.

Keywords:

Full-time doctors, full-time nurses, neurocritical care unit, neurocritical care

Introduction

The neurocritical care (NCC) specialty takes the NCC unit (NCCU) as the entity. The team is composed of multidisciplinary personnel from neurology, intensive care medicine, clinical pharmacology, clinical nutrition, and clinical rehabilitation, providing services to improve the prognosis of patients with critical neurological diseases. In the 21st century, although only a few countries have conducted NCCU surveys,[1,2] it has been suggested that the NCC specialty has entered a stage of rapid development. To this end, the American Neurocritical Care Society (NCS) launched the "NCS global partners program," which aims to bolster the global strength of NCC and advance toward the goal of improving the prognosis of severe neurological diseases. However, the most basic condition to achieve this goal is the reasonable development of NCCU volume and quality.

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In 2019, the Chinese NCC Committee (NCC China) joined the NCS-GPP program and compared the results of a national NCCU survey from 2020 with the results of surveys from 2015 to 2010 with the support of the neurology sub-association of Chinese Medical Doctor Association. The survey results on NCCU volume and quality can provide guidance for the development of the NCC specialty in China in the next 5~10 years.

Methods

Investigation organization and design

The NCC chairman was responsible for organizing the questionnaire design. NCC members were responsible for the distribution and collection of the NCCU questionnaires and the verification of the first data in the region. The NCC survey working group (NCC-SWG) was responsible for the sorting of questionnaires, the second data check, and statistical analysis. The three survey areas covered 31 Chinese mainland provinces, autonomous regions, and municipalities directly under the central government.

Investigation objects and methods

NCCUs of tertiary hospitals with full-time NCCU doctors (received or currently receiving NCCU professional training) were included in the survey. The survey method was a cross-sectional survey. The investigation process and steps [Figure 1] included three stages: questionnaire completion, data collection and sorting, and data verification and confirmation and statistical analysis. In the first stage (from October 1 to December 31 of that year), the NCC-SWG sent the self-report questionnaire to the regional principals (NCC members) by e-mail, and each member sent the questionnaire to the NCCU of his or her local hospital according to the survey inclusion conditions; the person in charge of the NCCU to be surveyed was asked to complete the questionnaire. In the second stage (from January 1 to March 31 of the following year), the person in charge of the

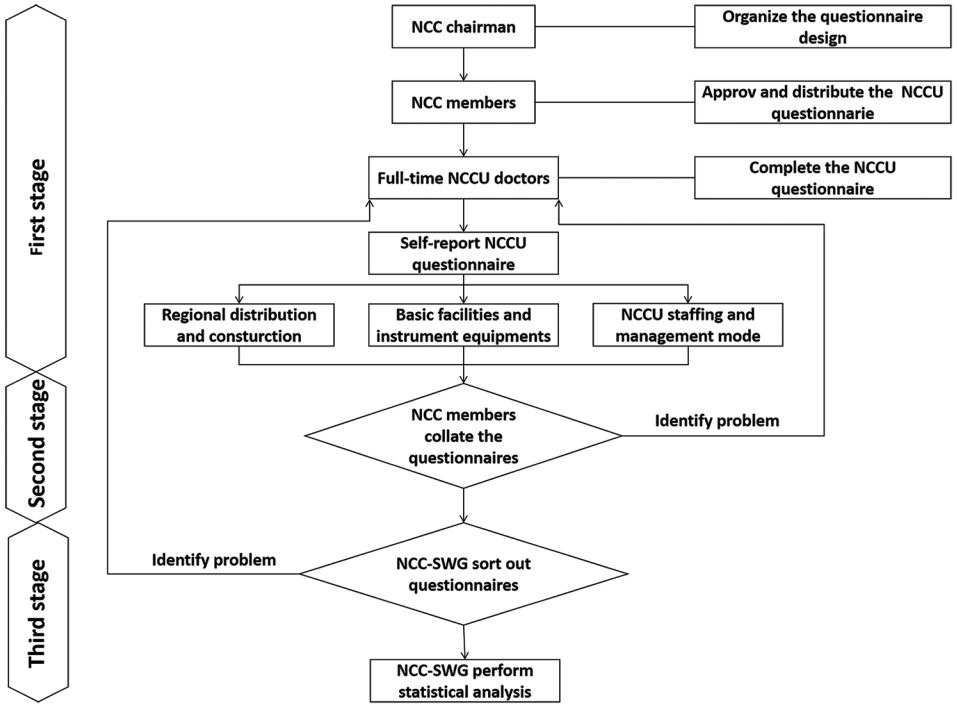

Figure 1: Investigation flow diagram. Neurocritical care (NCC), neurocritical care; NCC unit, neurocritical care unit; NCC-survey working group, neurocritical care survey working group. NCC: Neurocritical care, NCCU: Neurocritical care unit, SWG: Survey working group

