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ORIGINAL ARTICLE

The Italian hub-and-spoke network for the emergency neurology management

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Abstract

Objective The aim of the presentstudy was to assess emergency neurology management in Italy by comparing patients admitted to the hub and spoke hospitals.

Methods Data obtained from the annual Italian national survey (NEUDay) investigating the activity and facilities of neurology in the emergency room conducted in November 2021 were considered. Information for each patient who received a neurologic consultation after accessing the emergency room was acquired. Data on facilities were also gathered, including hospital classification (hub vs spoke), number of consultations, presence of neurology and stroke unit, number of beds, availability of neurologist, radiologist, neuroradiologist, and instrumental diagnostic accessibility.

Results Overall, 1,111 patients were admitted to the emergency room and had neurological consultation across 153 facilities (out of the 260 Italian ones). Hub hospitals had significantly more beds, availability of neurological staff, and instrumental diagnostic accessibility. Patients admitted to hub hospital had a greater need for assistance (higher number of yellow/red codes at neurologist triage). A higher propensity to be admitted to hub centers for cerebrovascular problems and to receive a diagnosis of stroke was observed.

Conclusions The identification of hub and spoke hospitals is strongly characterized by the presence of beds and instrumentation mainly dedicated to acute cerebrovascular pathologies. Moreover, the similarity in the number and type of accesses between hub and spoke hospitals suggests the need to look for adequate identification of all the neurological pathologies requiring urgent treatment.

Keywords NEUDay · Neurological disorders · Italian Neurological Wards · Emergency · Hub and Spoke Hospital model

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Introduction

Neurologicaldisorders are a major public health concern in the emergency setting because they are a common cause of access in emergency rooms [1] and are associated with poor prognosis [2, 3] and higher costs [4]. In order to identify the underlying condition and establish the best treatment, and thus improve the patients' prognosis, a thorough and timely assessment is crucial. Therefore, a consultation with a neurologist is essential for facing the complex management of these patients [5].

In Italy, emergency neurology management is arranged according to the hub-and-spoke organization design [6]. Briefly, hospitals are classified into two categories according to health services provided, availability of specialists, and instrumental diagnostic accessibility: the level 2 facilities, called hub centres, which offer a full range of services, and the level 1 facilities, called spoke centres, which offer limited services (or offer them for a limited numbers of hours per day and days per week). Thus, complex medical services are provided by a few hub centres, whereas basic healthcare services are broadly distributed across hospitals. The rationale is that main healthcare needs are addressed locally (at the spoke centres), and only patients who require specialized care are moved to the hub centres [7].

An annual national survey called "NEUDay" is carried out by the Italian Association for Emergency Neurology to investigate the role of neurologists in emergency rooms [8]. Using the data collected from the 2021 survey, we assessed emergency neurology management in Italy by comparing patients admitted to the hub and spoke centres in terms of the reason for the consultation, appropriateness of the consultation, and exams performed.

Methods

NEUDay survey

The NEUDay survey, promoted by the Italian Association for Emergency Neurology and endorsed by the Italian Society of Neurology and the Italian Society of Hospital Neurosciences, is carried out to assess the role of neurologists in emergency rooms in Italy. All hospitals that had an emergency department were invited to participate in the survey, and a referring neurologist was identified in each facility. A questionnaire was administered to acquire information for each patient who received a neurologic consultation after accessing the emergency room. The questionnaire includes questions on demographic characteristics, arrival mode, triage level, reason for the consultation, and neurological evaluation. Further details on the NEUDay survey are available in a previous paper [9].

The data used for the present study were retrieved from the 2021 survey carried out on November 29. In this survey, data on the facility were also gathered. In particular, data included:

- Hospital classification (hub vs spoke);
- Number of consultations;
- Presence of neurology ward and stroke unit;
- Number of beds (total, stroke, and for emergency care);
- Availability of neurologist, radiologist, and neuroradiologist;
- Instrumental diagnostic accessibility (electroencephalogram, cerebrospinal fluid analysis, ultrasound evaluation of the supra-aortic trunks, transcranial Doppler or Transcranical Color-Coded Sonography, brain non contrast computed tomography (NC-CT), advanced neuroimaging (CT Angiography, CT Perfusion imaging), brain magnetic resonance imaging (MRI), organized protocol for sharing neuroimaging studies between spokes and hubs.

