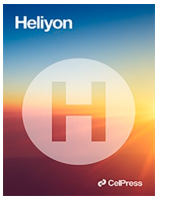
Heliyon 10 (2024) e32175

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Research article

Effect of Nurse's detection of neurological deterioration on the prognosis of patients with acute cerebral infarction

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ARTICLE INFO

Keywords:
Stroke
Cerebral infarction
Nurse
Neurological deterioration
Detection
Prognosis

ABSTRACT

Introduction: There is little evidence about the factors related to the detection of neurological deterioration by nurses. We examined the related factors and therapeutic outcomes of nurses' detections of patient's neurological deterioration.

Methods: This was a descriptive retrospective study. We included 549 adult stroke patients who were admitted to the acute stroke unit of a tertiary hospital between May 2018 and December 2019 and had changes in neurological symptoms that were detected by stroke nurses. We measured the following outcomes: stroke lesion progression, early neurological deterioration (increase in the total national institutes of health stroke scale score of 2 points or more, increase in the limb weakness score of 1 point or more, or decrease in the alertness score of 1 point or more), and additional clinical management (increasing intravenous fluids, diagnostic imaging, or neuro-intervention). Data was analyzed by logistic regression.

Results: A total of 651 new or aggravating symptoms were detected by nurses. The most detected symptom was motor aggravations (49.2 %). Symptoms were commonly detected during the day shift (51.0 %) and by scheduled neurochecks (71.3 %). Of 132 patients who underwent diagnostic imaging by nurses' detection, 63.6 % cases had stroke lesion progression. Nursing experience over 4 years was positively associated with finding stroke lesion progression (OR: 2.49, 95 % CI = 1.09–5.67). Early neurological deterioration was found in 70.7 %, and it was significantly higher during scheduled neurochecks (OR:2.65, 95 % CI = 1.04–6.72) and in the group of large artery atherosclerosis (OR: 2.19, 95 % CI = 1.06–4.49) Additional clinical management was provided to 49.9 % of detection, and scheduled neurocheks (OR: 4.76, 95 % CI = 2.18–10.39) and changes of alertness (OR: 2.89, 96 % CI = 1.51–5.26) were the significant factors.

Conclusion: Stroke nurses were able to detect a large number of stroke lesion progression and early neurological deterioration as well as to provide additional clinical management. Systematic guidelines for qualification of stroke nurses may be beneficial.

1. Introduction

Stroke is one of the top five causes of disability worldwide [1], and is responsible for severe functional and quality-of-life

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https://doi.org/10.1016/j.heliyon.2024.e32175
Received 19 April 2023; Received in revised form 24 May 2024; Accepted 29 May 2024
Available online 5 June 2024

impairment, which leads to disabilities in daily life [2]. Impairment after an acute stroke occurs in multiple conditions, including speech, language, dysphagia, incontinence, visual impairment, and physical impairment [1]. Notably, early detection of neurological symptom changes and intervention is critical to prevent further decline of physical and emotional conditions during the acute phase of stroke [1].

Assessing neurological symptoms in patients with acute cerebral infarction is one of the most basic aspects of nursing care. Early neurological deterioration (END) refers to the clinical worsening or recurrence in the acute stage of ischemic stroke [3–6], and is a common complication worldwide. The consequences of END are critical as they result in a worse quality of life and functional outcome in stroke patients [4,7,8]. The rate of END ranges from 15 % to 37 % across different populations [5,9]. Symptomatic changes in patients with acute cerebral infarction can be detected in their early stages by nurses [10]. Identifying clinically significant factors among the findings of nurses can make the patient more aware of the cause of deterioration, which can lead to a better prognosis.

Among different types of healthcare workers, nurses are often those who can detect the worsening of symptoms at the earliest stages [11–13]. Early detection of symptom changes leads to a better quality of treatment for stroke patients [10,12,13]. Accordingly, in the acute stroke unit (ASU), nurses are trained in various ways (e.g., videos and scenarios) to assess patients using the National Institutes of Health Stroke Scale (NIHSS) score [11,14,15], which significantly affects the predictive rate of deterioration by nurses [10,11,13,14]. Therefore, nurses who see stroke patients on a daily basis have an important role in accurately assessing the patient's condition and quickly detecting changes in symptoms. Although it is essential for nurses to check the status of stroke patients using the NIHSS score [10,11,13], there are only a few studies examining the effects of nurses' detection of END on therapeutic outcomes. Furthermore, understanding the factors related to the nurses' detection of END may be helpful in improving the rate of early detection and optimal management.

The purpose of this study is to explore the clinical effects of nurses' detection on the changes in neurological symptoms among acute stroke patients with the objectives below.

1) To determine the symptoms detected by nurses and their related factors
2) To assess the factors related to the presence of stroke lesion progression
3) To determine the factors related to the presence of END
4) To assess the factors related to the presence of additional clinical management

2. Methods

2.1. Study design, patients, and data collection

This was a descriptive study based on retrospective data analysis using electronic medical records. We included adult (age $\geq$18 years) Stroke patients who were admitted to the ASU at Asan Medical Center (Seoul, South Korea) between May 1, 2018 and December 31, 2019 and whose neurological symptoms were detected by a nurse. We included patients with both clear and unclear symptom onset. We excluded patients whose final diagnosis at discharge was not stroke. The indications of the ASU admission from the center protocol were as belows.