Table 1: Survey item name

Item number	Survey items	Item number	Survey items
I	Distribution and construction	II	The bed facilities configuration
1	Province	11	Air purification system
2	Hospital	12	Independent power supply equipment
3	Teaching hospital	13	Bed lighting
4	Tertiary Grade A hospital	14	Oxygen source
5	Hospital bed	15	Compressed air source
6	New construction/reconstrucation	16	Negative pressure aspirator
7	Department of neurology ICU/neurosurgical ICU/neurological ICU	17	Anti-pressure sore mattress
8	Bed	18	Noncontact hand disinfection device
9	Isolation bed	19	mEMR
10	Closed management mode		
III	ICU basic instrument and equipment configuration	IV	Respiratory circulation support equipment configuration
20	Aid cart	36	Central multifunctional ECG monitor
21	Simple respirator	37	Bedside multifunctional ECG monitor
22	Vibration sputum expectorator	38	Portable multifunctional ECG monitor
23	Cardiac defibrillator	39	Electrocardiograph
24	Invasive pressure device	40	PiCCO
25	Volumetric infusion pump	41	Desktop invasive ventilator
26	Syringe pump	42	Portable invasive ventilator
27	Temperature control blanket	43	Noninvasive ventilator
28	Enteral nutrition feeding pump	44	End-expiratory carbon dioxide detector
29	Indirect calorimetry (metabolic car)	45	Arterial blood gas analyzer
30	Bedside ultrasound diagnostic apparatus	46	Fiberoptic bronchoscopy
31	Mobile bedside X-ray machine	47	Extracorporeal membrane oxygenation apparatus
32	Biochemical detector		
33	Automatic coagulation detector		
34	Blood purification equipment		
35	Percutaneous endoscopic gastrostomy equipment		
V	Specialized instruments and equipment configuration	VI	Staffing
48	EEG monitor	62	Executive officer
49	Video EEG monitor	63	Resident/attending/chief physician
50	Evoked potential equipment	64	Physician bed ratio
51	TCD	65	Head nurse
52	Invasive intracranial pressure monitor	66	Nurse practitioner/nurse-in-charge/chief nurse
53	Intracranial minimally invasive hematoma puncture equipment	67	Certified nurse
54	Microinvasive lateral ventricle puncture equipment	68	Nurse bed ratio
55	Body surface temperature controller	69	Ventilator therapist
56	Endovascular temperature controller	70	Clinical pharmacist
57	Head CT examination equipment	71	Clinical nutritionist
58	Head MRI equipment	72	Neurotherapist
59	Intracranial vascular examination and treatment equipment		
60	Neuropathological examination equipment		
61	Neuropharmaceutical testing equipment		

TCD: Transcranial Doppler, PiCCO: Pulse indicator continuous cardiac output monitor, mEMR: Mobile electronic medical records, CT: Computed tomography, MRI: Magnetic resonance imaging, EEG: Electroencephalogram, ECG: Electrocardiogram, ICU: Intensive care unit

NCCU in this region submitted the questionnaire to NCC members. After each member collected and checked the questionnaire, he or she submitted the questionnaire to the NCC-SWG project team by e-mail. In the third stage (from April 1 to June 30 of the next year), the NCC-SWG first collated and verified the questionnaires (verified the query information or data by telephone or e-mail) and then performed statistical analysis on the survey results.

Questionnaire design

The questionnaire included closed questions collecting information on the actual situations of the NCCU. The survey included 6 parts and 72 items, including the location and construction of NCCUs, hospital bed facilities, basic instruments and equipment, respiratory and circulatory support instruments and equipment, neurological specialized

instruments and equipment, and NCC full-time personnel [Table 1].

Clinical trial registry

No clinical trials were involved.

Statistics

SPSS Statistics for Windows, Version 19.0 (SPSS Inc., Chicago, IL) statistical software was used for statistical analyses. Descriptive statistics were used. The enumeration data were expressed as the number of cases (percentage), and the measurement data were expressed as the mean and range (minimum and maximum).

This study was approved by the Ethics Committees of the Xuanwu Hospital, Capital Medical University, adhering to the principles of the Declaration of Helsinki.

Results

Comparison of neurocritical care unit location and construction

At the second and third surveys, the number of NCCUs (76/112/206) increased by 47% and 84%, respectively. There were NCCUs located in most (24/28/29) provinces, with at least one and at most 20 in each province [Figure 2]. Across the three survey time points, there were an increasing number of hospitals with NCCUs (65/100/181), most of which were teaching hospitals and tertiary Grade A hospitals, with an average of 1639/2134/2442 hospital beds. In each survey, nearly 30% of NCCUs were rebuilt or newly built; the number of NCCUs in neurology departments increased more quickly (43/75/139) than the number of NCCUs in other departments and accounted for a higher proportion of NCCUs (57%/67%/67%). The NCCUs had different sizes, with a minimum of 4 beds and a maximum of 70 beds; half of them had 8–14 beds, and 59.8%~75.7% had isolated beds. The average proportion of specialized beds in

Table 2: Neurocritical care unit distribution and construction: comparison between 2010, 2015, and 2022