Study cohort

Overall, 1111 patients were admitted to the emergency room and had a neurological consultation across 153 facilities (out of the 260 Italian facilities). However, the facility data section was filled by only 79 centres. Because there was no evidence that individuals treated in a facility with available data differed from those for which these data were missing (Supplementary Tables S1-S5), the results from the analyses of patients with all available data were included in the present study.

Data analysis

Summary statistics are expressed as means (standard errors), median (interquartile range), or frequencies (percentages), as appropriate. Descriptive statistics for both hospital and patient variables were compared between groups (i.e., hub vs spoke). Comparisons between groups for continuous variables were performed with the *t* test or with the Mann-Whitney test, whereas the chi-square test, or its version for the trend, was calculated for categorical variables.

All analyses were performed using the Statistical Analysis System Software (version 9.4; SAS Institute, Cary, NC). For all hypotheses tested, a two-tailed p value < 0.05 was considered significant.

Results

Facilities

Among the 79 facilities with available data, 50 were classified as spoke and 29 as hub. Table 1 shows the characteristics of the facilities. Compared to spoke facilities, hub hospitals had significantly more beds (both total and stroke beds), more availability of neurological staff (neurologist and neuroradiologist), and instrumental diagnostic accessibility (EEG, carotid and vertebral artery spectral Doppler, perfusion imaging, and cerebral magnetic resonance imaging).

Participants

The characteristics of the cohort members are shown in Table 2 according to hospital classification. The mean age was 62 years, and 50% were women. Regarding comorbidities and previous acute events, about one in three patients had hypertension, one in six patients experienced an acute myocardial infarction, and one in seven patients had diabetes. There were no differences in the characteristics distribution between groups. Eight (1.3%) patients were positive for SARS-CoV-2 infection.

Almost 60% of the patients arrived by ambulance (56% spoke vs 59% hub, p value = 0.390) and were accompanied (56% spoke vs 60% hub, p value = 0.366), with no differences between groups. The median time from the request to neurological consultation was 38 min (13–84 min) in spoke hospitals and 39 min (15–75 min) in hub hospitals (p value = 0.925).

Triage levels and appropriateness of the consultation

The distributions of triage levels determined by emergency physicians did not differ between groups (Fig. 1, left panel). About one in five patients was classified with a red code (immediate), while only 3% with a white code (expectant). Conversely, the triage levels determined by neurologists showed that, compared with patients admitted to spoke hospitals, those admitted to hub hospitals had a greater need for assistance (Fig. 1, right panel) ($p = 0.015$): the percentage of patients who received a yellow/red code (urgent/immediate) was 53% in the first and 65% in the second group, respectively.

The appropriateness of the consultation was similar between groups (p value = 0.056). Neurologists judged 76% of consultation requests to be pertinent, 22% partially pertinent, and 2% not pertinent.

Reasons for the consultation, examinations, and diagnoses

The reasons for consultation are reported in Table 3. The largest differences were observed for neurological deficits (22% vs 31%), epileptic manifestation (6% vs 12%), headache (10% vs 6%), dizziness (10% vs 6%), strength deficiency or sensory disturbances (5% vs 8%), and head trauma (9% vs 1%). By classifying the reasons for consultation into vascular-related ("strength deficiency or sensory disturbances," "focal neurological deficits," and "acute visual disturbances") and neurological-related (all other reasons reported in Table 3 except "Other"), there was a higher propensity to be admitted to hub centres for conditions in the vascular area (42% hub vs. 29% spoke) than in the neurological area (54% hub vs. 66% spoke) ($p = 0.007$).

Overall, no significant differences were observed in the examinations carried out in the two groups (Fig. 2).

Table 4 shows the diagnoses formulated by neurologists. The diagnostic hypotheses that showed major differences were ischemic stroke (15% vs 20%), primary headache (9% vs 4%), peripheral vertigo (7% vs 3%), monoradicular-plexopathy (2% vs 6%), and head trauma (9% vs 0%).

Discussion

Our study highlights the higher level of resource availability and expertise of hub centres compared to spoke providers. Indeed, the NEUDay survey showed that hub centres have a higher availability of beds, personals (neurologist and neuroradiologist), and instrumental diagnostic accessibility (EEG, carotid and vertebral artery spectral Doppler, perfusion imaging, cerebral magnetic resonance imaging). This is in line with the definition of the hub-and-spoke organization [7], and with national and international observations [10, 11].