- Patients with acute stroke whose symptoms manifest within 72 h.
- Patients whose NIHSS score worsens by 1 point or more, even if more than 72 h have passed since symptom onset.
- Patients with acute stroke who have experienced a recent recurrence or worsening within the last week after the acute phase, and whose condition is unstable, requiring intensive monitoring.
- Patients who have received intravenous thrombolysis for acute stroke treatment.

All data were collected through the electronic medical record including the nursing record, NIHSS score record, laboratory sheet, progress record, doctor's order sheet, medication record, admission record, and discharge record. The collected data include sex, age, hospitalization date, discharge date, NIHSS score and modified Rankin scale (mRS) at admission and at discharge, stroke lesion location (anterior circulation, posterior circulation, and multiple territories), Trial of ORG 10172 in Acute Stroke Treatment (TOAST) classification at discharge, date of detected symptom, neurological symptoms (alertness, aphasia, neglect, limb weakness, dysarthria, facial palsy, sensory, visual disturbance, ataxia), NIHSS scores before and after the time of detection, situation of detection (admission to the ASU, scheduled neurocheck, additional neurocheck, and patient's complaint), shift (day; 7 a.m.-3 pm, evening; 3 p.m.–11 p.m., night; 11 p.m.-7 am), additional clinical management (observation, increasing intravenous fluids, neuro-intervention, taking images), and MR/CT results. Nurses' working years in neurology units were obtained by checking both nursing records and data from the nursing unit regarding the year of appointment to the neurology department.

Using G-power analysis 3.1.9, the sample size was calculated with odds ratio = 1.3, α probability = 0.05, and power = 0.8 for determining the predictive rate of deterioration and the primary outcome variable. As a result, the minimum sample size needed was 568. In this study, 651 cases of neurological symptoms were found in a total of 549 patients, which were finally analyzed.

2.2. Measurements

Neurological symptom. Newly developed or aggravating neurological symptoms were divided into five categories classified in NIHSS scoring system as follows: alertness, cortical sign (visual field defect, aphasia, neglect) [16], motor (limb weakness, dysarthria,

facial palsy) [17], sensory, and posterior circulation sign (gaze limitation, ataxia) [18]. We also examined cases that showed symptoms in two or more categories.

Experienced nurse. We divided the nurses according to their level of experience at neurology units by referring to a previous study [19] as follows: novice (1–3 years) and experienced (over 4 years); the contents of nursing work were not different according to the level of experience, and all nurses undertook the same type of nursing work.

Scheduled neurocheck. Neurocheck refers to neurological assessment according to the NIHSS score. The scheduled neurocheck was defined as follows. Patients received a scheduled neurocheck every 4 h except for the following cases in which neurology exams were performed every 2 h: (1) continuous administration of phenylephrine hydrochloride drug, (2) within 24 h of the cerebrovascular procedure, and (3) within 24 h of administration of tissue plasminogen activation.

NIHSS score. NIHSS score was measured from 0 to 42 points in total depending on the severity of symptoms, with higher scores indicating higher neurological severity [20]. NIHSS scores were measured by trained stroke nurses. It categorized as mild (0–6), moderate (7–15), or severe (over 16) as a previous literature [21,22].

mRS. mRS represents the degree of disability after stroke. mRS score of 0–2 indicates the degree of disability that does not require assistance in daily life, a score of 3–5 indicates the need for assistance in daily living, and a score of 6 indicates death [23].

TOAST classification. TOAST classification is categorized according to the stroke etiology as follows [24]: large artery atherosclerosis (LAA), small vessel occlusion (SVO), cardio embolism (CE), other determined (OD), and undetermined (UD).

2.3. Outcome variables

1) ***Stroke lesion progression.*** The presence of stroke lesion progression indicates that stroke lesion extension or new stroke lesion was found in follow-up MR or CT. The results were judged by experienced neuro-radiologists.
2) ***Early neurological deterioration (END).*** As defined by the guidelines of the Korea Stroke Registry [25], END was defined as an increase in the total NIHSS score of 2 points or more, an increase in the limb weakness score of 1 point or more, or a decrease in the alertness score of 1 point or more. These criteria represent a standard that is representative of stroke treatment guidelines in South Korea and generally in line with international standards worldwide in stroke care [26–28]. Studies on END have primarily focused on the anterior circulation, while it is widely acknowledged that the NIHSS score has limitations in evaluating the neurological severity of the posterior circulation. Nevertheless, there remains a lack of viable alternatives for its assessment, and presently, it is also utilized in defining END within the posterior circulation [29–31]. Hence, in this study, we aim to define END based on the NIHSS score for both anterior and posterior circulation, conducting research on END in both circulations. However, due to possible collinearity between lesion location and TOAST classification, lesion location was excluded from the multivariable analysis and presented only in the supplementary materials. The END was assessed continuously (additional neurocheck and at patient's complaint) and at specific time points (at admission to the ASU and scheduled neurocheck) in this study.
3) ***Additional clinical management.*** We examined increases in intravenous fluids, image taking (CT or MR), and neuro-intervention (increasing intravenous fluids or image taking). In our study, neuro-intervention included stent insertion, angioplasty, and thrombectomy in the brain.