Items	2010 (76 NCCUs)	2015 (112 NCCUs)	2020 (206 NCUs)
NCCU distribution			
Number of provinces, (number of NCCUs per province)	24 (1–14)	28 (1–18)	29 (1–20)
Number of hospitals, (number of NCCUs per hospital)	65 (1–2)	100 (1–2)	181 (1–2)
Number of teaching hospitals (%)	49 (72)	97 (86.6)	188 (91.3)
Number of tertiary Grade A hospital	76 (100)	107 (95.5)	197 (95.6)
Average number of beds (range)	1639 (500–4400)	2134 (460–7000)	2442 (300–6100)
NCCU construction			
Number of reconstruction NCCUs/new construction NCCUs (%)	-	30/33 (27/29)	57/57 (28/28)
Number of NCCUs in department of neurology ICU/neurosurgical ICU/neurological ICU (%)	43/27/6 (57/36/7)	75/28/9 (67/25/8)	139/43/24 (67/21/12)
The average number of beds (range, %)	13 (4–45, 11)	14 (4–40, 8)	15 (4–70, 9)
Number of NCCUs with isolation beds (%)	-	67 (59.8)	156 (75.7)
Number of NCCUs with closed management mode	48 (63.2)	95 (84.8)	178 (86.4)

Reconstruction: The NCCU was rebuilt within 5 years before the survey year. Closed management: NCCU is managed by a full-time neurocritical care team.
NCCU: Neurocritical care unit, ICU: Intensive care unit

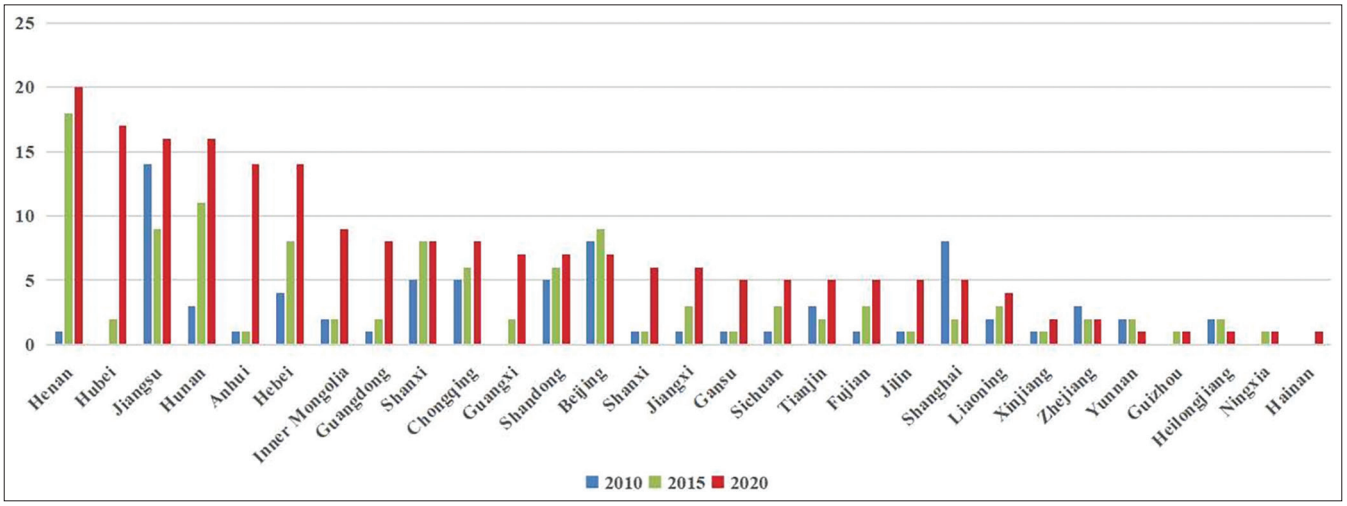

Figure 2: Distribution and quantity of neurocritical care units (NCCUs) in Chinese mainland: 206 distributed in 181 hospitals in 29 provinces, autonomous regions and municipalities in 2020. Among them, 7 provinces had more than 8 NCCUs, 15 provinces had 4~8 NCCUs, 7 provinces had 1~3, and 2 provinces had no NCCU