The neurology of the Level II Hospital (hub in the hub&spoke functional model) is characterized by the presence of a Stroke Unit and of the specific diagnostic and therapeutic resources (CT, AngioCT, diffusion-perfusion MRI) for elective treatment of cerebrovascular emergencies. Of course, this setting is not always functional for non-vascular neurology. Therefore, a framing and a more accurate definition of the resources of the Emergency Neurology setting must be the first step for a more appropriate definition of that neurological semi-intensive area, postulated in recent years and comprising a Stroke Unit and Emergency Neurology, capable of defining, treating, and managing also non-vascular cases of neurological urgency. Indeed, albeit a consensus statement to define the providers' organization was published in Italy

Table 1 Characteristics of facilities according to the hospital classification

	Total $N=79$	Level 1 (spoke) $N=50$	Level 2 (hub) $N=29$	p value
Total hospital beds				0.002
0	3 (3.8%)	2 (4.0%)	1 (3.5%)	
1–10	11 (13.9%)	10 (20.0%)	1 (3.5%)	
11–20	43 (54.4%)	31 (62.0%)	12 (41.4%)	
> 20	22 (27.9%)	7 (14.0%)	15 (51.7%)	
Hospital beds available for emergency care				0.909
0	11 (13.9%)	8 (16.0%)	3 (10.3%)	
1–4	15 (19.0%)	11 (22.0%)	4 (13.8%)	
5–8	15 (19.0%)	10 (20.0%)	5 (17.2%)	
Missing	38 (48.1%)	21 (42.0%)	17 (58.6%)	
Stroke beds				0.001
0	5 (6.3%)	5 (10.0%)	0 (0.0%)	
1–4	28 (35.4%)	24 (48.0%)	4 (13.8%)	
5–8	32 (40.5%)	17 (34.0%)	15 (51.7%)	
9–12	10 (12.7%)	3 (6.0%)	7 (24.1%)	
> 12	4 (5.1%)	1 (2.0%)	3 (10.3%)	
Availability of neurologist				< 0.001
24 h daily	44 (55.7%)	19 (38.0%)	25 (86.2%)	
12 h daytime + 12 h on call	32 (40.5%)	28 (56.0%)	4 (13.8%)	
Restricted daytime hourly availability	3 (3.8%)	3 (6.0%)	0 (0.0%)	
Availability of neurologist in other facilities				0.173
Some days	27 (34.2%)	21 (42.0%)	6 (20.7%)	
On call	15 (19.0%)	7 (14.0%)	8 (27.6%)	
Telemedicine	10 (12.7%)	5 (10.0%)	5 (17.2%)	
No	27 (34.2%)	17 (34.0%)	10 (34.5%)	
Availability of radiologist				0.152
No hourly limitations (24 h daily)	73 (92.4%)	44 (88.0%)	29 (100.0%)	
Wide daytime availability (6–12 h daily)	3 (3.8%)	3 (6.0%)	0 (0.0%)	
Restricted daytime availability (< 6 h)	3 (3.8%)	3 (6.0%)	0 (0.0%)	
Availability of neuroradiologist				< 0.001
No hourly limitations (24 h daily)	38 (48.1%)	15 (30.0%)	23 (79.3%)	
Wide daytime availability (6–12 h daily)	10 (12.7%)	8 (16.0%)	2 (6.9%)	
Restricted daytime availability (< 6 h)	31 (39.2%)	27 (54.0%)	4 (13.8%)	
EEG				0.001
No hourly limitations (24 h daily)	29 (36.7%)	15 (30.0%)	14 (48.3%)	
Wide daytime availability (6–12 h daily)	37 (46.8%)	31 (62.0%)	6 (20.7%)	
Restricted daytime availability (< 6 h)	13 (16.5%)	4 (8.0%)	9 (31.0%)	
Cerebral spinal fluid analysis				0.213
No hourly limitations (24 h daily)	74 (93.7%)	45 (90.0%)	29 (100.0%)	
Wide daytime availability (6–12 h daily)	3 (3.8%)	3 (6.0%)	0 (0.0%)	
Restricted daytime availability (< 6 h)	2 (2.5%)	2 (4.0%)	0 (0.0%)	
Carotid and vertebral artery spectral Doppler				0.001
No hourly limitations (24 h daily)	25 (31.7%)	10 (20.0%)	15 (51.7%)	
Wide daytime availability (6–12 h daily)	40 (50.6%)	33 (66.0%)	7 (24.1%)	
Restricted daytime availability (< 6 h)	14 (17.7%)	7 (14.0%)	7 (24.1%)	
Transcranial Doppler ultrasound				0.129
No hourly limitations (24 h daily)	8 (10.1%)	4 (8.0%)	4 (13.8%)	
Wide daytime availability (6–12 h daily)	47 (59.5%)	34 (68.0%)	13 (44.8%)	
Restricted daytime availability (< 6 h)	24 (30.4%)	12 (24.0%)	12 (41.4%)	
Cranial computed tomography scan				0.443