Table 1
General characteristics of the study patients.

Characteristics		N = 549
Age (years)		68.9 ± 12.6
Male sex		330 (60.1)
Onset to door time (hours) in clear onset patients		15.2 (0.3–358.8), n = 489 (89.1)
Comorbidities	Hypertension	362 (65.9)
	Diabetes mellitus	211 (38.4)
	Hyperlipidemia	229 (41.7)
	Herat disease	192 (34.5)
	Previous stroke	147 (26.8)
	Current smoker	203 (37.0)
NIHSS score at admission		1 (0–7)
Stroke lesion location	Anterior circulation	360 (65.6)
	Posterior circulation	162 (29.5)
	Multiple lesions	21 (3.8)
TOAST classification	LAA	157 (28.6)
	SVO	146 (26.6)
	CE	98 (17.9)
	UD	93 (16.9)
	Other	55 (10.0)
NIHSS score on discharge		5 (2–8)
mRS on discharge		3 (2–4)
Detection of symptoms from admission to the ASU, days		2.7 ± 2.8

Data are mean ± standard deviation, median (interquartile range), or N (%).
CE; cardio embolism, LAA; large artery atherosclerosis, mRS; Modified Rankin Scale, NIHSS; National Institutes of Health Stroke Scale, SD; standard deviation, SVO; small vessel occlusion, TOAST; Trial of ORG 10172 in Acute Stroke Treatment, UD; undetermined.

2.4. Data analysis

The data was analyzed using the SPSS/WIN 20.0 program, with statistical significance determined by two-sided tests at a p-value of < 0.05 for overall analyses in our study. Descriptive statistics, including mean, standard deviation, and frequency and percentage, were used for descriptive data: demographic characteristics (age, sex), and factors related to early symptom detection. The Chi-squared test was first performed to examine the association between each risk factor (categorical) and our three primary outcomes as categorical variables (presence of stroke lesion progression, END, and additional clinical management) as univariate analyses. Then, to examine the strengths of the effect of factors related to early symptom detection on the three main outcome variables, we conducted multivariable logistic regression for each primary outcome. For the multivariate logistic regression, we only included variables potentially showing significant associations with outcome variables in the univariate analysis. Specifically, when we chose independent variables for the multivariate logistic regression, we used a $p < 0.10$ as a cutoff point to ensure that potentially important predictors are not omitted from the multivariate analysis.

3. Results

3.1. General characteristics

During the study period, 549 patients showed a total of 651 newly developed or aggravating neurological symptoms that were

Table 2
Symptoms detected by nurses and the related factors.

Factors		symptoms						
		Alertness	Motor	Cortex sign	Posterior circulation sign	Sensory	≥2 categories	Total
Neurological working years	1–3 years	25 (65.8)[a]	181 (56.6)[a]	36 (53.7)[a]	60 (60.0)[a]	22 (71.0)[a]	48 (50.5)[a]	372 (57.1)[b]
	Over 4 years	13 (34.2)[a]	139 (43.4)[a]	31 (46.3)[a]	40 (40.0)[a]	9 (29.0)[a]	47 (49.5)[a]	279 (42.9)[b]
Shift	Day	29 (76.3)[a]	156 (48.8)[a]	27 (40.3)[a]	58 (58.0)[a]	20 (64.5)[a]	42 (44.2)[a]	332 (51.0)[b]
	Evening	5 (13.2)[a]	83 (25.9)[a]	15 (22.4)[a]	24 (24.0)[a]	6 (19.4)[a]	30 (31.6)[a]	163 (25.0)[b]
	Night	4 (10.5)[a]	81 (25.3)[a]	25 (37.3)[a]	18 (18.0)[a]	5 (16.1)[a]	23 (24.2)[a]	156 (24.0)[b]
Situation	Admission to the acute stroke unit	2 (5.3)[a]	40 (12.5)[a]	7 (10.4)[a]	25 (25.0)[a]	5 (16.1)[a]	29 (30.5)[a]	108 (16.6)[b]
	Scheduled neurocheck	24 (63.2)[a]	245 (76.6)[a]	53 (79.1)[a]	66 (66 0)[a]	20 (64.5)[a]	56 (58.9)[a]	464 (71.3)[b]
	Nurse's additional neurocheck	5 (13.2)[a]	14 (4.4)[a]	6 (9.0)[a]	8 (8.0)[a]	2 (6.5)[a]	9 (9.5)[a]	44 (6.8)[b]
	Patient's own complaints	7 (18.4)[a]	21 (6.6)[a]	1 (1.5)[a]	1 (1.0)[a]	4 (12.9)[a]	1 (1.1)[a]	35 (5.4)[b]
TOAST	LAA	9 (23.7)[a]	101 (31.6)[a]	21 (31.3)[a]	28 (28.0)[a]	7 (22.6)[a]	35 (36.8)[a]	201 (30.9)[b]
	SVO	4 (10.5)[a]	106 (33.1)[a]	5 (7.5)[a]	30 (30.0)[a]	11 (35.5)[a]	19 (20.0)[a]	175 (26.9)[b]
	CE	10 (26.3)[a]	35 (10.9)[a]	22 (32.8)[a]	22 (22.0)[a]	5 (16.1)[a]	16 (16.8)[a]	110 (16.9)[b]
	UD	11 (28.9)[a]	52 (16.3)[a]	9 (13.4)[a]	14 (14.0)[a]	5 (16.1)[a]	13 (13.7)[a]	104 (16.0)[b]
	OD	4 (10.5)[a]	26 (8.1)[a]	10 (14.9)[a]	6 (6.0)[a]	3 (9.7)[a]	12 (12.6)[a]	61 (9.4)[b]
Additional clinical management	Observation	13 (34.2)[a]	146 (45.6)[a]	41 (61.2)[a]	65 (65.0)[a]	18 (58.1)[a]	43 (45.3)[a]	326 (50 1)[b]
	Increasing intravenous fluids	2 (5.3)[a]	130 (40.6)[a]	12 (17 0.9)[a]	17 (17.0)[a]	13 (41 9)[a]	27 (28.4)[a]	201 (30.9)[b]
	Taking image only	13 (34.2)[a]	30 (9.4)[a]	7 (10.4)[a]	10 (10.0)[a]	0 (0.0)[a]	14 (14.7)[a]	74 (11.4)[b]
	Taking image & increasing intravenous fluids	4 (10.5)[a]	5 (1.6)[a]	3 (4.5)[a]	4 4.0)[a]	0 (0.0)[a]	6 (6.3)[a]	22 (3.4[a])[b]
	Neuro-intervention	6 (15.8)[a]	9 (2.8)[a]	4 (6.0)[a]	4 (4.0)[a]	0 (0.0)[a]	5 (5.3)[a]	28 (4.3)[b]
Total		38 (5.8)[c]	320 (49.2)[c]	67 (10.3)[c]	100 (15.4)[c]	31 (4.8)[c]	95 (14.6)[c]	651 (100.0)