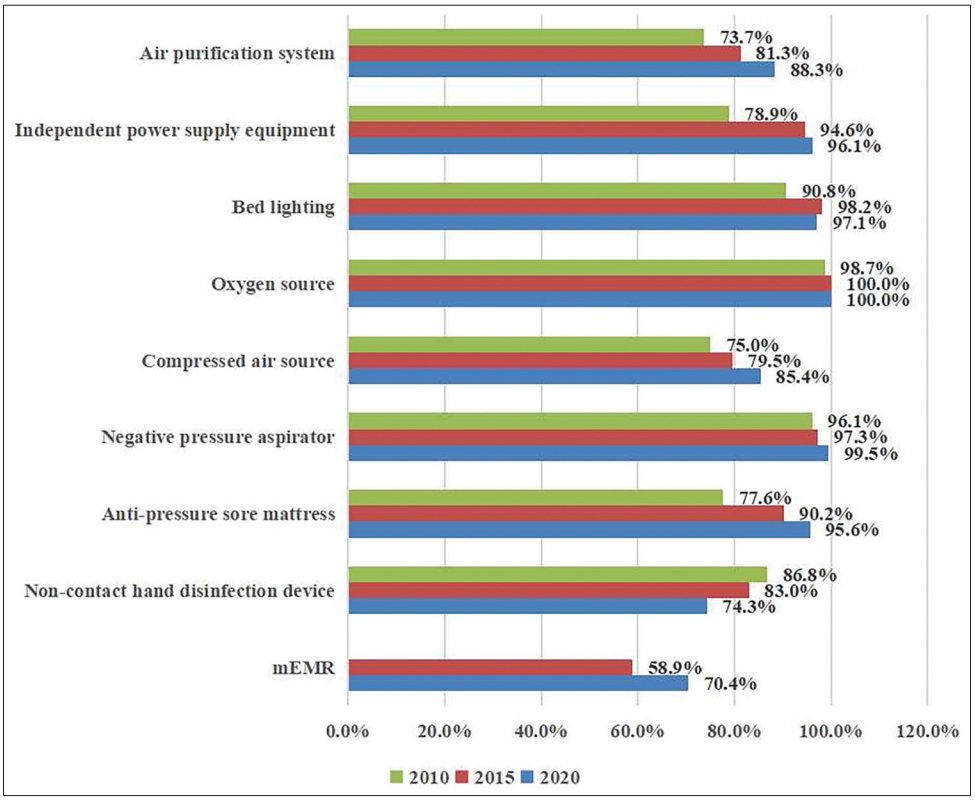

Figure 3: Neurocritical care unit bed facility allocation rate: comparison between 2010, 2015, and 2020. In 2015, the mEMR survey item was added. mEMR, mobile electronic medical record. mEMR: Mobile electronic medical record

the NCCUs was 8%~11%, and closed management showed a significant increasing trend (63.2/84.8/86.4%) [Table 2].

Comparison of neurocritical care unit bed facilities

In 2010, the rate of 8-bed facilities was 73.7%~98.7%. Compared with 2010, in 2015, there was a new survey item to assess the use of mobile electronic medical records (mEMRs); in addition, the fastest-growing technologies were independent power supply equipment and air cushion beds for pressure ulcer prevention (19.9% and 16.2%), and the rate of 8-bed facilities reached 80%~100%. Compared with 2015, in 2020, the growth in the rate of mEMR use was 19.5%, but the equipment rate was still lower than 71% [Figure 3].

Comparison of basic neurocritical care unit instruments and equipment

In 2010, the equipment rates of the vibrating sputum extractors, invasive pressure devices, and automatic bleeding and coagulation detectors were lower than 46.1%, and the equipment rates for the other 11/14 items were 52.6%~94.7% [Figure 4a]. Compared with 2010, in 2015, except for the newly added metabolic car and percutaneous endoscopic gastrostomy (PEG)/percutaneous endoscopic jejunostomy (PEJ) survey items, the equipment growth rate of the other 12/14 items was 4.2%–93.1%, and the equipment rate was 52.7%–99.1%. Only the equipment rate of indirect calorimetry and blood purification devices was <40%. Compared with 2015, the equipment rate of vibrating sputum extractors and invasive pressure devices continued to grow in 2020 (23.6% and 27.1%), and the equipment rates reached 92.7% and 67.0%, respectively. However, the equipment rates of indirect calorimetry, blood purification devices, and PEG/PEJ were still lower than 42%. The allocation rate of NCCU's six hospital support projects showed an overall increasing trend in the three surveys [Figure 4b].

Comparison of neurocritical care unit respiratory and circulatory support instruments and equipment

In 2010, the equipment rates of pulse index continuous cardiac output (PiCCO) systems, portable invasive ventilators, end-tidal CO2 (EtCO2), and arterial blood gas analyzers were lower than 42.1%, and the equipment rates for the other 5/9 items reached 69.7%~100% [Figure 5]. Compared with 2010, in 2015, except for noninvasive ventilators, fiber-optic bronchoscopes, and extracorporeal membrane oxygenators (ECMOs), the growth rate in the equipment rates of the other 5/9 items was 3.4%~117.3%, and the equipment rates reached 81.3%~100%. Compared with 2015, in 2020, the growth in the equipment rate of ECMOs was the fastest (113.8%). However, the