Table 1 (continued)

	Total $N=79$	Level 1 (spoke) $N=50$	Level 2 (hub) $N=29$	p value
No hourly limitations (24 h daily)	78 (98.7%)	49 (98.0%)	29 (100.0%)	
Wide daytime availability (6–12 h daily)	1 (1.3%)	1 (2.0%)	0 (0.0%)	
Restricted daytime availability (< 6 h)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Computed tomography angiography				0.275
No hourly limitations (24 h daily)	77 (97.5%)	48 (96.0%)	29 (100.0%)	
Wide daytime availability (6–12 h daily)	2 (2.5%)	2 (4.0%)	0 (0.0%)	
Restricted daytime availability (< 6 h)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Perfusion imaging				< 0.001
No hourly limitations (24 h daily)	33 (41.8%)	9 (18.0%)	24 (82.8%)	
Wide daytime availability (6–12 h daily)	15 (19.0%)	14 (28.0%)	1 (3.4%)	
Restricted daytime availability (< 6 h)	31 (39.2%)	27 (54.0%)	4 (13.8%)	
Cerebral magnetic resonance imaging				< 0.001
No hourly limitations (24 h daily)	34 (43.0%)	9 (18.0%)	25 (86.2%)	
Wide daytime availability (6–12 h daily)	37 (46.8%)	35 (70.0%)	2 (6.9%)	
Restricted daytime availability (< 6 h)	8 (10.1%)	6 (12.0%)	2 (6.9%)	
Neuroimages sharing				0.166
No hourly limitations (24 h daily)	63 (79.7%)	37 (74.0%)	26 (89.7%)	
Wide daytime availability (6–12 h daily)	4 (5.1%)	4 (8.0%)	0 (0.0%)	
Restricted daytime availability (< 6 h)	12 (15.2)	9 (18.0%)	3 (10.3%)	

Table 2 Characteristics of cohort members according to the hospital classification

Characteristics	Level 1 (spoke) $N=326$	Level 2 (hub) $N=270$	p value
Age: mean [SD]	62.3 [22.4]	62.0 [21.7]	0.864
Sex: male	154 (47.2%)	143 (53.0%)	0.164
Diabetes	47 (14.4%)	37 (13.7%)	0.803
Hypertension	112 (34.4%)	103 (38.2%)	0.337
Dyslipidaemia	40 (12.3%)	34 (12.6%)	0.905
Acute myocardial infarction	50 (15.3%)	48 (17.8%)	0.424
Transient ischemic attack	29 (8.9%)	23 (8.5%)	0.871
Mental disorders	22 (6.8%)	15 (5.6%)	0.548
Dementia	28 (8.6%)	22 (8.2%)	0.847
Degenerative disorders of the central nervous system	10 (3.1%)	12 (4.4%)	0.375
Respiratory diseases	17 (5.2%)	16 (5.9%)	0.706
Chronic kidney disease	15 (4.6%)	17 (6.3%)	0.361
Cancer	21 (6.4%)	23 (8.5%)	0.334

[12], no law was promulgated on this issue. Therefore, except for stroke, myocardial infarction, and head injury, Italian law does not define the requirements for the hub centres for non-vascular neurological emergencies [13].