Data are n (%), CE; cardio embolism, LAA; large artery atherosclerosis, OD; other determined, SVO; small vessel occlusion, TOAST; Trial of ORG 10172 in Acute Stroke Treatment, UD; undetermined.

[a] percentages according to symptoms.

[b] percentages according to factors.

[c] percentages according to total cases.

Table 3
Factors related to stroke lesion progression.

		Taking image	Stroke lesion progression	Stroke lesion progression rate (%)	p^a	Univariate analysis			Multivariate analysis		
						OR	95 % CI	p	OR	95 % CI	p
Age (year)	≥80	22	11	50.0	0.491	Reference					
	20≤ <40	4	3	75		1.40	0.05-0.43.17	0.849			
	40≤ <60	23	16	69.6		1.88	0.26–13.57	0.532			
	60≤ <80	83	54	65.1		1.08	0.23–5.09	0.923			
Gender	Female	48	30	62.5		Reference					
	Male	84	54	64.3	0.837	0.66	0.20–2.17	0.490			
Onset to door time	<72 h	9	4	44.4		Reference					
	72 h≤ <7 days	75	45	60.0		1.36	0.15–12.14	0.781			
	≥7 days	39	29	74.4	0.151	2.40	0.26–22.00	0.440			
Comorbidities	Hypertension	96	59	61.5	0.396	0.77	0.21–2.79	0.687			
	Diabetes Mellitus	48	34	70.8	0.194	2.56	0.78–8.39	0.120			
	Hyperlipidemia	53	37	69.8	0.227	2.29	0.70–7.50	0.172			
	Heart disease	39	24	61.5	0.746	1.35	0.36–5.09	0.659			
	Previous stroke	32	20	62.5	0.878	0.79	0.24–2.64	0.704			
	Current smoker	40	25	65.2	0.858	1.50	0.43–5.28	0.527			
NIHSS score at admission	≥16	6	2	33.3	0.210	Reference			Reference		
	0–6	98	62	74.2		96.30	2.63–3530.21	**0.013**	0.73	0.26–2.08	0.559
	7–15	28	20	71.4		62.57	1.67–2348.40	**0.025**	11.65	1.46–93.69	**0.021**
Detected symptoms	Alertness	24	13	54.2		Reference					
	Motor	46	27	58.7		0.98	0.22–4.48	0.983			
	Cortex sign	17	13	76.5		0.18	0-02-1.59	0.122			
	Posterior circulation sign	18	12	66.7		0.58	0.08–4.08	0.584			
	Two or more categories	27	19	70.4	0.521	0.47	0.08–2.88	0.413			
Neurological working years	1–3 years	72	41	56.9		Reference			Reference		
	Over 4 years	60	43	71.7	0.080	2.87	0.98–8.40	**0.055**	2.49	1.09–5.66	**0.030**
Shift	Night	21	12	57.1		Reference					
	Day	82	54	65.9		2.88	0.59–14.08	0.192			
	Evening	29	18	62.1	0.745	4.39	0.73–26.27	0.105			
Situation	Patient's own complaints	12	5	41.7		Reference			Reference		
	Scheduled neurocheck	88	57	64.8		6.87	1.02–46.25	**0.048**	2.98	0.49–18.28	0.238
	Admission to the acute stroke unit	16	10	62.5		1.75	0.22–13.93	0.598	1.43	0.38–5.33	0.596
	Nurse's additional neurocheck	16	12	75.0	0.327	24.21	1.75–335.88	**0.018**	2.67	0.49–14.48	0.256
TOAST	SVO	17	6	35.3		Reference			Reference		
	LAA	39	24	61.5		6.16	1.23–30.93	**0.027**	36.62	4.86–275.99	**<001**
	CE	30	22	73.3		19.56	2.99–128.01	**0.002**	15.10	2.33–97.78	**0.004**
	UD	24	12	50.0		2.85	0.49–16.58	0.244	5.75	0.88–37.42	0.067
	OD	22	20	90.9	**0.003**	93.36	7.95–1096.24	**<0.001**	21.37	3.11–147.01	**0.002**
Total		132	84	63.6	**<0.001**						