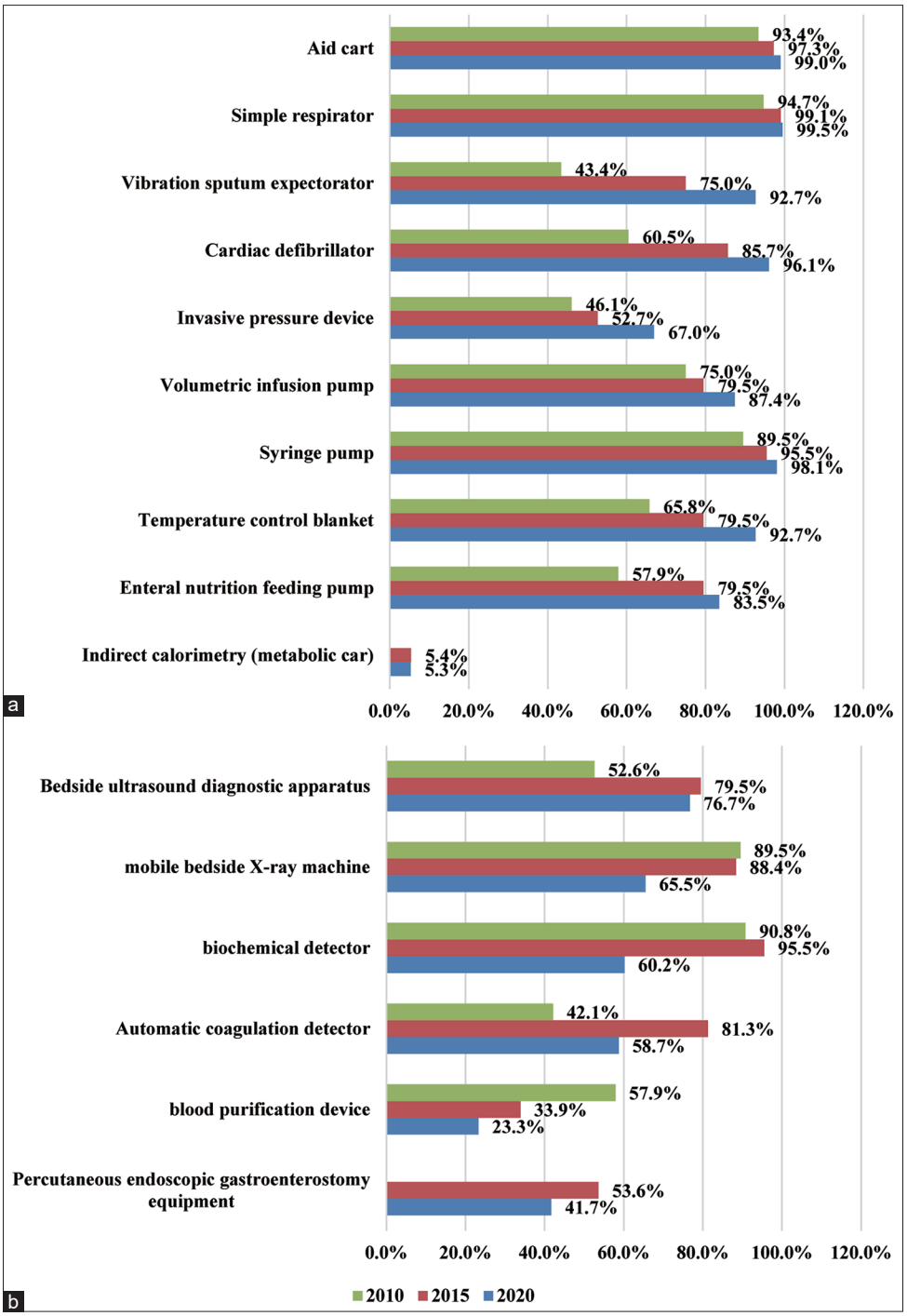

Figure 4: Neurocritical care unit (NCCU) basic instrument and equipment configuration: comparison between 2010, 2015, and 2020. (a) NCCU independent equipment project; (b) hospital support equipment project

equipment rates of three items (PiCCO, EtCO2, and ECMO) were still lower than 35%.

Comparison of neurocritical care unit specialized instruments and equipment

Among the specialized items of the NCCU, in 2010, except for the equipment rate of electroencephalogram (EEG) monitoring reaching 63.1%, the equipment rates of the other 6 items were lower than 39% [Figure 6a]. Compared with 2010, in 2015, the newly added investigation items were intracranial minimally invasive hematoma puncture equipment and body surface temperature controllers, and the equipment rates were 76.8% and 72.3%, respectively. The growth in the equipment rates of the other seven items was 40.1%~258.9%, and the equipment rates (except for the intravascular temperature controller) reached 63.4%~88.4%.

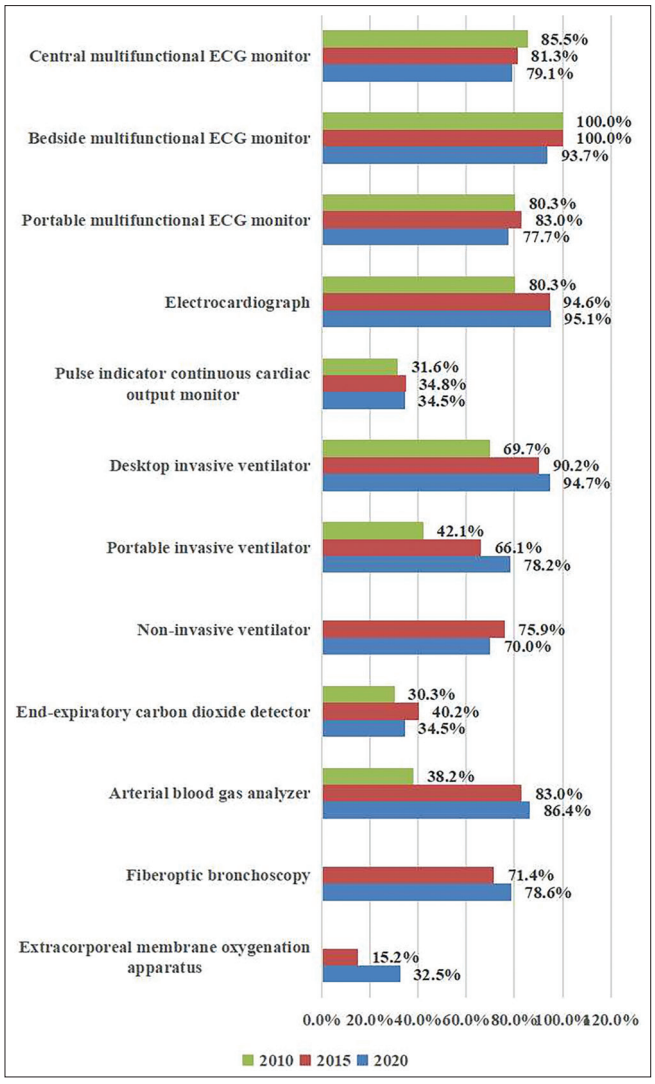

Figure 5: Neurocritical care unit respiratory and circulatory support instrument and equipment configuration: comparison between 2010, 2015, and 2020. ECG: Electrocardiogram