Other two findings regarding the comparison between patients admitted to hub and those admitted to spoke hospitals should be mentioned. First, the arrival mode (i.e., ambulance vs self-presentation, and accompanied vs alone) and the triage level were superimposable between groups. This suggests that more severe patients, either independently or referred through health personnel, did not go to the hub centres. Albeit our data cannot justify the reasons for this result, a possible explanation might be the poor knowledge of the population about the best choice regarding the hospital for their health needs (according to symptoms). This implies that policies aimed at enhancing the information on the hospital network might improve patients' outcomes. Second, there was a higher propensity to be admitted to hub centres for conditions in the vascular area and to receive a diagnosis of stroke. This suggests that patients with (symptoms of) stroke are driven to hub centres, where hyperacute stroke treatments can be performed [14, 15]. However, because the difference between groups is not huge (42% vs 29%), there is room for improvement. A possible explanation for this result is the lack of planning in territorial emergency systems. In Italy, patients are taken to the nearest hospital regardless of its level of resource availability. Although some initiatives to establish an effective network for neurological conditions are ongoing in some Italian Regions [16], an effort should also be pursued to equip emergency services with appropriate models aimed at the identification of these pathological manifestations and algorithms for the best treatment of

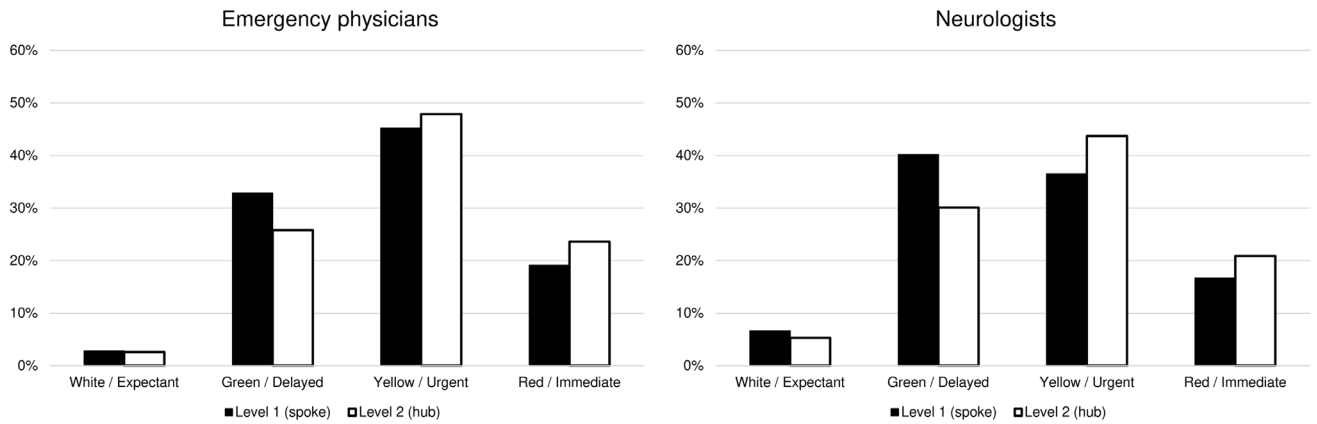

Fig. 1 Percentage distributions of triage level assigned by emergency physicians and neurologists according to the hospital classification

Table 3 Distribution of the reasons for neurological consultation according to the hospital classification

Reason	Level 1 (spoke) $N=326$	Level 2 (hub) $N=270$
Focal neurological deficits	71 (21.8%)	84 (31.1%)
Transient loss of consciousness	39 (12.0%)	33 (12.2%)
Epileptic manifestation	20 (6.1%)	32 (11.9%)
Headache	34 (10.4%)	16 (5.9%)
Delirium/acute confusional state	31 (9.5%)	22 (8.2%)
Dizziness	34 (10.4%)	17 (6.3%)
Strength deficiency or sensory disturbances	16 (4.9%)	22 (8.2%)
Head trauma	28 (8.6%)	2 (0.7%)
Acute visual disturbances	9 (2.8%)	7 (2.6%)
Coma	8 (2.5%)	7 (2.6%)
Movement disorders (hyper or hypokinesia)	5 (1.5%)	5 (1.9%)
Fever and neurological signs	6 (1.8%)	2 (0.7%)
Paraplegia/quadriplegia	3 (0.9%)	5 (1.9%)
Functional/psychiatric disorders	4 (1.2%)	3 (1.1%)
Muscle pain	3 (0.9%)	3 (1.1%)
Other reason	15 (4.6%)	10 (3.7%)