CI; confidential interval, CE; cardio embolism, LAA; large artery atherosclerosis, OD; other determined, NIHSS; National institute of health stroke scale, OR; odds ratio, SVO; small vessel occlusion, TOAST; Trial of ORG 10172 in Acute Stroke Treatment, UD; undetermined·

[a] was based on chi-square test.

Table 4
Factors related to early neurological deterioration.

		Detected case	END	END rate (%)	p^a	Univariate analysis			Multivariate analysis		
						OR	95 % CI	*p*	OR	95 % CI	*p*
Age (year)	20≤ <40	13	10	76.9		Reference					
	40≤ <60	122	79	64.8		1.29	0.28–5.85	0.746			
	60≤ <80	405	285	70.4		1.59	0.36–7.05	0.541			
	≥80	111	86	77.5	0.187	1.94	0.41–9.17	0.403			
Gender	Female	256	184	71.9		Reference					
	Male	395	276	69.9	0.584	1.05	0.71–1.55	0.817			
Onset to door time	<72 h	52	40	76.9		Reference					
	72 h≤ <7 days	328	227	69.2		0.70	0.33–1.48	0.354			
	≥7 days	212	152	71.7	0.490	0.82	0.38–1.77	0.609			
Comorbidities	Hypertension	442	317	71.7	0.388	1.04	0.68–1.58	0.857			
	Diabetes Mellitus	250	177	70.8	0.951	1.16	0.77–1.73	0.482			
	Hyperlipidemia	278	192	69.1	0.440	0.85	0.58–1.25	0.404			
	Heart disease	132	93	70.5	0.954	0.96	0.58–1.57	0.867			
	Previous stroke	164	16	70.7	0.982	1.05	0.68–1.63	0.834			
	Current smoker	242	168	69.4	0.593	1.00	0.68–1.47	0.995			
NIHSS score at admission	0–6	505	340	67.3		Reference			Reference		
	7–15	122	99	81.1		1.88	1.11–3.19	**0.019**	2.79	0.80–9.77	0.109
	≥16	24	21	87.5	**0.006**	4.58	1.00–20.97	**0.050**	1.51	0.41–5.62	0.540
Neurological working years	1–3 years	372	258	69.4		Reference					
	Over 4 years	279	202	72.4	0.434	1.17	0.80–1.72	0.426			
Shift	Day	332	233	70.2		Reference					
	Evening	163	116	71.2		0.0.92	0.58–1.47	0.726			
	Night	156	111	71.2	0.963	0.92	0.58–1.46	0.731			
Situation	Patient's own complaints	35	14	40.0		Reference			Reference		
	Scheduled neurocheck	464	341	73.5		3.45	1.57–7.60	**0.002**	2.65	1.04–6.72	**0.040**
	Admission to the acute stroke unit	108	76	70.4		3.15	1.30–7.64	**0.011**	0.66	0.341.29	0.224
	Nurse's additional neurocheck	44	29	65.9	**<0.001**	1.97	0.72–5.41	0.188	0.76	0.35–1.63	0.479
TOAST	SVO	175	108	61.7		Reference			Reference		
	LAA	201	147	73.1		1.42	0.88–2.30	0.153	2.19	1.06–4.49	**0.033**
	CE	110	82	74.5		1.26	0.70–2.25	0.446	1.41	0.692.90	0.347
	UD	104	74	71.2		1.40	0.78–2.49	0.258	1.48	0.68–3.24	0.327
	OD	61	49	80.3	**0.028**	2.30	1.04–5.09	**0.039**	1.53	0.70–3.33	0.284
Total		651	460	70.7	**<0.001**						

CI; confidential interval, CE; cardio embolism, END; early neurological deterioration, LAA; large artery atherosclerosis, OD; other determined, NIHSS; National institute of health stroke scale, OR; odds ratio, SVO; small vessel occlusion, TOAST; Trial of ORG 10172 in Acute Stroke Treatment, UD; undetermined.

[a] was based on chi-square test.

Table 5
Factors related to additional clinical management.