Compared with 2015, in 2020, only the equipment rate of video EEG monitoring increased (8.1%). Although the equipment rate of intravascular temperature controllers was still very low (8.7%), the equipment rates of all other items were higher than 61%. The allocation rates of five hospital support projects for NCCUs changed little across the three surveys (76.3%~94.7%, 75.9%~96.4%, 65.5%~90.3%) [Figure 6b].

Neurocritical care unit staffing comparison

In 2010, the staffing rates of full-time chief physicians, attending physicians, and resident physicians (third-level physicians) at NCCU were all insufficient (46.1%/77.6%/78.9%), with equal proportions of resident physicians and attending physicians (41%) [Figure 7]. Compared with 2010, in 2015, the allocation rate of tertiary hospital doctors increased (75.0%/84.8%/90.2%), and the proportions were equal (1/3 each). Compared with 2015, in 2020, there were no significant changes in the allocation rate and proportions. The ratio of doctors to beds in the three surveys was fixed at 0.4:1. The nurse allocation rate in 2010 was insufficient (77.6%). In 2015, the staffing rate of nurses at all levels was basically sufficient, and the proportion of nurses at all levels was basically reasonable, and 2020 was better than 2015. The ratio of nurses to beds in the three surveys increased from 0.9:1 to 1.3:1. The other staffing rates of NCCU have only slightly increased.

Discussion

The NCCU survey was conducted in China at 5-year intervals in the first 20 years of this century, in parallel to the start and development of the NCC specialty. After comparing the results of three surveys, we found that the number of constructed NCCUs was still growing continuously and rapidly, and the quality of NCCU construction was also continuously and reasonably improved. Whether this change meets the need for good prognoses for severe neurological diseases is worth studying and discussing.

Number and distribution of neurocritical care units

The three surveys suggested that the number of NCCUs expanded at rates of 47% and 84% and that the expansion was concentrated in large tertiary grade A hospitals and/or teaching hospitals in some provinces and cities of China (Henan, Hubei, Jiangsu, Hunan, Anhui, Hebei, Inner Mongolia, Guangdong, Shanxi, and Chongqing). However, the expansion in the number of NCCUs does not seem to be completely parallel to the large population, developed economy, and medical level. This suggests that the number of NCCUs has not met the demand, and the distribution of NCCUs is not adequate. The problems that the NCC needs to study and solve in the next 5~10 years are as follows: (1) We should not only pay attention to and support the construction of NCCUs in remote and less developed areas but also urge the construction of NCCUs in some economically developed areas; and (2) while expanding the number of NCCUs, we should promote consensus among Chinese experts on the construction of standardized NCCUs[3] to ensure that the infrastructure, construction scale, and management mode of NCCUs are acceptable.[4,5]

Neurocritical care unit instruments and equipment

The three surveys showed that >70% of NCCU beds tend to be equipped with complete basic facilities, but there are still problems. Although the use of mEMR indicated high informatization and had a rapid growth rate (19.5%), the equipment rate was still insufficient (70.4%). Prospective studies have suggested that since the use of mEMR, the speed of medical information collection and processing