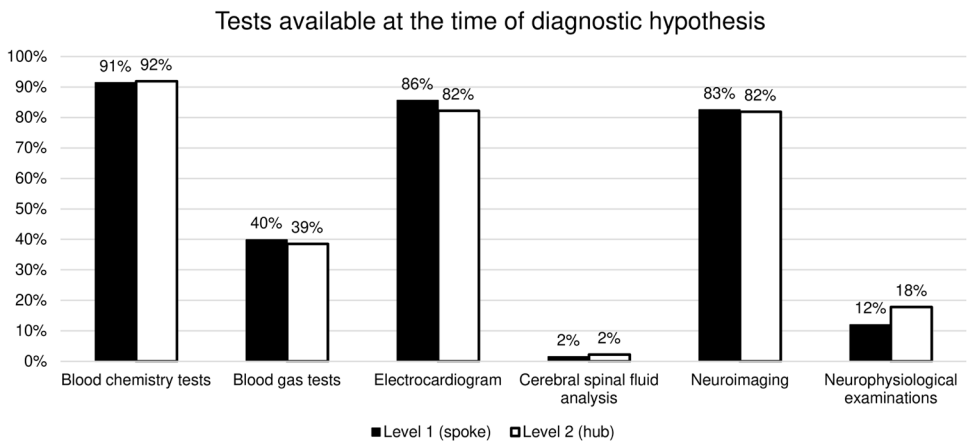

Fig. 2 Tests available at the time of diagnostic hypothesis according to the hospital classification

Table 4 Distribution of diagnostic hypotheses formulated by the neurologists after consultations according to the hospital classification

Diagnostic hypothesis	Level 1 (spoke) $N=326$	Level 2 (hub) $N=270$
Ischemic stroke	50 (15.3%)	55 (20.4%)
Transient ischemic attack	16 (4.9%)	18 (6.7%)
Primary headache	30 (9.2%)	12 (4.4%)
Seizure in known epilepsy	14 (4.3%)	18 (6.7%)
First epileptic seizure	14 (4.3%)	19 (7.0%)
Peripheral vertigo	22 (6.8%)	9 (3.3%)
Cardiogenic syncope	18 (5.5%)	14 (5.2%)
Monoradiculo-plexopathy	8 (2.5%)	17 (6.3%)
Head trauma	28 (8.6%)	1 (0.4%)
Delirium in dementia	15 (4.6%)	6 (2.2%)
Cerebral haemorrhage	9 (2.8%)	12 (4.4%)
Symptomatic headache	9 (2.8%)	7 (2.6%)
Psychiatric disorder	12 (3.7%)	9 (3.3%)
Metabolic encephalopathy	11 (3.4%)	8 (3.0%)
Central vertigo	13 (4.0%)	5 (1.9%)
Neurologic syncope	10 (3.1%)	7 (2.6%)
CNS cancer	6 (1.8%)	9 (3.3%)
Other conditions	41 (12.6%)	44 (16.3%)

them [17, 18], including the choice of the best facility irrespective of the distance from the patient.

Our study has some limitations. First, data sent from the local participants could not be checked. Second, although all hospitals that had an emergency department were invited to participate in the survey ($n=260$), some did not take part ($n=107$) or did not complete the questionnaire ($n=74$). Because we could not compare the characteristics of facilities and patients admitted to responsive and non-responsive hospitals, selection bias cannot be excluded. Finally, the main limitation of our study was that we do not have data on the pathways and outcomes experienced by patients during the hospital stay; thus, we cannot assess the effectiveness of the hub-and-stroke organization design [19, 20].

In conclusion, our study offers a snapshot of emergency neurology management in Italy through the hub-and-spoke network. A detailed description of the availability of the number of beds, personals, and instrumental diagnostic accessibility according to hospital classification was provided. In addition, differences in patients admitted to hub and those admitted to spoke hospitals were highlighted. Future studies are needed to assess the impact of the hub-and-spoke network on patients' outcomes. It is certain, however, that the figure of the emergency neurologist and neurology that has been strengthened in its staffing and equipment will be one of the working tools at the disposal of healthcare in the coming years.

Appendix

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Data availability Data can be obtained by contacting the corresponding author upon reasonable request.

Code availability Statistical analysis was performed using the Statistical Analysis System Software (version 9.4; SAS Institute, Cary, NC, USA). Codes can be obtained by contacting the corresponding author.

Declarations

Ethical approval None.

Informed consent The project and execution of NEUDay 2021 have been notified to all ethical committees of the participating units.

Conflict of interestl The authors declare no competing interests.

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