		Detected case	Additional management	Rate of additional clinical management (%)	p^a	Univariate analysis			Multivariate analysis		
						OR	95 % CI	p	OR	95 % CI	p
Age (year)	20≤ <40	13	6	46.2		Reference					
	40≤ <60	122	71	58.2		2.88	0.70–11.89	0.143			
	60≤ <80	405	194	47.9		1.82	0.46–7.28	0.395			
	≥80	111	54	48.6	0.246	2.20	0.53–9.21	0.281			
Gender	Female	256	128	50.0		Reference					
	Male	395	197	49.9	0.975	1.10	0.76–1.59	0.631			
Onset to door time	<72 h	52	31	59.6		Reference					
	72 h≤ <7 days	328	156	47.6		0.73	0.37–1.42	0.352			
	≥7 days	212	106	50.0	0.267	0.88	0.44–1.79	0.725			
Comorbidities	Hypertension	229	213	48.2	0.161	1.38	0.93–2.07	0.114			
	Diabetes Mellitus	250	124	49.6	0.896	0.95	0.65–1.39	0.792			
	Hyperlipidemia	278	131	47.1	0.217	0.78	0.54–1.12	0.172			
	Heart disease	132	75	56.8	0.076	1.61	0.10–2.60	0.051	1.53	1.02–2.31	**0.041**
	Previous stroke	164	87	53.0	0.355	1.14	0.76–1.74	0.513			
	Current smoker	242	122	46.3	0.153	0.81	0.56–1.17	0.259			
NIHSS score at admission	0–6	505	259	51.3		4.58	1.40–15.05	0.012	3.25	1.13–9.37	**0.029**
	7–15	122	60	49.2		3.26	0.96–11.02	0.058	0.78	0.51–1.18	0.240
	≥16	24	6	25.0	0.085	Reference			Reference		
Detected symptoms	Posterior circulation sign	100	35	35.0		Reference			Reference		
	Alertness	38	25	65.8		4.83	1.97–11.86	**0.001**	2.89	1.58–5.26	**0.001**
	Motor	320	174	54.4		2.48	1.47–4.18	**0.001**	0.68	0.29–1.57	0.365
	Cortex sign	67	26	38.8		1.67	0.80–3.50	0.172	1.12	0.69–1.82	0.648
	Sensory	31	13	41.9		1.01	0.40–2.52	0.983	1.69	0.85–3.35	0.136
	Two or more categories	95	52	54.7	**<0.001**	2.45	1.28–4.69	**0.007**	2.12	0.90–4.99	0.084
Neurological working years	1–3 years	372	177	47.6		Reference					
	Over 4 years	279	148	53.0	0.179	1.30	0.90–1.87	0.165			
Shift	Evening	163	75	46.0		Reference					
	Day	332	174	52.4		1.14	0.73–1.78	0.553			
	Night	156	76	48.7	0.385	0.97	0.59–1.62	0.915			
Situation	Admission to the acute stroke unit	108	32	29.6		Reference			Reference		
	Scheduled neurocheck	464	243	52.4		2.58	1.53–4.37	**<0.001**	4.76	2.18–10.39	**<0.001**
	Patient's own complaints	44	29	65.9		3.80	1.46–9.87	**0.006**	1.86	0.94–3.66	0.073
	Nurse's additional neurocheck	35	21	60.0	**<0.001**	5.15	2.22–11.95	**<0.001**	1.75	0.67–4.57	0.460
TOAST	CE	110	43	39.1		Reference					
	LAA	201	102	50.7		1.54	0.89–2.67	0.122			
	SVO	175	94	53.7		1.70	0.95–3.06	0.075			
	UD	104	48	46.2		1.24	0.66–2.31	0.502			
	OD	61	38	62.3	**0.032**	2.03	0.94–4.37	0.071			
Total		651	325	49.9	**<0.001**						

CI; confidential interval, CE; cardio embolism, END; early neurological deterioration, LAA; large artery atherosclerosis, OD; other determined, NIHSS; National institute of health stroke scale, OR; odds ratio, SVO; small vessel occlusion, TOAST; Trial of ORG 10172 in Acute Stroke Treatment, UD; undetermined.

[a] was based on chi-square test.

detected by nurses (Table 1). The average age of the patients was 68.9 ± 12.6 years, and males accounted for 60.1 %. The median (interquartile range) of onset to door time was 15.2 h (0.3–358.8) from the 489 (89.1 %) clear-onset-patients. The median (interquartile range) NIHSS score was 1 (0–7) at admission and 5 (2–8) at discharge. The mRS score was 3 (1–4) at admission and 3 (2–4) at discharge. Among the TOAST classifications, LAA (n = 157, 28.6 %), SVO (n = 146, 26.6 %), and CE (n = 98, 17.9 %) were found, and the newly developed or aggravated symptoms were detected at a mean of 2.7 ± 2.8 days from admission to the ASU. A total of 30 nurses with an average experience in neurology units of 4.3 ± 3.2 years.

3.2. Symptoms detected by nurses and their related factors

Among the total of 651 symptoms that were detected by nurses, motor-related symptoms were the most common (n = 320, 49.2 %), followed by posterior circulation sign (n = 100, 15.4 %); also, simultaneous symptoms across two or more categories were found in 95 cases (14.6 %; Table 2).