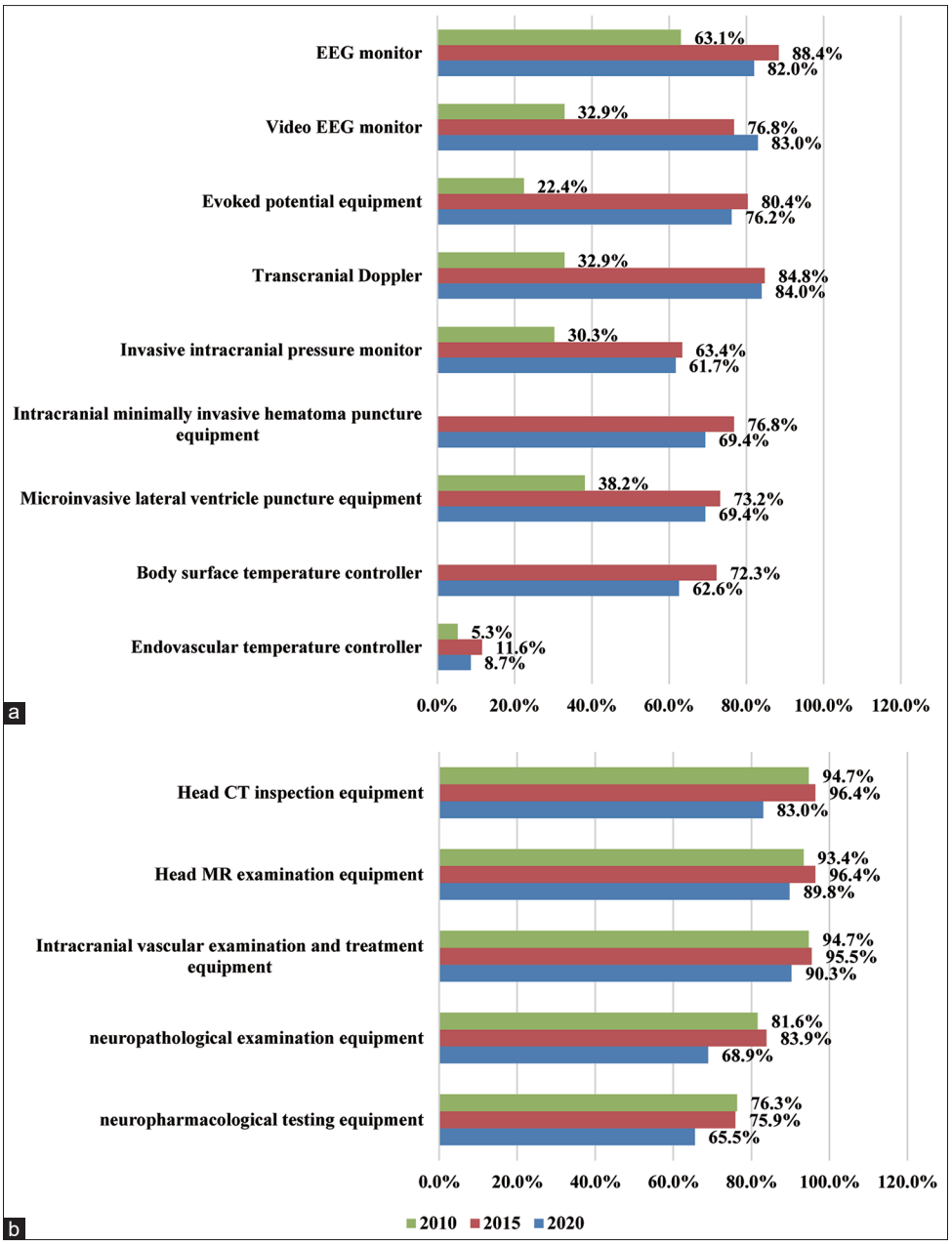

Figure 6: Neurocritical care unit (NCCU) specialized instrument and equipment configuration: comparison between 2010, 2015, and 2020. (a) NCCU independent equipment project; (b) hospital support equipment project. EEG: Electroencephalogram, CT: Computed tomography, MR: Magnetic resonance

has accelerated, the bedside working hours of medical staff have increased, the clinical work efficiency has been improved, and patient-oriented service has been improved.[6,7] More than 60% of the NCCUs' basic instruments and equipment were sufficient, but instruments and equipment related to new concepts and new technology of neurocritical illness were insufficient. Only 5.3% of the NCCUs were equipped with metabolic vehicles, which is inconsistent with the demand for accurate energy metabolism support for critical neurological diseases. Only 23.3% of the NCCUs were equipped with blood purification equipment, which is far from meeting the increasing demand for plasma exchange treatment for critical autoimmune neurological diseases. Whether these basic instruments and equipment are present in NCCUs is related to high-quality disease diagnosis and treatment.[8,9] The presence of more than 70% of the respiratory and circulatory support instruments and equipment in the NCCUs tended to be sufficient, but the equipment rates of PiCCO and EtCO2 were insufficient (34.5% and 34.5%). Therefore, accurate monitoring and support of respiration and circulation are still a weakness of NCCUs, and the strong correlation between heart, lung, and brain function cannot be ignored.[10,11] Although the allocation rate of ECMO increased at a rate of 113.8%, reaching 32.5%, the conflict