Of the 651 symptoms, 372 (57.1 %) were detected by nurses with 1–3 years of experience in neurology units, and the rest were detected by nurses with over 4 years of experience; particularly, nurses with 1–3 years of experience detected the majority of alertness (n = 25/38, 65.8 %) and sensory symptoms (n = 22/31, 71.0 %). In terms of the situation variables, the majority of symptoms (n = 464, 71.3 %) were detected during the nurses' scheduled neurocheck.

In terms of TOAST classification, symptoms were most commonly found in cases of LAA (n = 201, 30.9 %) and SVO (n = 175, 26.9 %). Simultaneous symptoms of two or more categories were most commonly found in LAA (n = 35/95, 36.8 %). In SVO cases, motor symptom (n = 106/320, 33.1 %) was the most common symptom. Of the reported symptoms, 49.9 % (n = 525/651) received additional clinical management, among which intravenous fluids increase (n = 201/651, 30.9 %) was the most common. Image taking was the most common clinical management in cases that showed change in alertness (n = 23/38, 60.5 %) and simultaneous symptoms in two or more categories (n = 25/95, 27.2 %).

3.3. Factors related to the presence of stroke lesion progression

A total of 132 patients underwent image taking according to symptom detection, of whom 83 (63.6 %) were found to have stroke lesion progression (Table 3). In the multivariate analysis, stroke lesion progression was more likely to be found in the group of NIHSS score of 7–15 at admission (OR = 11.68, 95 % CI = 1.46–93.69, $p = 0.021$) compared with the group of NIHSS score of over 16. Also, nurses with over 4 years of experience detected more stroke lesion progression than by those with 1–3 years of experience (OR = 2.49, 95 % CI = 1.09–5.66, $p = 0.030$). In terms of TOAST classification, stroke lesion progression was the most likely to be found in cases classified as LAA (OR = 36.62, 95 % CI = 4.86–275.99, $p \leq 0.001$) compared with SVO.

3.4. Factors related to the presence of early neurological deterioration

END was reported in 460 cases (70.7 %; Table 4). Scheduled neurocheck had the highest association with the detection of END (OR = 2.65, 95 % CI = 1.04–6.72, $p = 0.040$) compared with patient's own complaints in the situation factors. Among the TOAST classifications, END was more likely to be found in LAA (OR = 2.19, 95 % CI = 1.06–4.49, $p = 0.033$) compared with SVO. As the definition of END, incorporating NIHSS, is primarily employed in the anterior circulation, we conducted a separate analysis of END in the anterior circulation and presented it in the supplementary material. The findings indicated a similar significance of scheduled neurochecks (supplementary materials, Table 1).

3.5. Factors related to the presence of additional clinical management

Of the symptoms detected by nurses, 49.9 % (n = 325) were subject to receive an additional clinical management (Table 5). Additional clinical managements did 1.53 times more with patients with heart disease (OR = 1.53, 95 % CI = 1.02–2.31, $p = 0.041$). In the group of NIHSS score 0–6 was taken more additional clinical managements (OR = 3.25, 95 % CI = 1.13–9.37, $p = 0.029$) compared with the group of NIHSS score over 16. Alertness (OR = 2.89, 95 % CI = 1.58–5.26, $p = 0.001$) had the highest rates of additional clinical management ($p = 001$). Among the situational factors, scheduled neurocheck had the highest rate of additional clinical management (OR = 4.77, 95 % CI = 2.18–10.39, $p < 0.001$) compared with the detection at the admission to stroke unit.

4. Discussion

In this study, we analyzed the factors related to the nurses' detection of newly developed or aggravating symptoms in the ASU, presence of stroke lesion progression, END, and additional clinical management. Of the 549 patients who had neurological changes, 651 symptoms were found on an average of 2.70 ± 2.78 days, which is in line with previous studies [3–6,26,32,33] those are support the notion that neurological symptoms worsen significantly within the first 72 h, emphasizing the importance of closely monitoring changes in patient condition as highlighted in prior studies. Collectively, our study suggests the importance of appropriate neurological detections in the early stages of symptom onset.

The most commonly detected symptom was motor progression. The possibility of motor change is the same as those shown in previous studies that analyzed the records of nurses' change findings in the ASU [11,34,35]; this may be because motor function evaluation is the most widely used factor in the assessment of acute stroke patients, as it is a well-known symptom of cerebral

infarction. Also, a considerable portion of patients reported neurological symptom changes in two or more symptom categories, indicating that stroke patients might experience multiple co-occurring symptom changes.

We found that changes in alertness were frequently detected during the day shift (76.4 %), and that such cases most commonly underwent diagnostic imaging (60.5 %), followed by neuro-interventions (15.8 %). Alertness is the most powerful factors influenced on the presence of additional clinical management up to 2.89 times more in detected symptoms. These results indicate that changes in alertness may serve as an important indicator of neurological deterioration by nurses, specifically during the day shift, who should be aware of this symptom and provide early interventions [32].