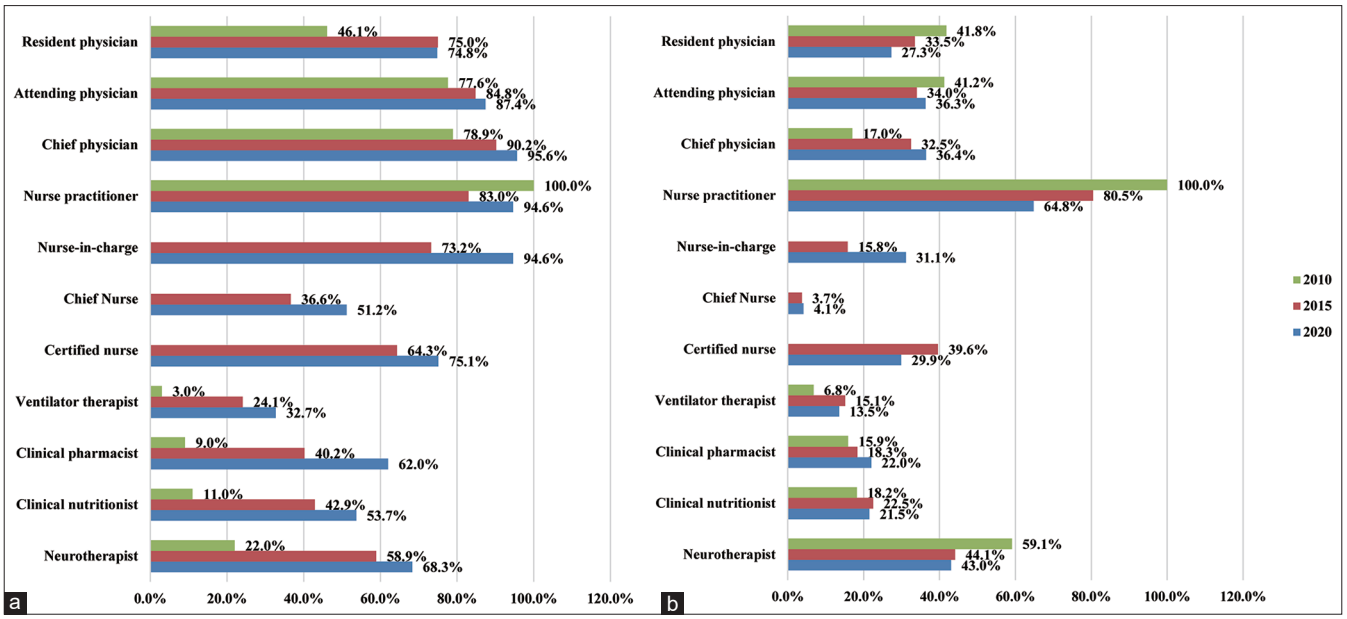

Figure 7: Neurocritical care unit (NCCU) staffing: comparison between 2010, 2015, and 2020. (a) NCCU personnel allocation; (b) the proportion of NCCU personnel

between its impact on systemic circulatory support and cerebral blood flow is debatable.[12] More than 70% of NCCU specialized instruments and equipment were sufficient, but the presence of invasive intracranial pressure monitoring was insufficient (61.7%), and the presence of intravascular hypothermia instruments was even worse (8.7%). There is still a gap in terms of meeting the need for accurate intracranial pressure monitoring and accurate hypothermia treatment.[13-18] It is suggested that NCCU instruments and equipment still face challenges of insufficient informatization, accuracy, and specialization. In the next 5~10 years, the NCS needs to pay attention to and pursue the following directions: (1) The electronization of a large amount of complicated medical information at the bedside to improve work efficiency and save medical costs; and (2) accurate and professional configuration of instruments and equipment to meet the needs of patients with severe neurological diseases.

Neurocritical care unit team building

The three surveys suggested that although the number of full-time doctors and nurses in NCCUs is increasing, the doctor–bed ratio (0.4:1) and nurse–bed ratio (1.3:1) in 2020 still suggested that the allocation of medical staff was insufficient, which may affect the quality of closed management. In addition, surprisingly, the allocation of other relevant personnel in the NCCU has increased significantly. In 2020, approximately 1/3~1/2 of NCCUs were equipped with a ventilator master, clinical pharmacists, clinical nutritionists, and neurorehabilitation specialists. This change stems from the promotion of the new concept of NCCU team building. This suggests that NCCU team construction is mixed, and the shortage of full-time medical staff has become the main problem. In the next 5~10 years, the NCC needs to urgently solve the following problems: (1) Supplement the number of full-time medical staff in NCC and improve their treatment ability[19] to approach or meet the requirements of the "Consensus of Chinese experts on the Construction of NCCU" (doctor–bed ratio of 0.8~1.0:1 and nurse–bed ratio of 2~3:1);[3] (2) accelerate the professional training and qualification of full-time personnel to treat patients with severe neurological diseases;[20] and (3) encourage other relevant professionals to support and contribute to the NCCU.

Limitations

Some variables were not evaluated. The data comes from before 2020, with poor timeliness and representativeness.

Conclusion

In the first two decades of the 2000s, the growth rate of NCCUs in China accelerated. The NCC needs to complete four tasks for the transformation of NCCUs: (1) Change the focus from the growth of NCCUs in terms of quantity to the improvement of quality; (2) change the focus from traditional diagnosis and treatment instruments and equipment in NCCUs to diagnosis and treatment instruments and equipment based on new ideas and new technologies; (3) change the insufficient allocation of full-time medical staff in NCCUs to have more sufficient allocation; and (4) change from a traditional medical management system to a highly informatized management system.

Author contributions

(1) The conception and design of the study: Yingying Su; (2) Acquisition of data: Junfang Teng, Fei Tian, Jing Jing, Huijin Huang, Suyue Pan, Wen Jiang, Furong Wang, Le Zhang, Liping Liu, Jie Cao, Huaiqiang Hu, Wei Li, Cheng Liang, Liansheng Ma, Xuegang Meng, Linyu Tian, Changqing Wang, Lihua Wang, Yan Wang, Zhenhai Wang, Zhiqiang Wang, Zunchun Xie, Mingyao You, Jun Yuan, Chaosheng Zeng, Li Zeng, Lei Zhang, Xin Zhang, Yongwei Zhang, Bin Zhao, Saijun Zhou, Zhonghe Zhou; (3) Analysis and interpretation of data: Junfang Teng, Fei Tian, Jing Jing, Huijin Huang; (4) Drafting the article or revising it critically for important intellectual content: Yingying Su; (5) Final approval of the version to be submitted: All authors.

Declaration of patient consent

Not applicable.

Data availability statement

Data sharing not applicable to this article as no datasets were generated and/or analyzed during the current study.

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Nil.

Conflicts of interest

Dr. Liping Liu is an Editorial Board member of Brain Circulation. The article was subject to the journal's standard procedures, with peer review handled independently of this Editorial Board member and their research groups.

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