Nurses most frequently detected overall symptom changes during the day shifts. In a previous meta-analysis, 49 % of stroke onset was reported in the morning hours due to the interplay of the circadian rhythm with the onset of neurological symptoms [36]. The higher number of professional medical staff in the ASU during daylight hours might also contribute to this result. For example, stroke clinical nurse specialists and the majority of neurologists work during day shifts, and the increase in the number of nursing staff has a positive effect on the prevention of exacerbation of patients [37]. Also, one study showed that an expanded system with more than one stroke physician on standby in the ASU can help improving the prognosis of stroke patients [38]. It is also important to keep the appropriate level of nursing ratio (patient: nurse = 1.25:1 or less) as suggested by the Health Insurance Review and Assessment Service of South Korea [39]. The average number of beds per nurse in this study was 1.125:1, which might have influenced the rate of symptom detection.

Symptom changes in two or more categories (26.9 %) and the posterior circulation signs (23.1 %) were most commonly found when admission to the ASU. Therefore, it is important to shorten the waiting time of stroke patients in the emergency department to prevent the worsening of the prognosis [35,40]. Considering that stroke patients tend to show deterioration in symptoms during transfers [41], optimal communication between medical staff in the emergency room and stroke units about the neurological status of stroke patients is needed.

There were differences between the examination by residents in the emergency room and stroke unit nurses, especially in terms of the posterior circulation sign in our study. This may be due to difficulties in directly checking the walking status in the emergency room and the accurate identification of symptoms due to changes in the patient's acute condition. Also, there may have been some omissions in the neurological examination when the patients are being quickly examined in the emergency department.

There were totally 1603 patients in acute stroke unit of our hospital and 282 patients were defined as END (17.6 %) in the study period. In previous study about acute stroke patient within 72 h from symptom onset, approximately 14.1 % patients were occurred of END which is similar with our results [26]. Of the situations, scheduled neurochecks was not only tended to have a significant impact on END, but also was the highest rate of presence of additional clinical managements. In a previous study, ~45 % of neurological deteriorations in stroke patients were detected during scheduled neurochecks [41]. The rate of early detection is affected by the basic rules of rounds in the ASU, although the definition of scheduled neurocheck may be different in each clinical situation. Periodic rounding therefore seems to be important in this area.

Additional clinical management was performed in 49.9 % of cases with symptom changes that were detected by nurses, which in turn contributed to the prevention of deterioration. In the cases that underwent diagnostic imaging, changes in alertness or in two or more categories were the most frequent cases. Additional clinical management was 5.15 times more likely to be provided to cases that were detected during additional neurochecks compared with those that were detected at admission to the ASU in the univariate analysis. This suggests that nurses detecting changes during additional neurochecks was likely to lead to the attending doctors being more mindful of the notification. In a prior study, nurses discovered about 26 % of END cases outside of scheduled neurochecks [41]. Nurses' experience would be important for judging the situation during not only routine examinations but also in additional neurochecks.

Stroke lesion progression, which can be regarded as a more objective indicator of detecting stroke deterioration than the presence of END or additional clinical management, was present in 63.6 % of cases with symptom changes that were detected by nurses. In another study, the detection rate of stroke lesion progression according to the neurological changes by nurses was 47.0 % after one year of NIHSS application in the ASU [11]. Our study was conducted 8.5 years after the application of the NIHSS to nurses.

The group of NIHSS score of 7–15 which means moderate stroke severity and LAA stroke patients were highly influenced on detect the stroke lesion progression in our results. Among the TOAST classification, LAA was also the highest relating factor in the presence of END. That is similar to previous studies [42] which represented that stroke deterioration was found mostly in the group of LAA than other stroke subtypes.

Stroke lesion deterioration was 2.41 times more likely to be detected by nurses with 4 or more years of experience than those with 1–3 years of experience. It is important for nurses to acquire plenty of experience with stroke patients and receive systematic ASU education. The ASU certification criteria [43] presented by the Korean Stroke Society include a certain level of stroke education for nurses. In Korea, a self-e-learning course completes the NIHSS score through video, but this is optional [44] and not mandatory in hospital settings. Also, there are no essential guidelines to evaluate the content or results of education for stroke nurses. The content and effectiveness of education should also be checked rather than just measuring the length of education.

Nurses' detection of changes in stroke symptoms might be positively affected by comprehensive education and management of stroke clinical nurse specialists. There was a stroke clinical nurse specialist in this research, and the theory and practical education on stroke were provided to novice nurses one-on-one or in groups until they started working in the ASU. In addition, the clinical nurse specialist shared knowledge on matters that the nurses should intensively check with regard to the patient's status. While some hospitals have stroke clinical nurse specialists or coordinator nurses, there are no qualification requirements for them. Therefore, it is necessary to prepare structural guidelines for the Korean Stroke Society and develop a comprehensive and systematic program.

5. Limitations

Our study has the following limitations. First, the results were gathered from a single ASU in a tertiary hospital in Korea. Also, due to the retrospective study design, we could not check the reasons for nurses' additional neurochecks or examine the reasons for stroke deterioration. Lastly, in this study, the clinical nurse specialist was managing stroke patients and nurses in this hospital, but it was not possible to measure the effects of this. Continued researches are necessary to fully understand the impact of clinical nurse specialists and to optimize their role in clinical setting.

6. Conclusions

The most detected symptom was motor changes, and deterioration of symptoms were the most likely to be found during day shifts, scheduled neurochecks, and in LAA cases. We studied about related factor to 3 main outcomes: the presence of stroke lesion progression, END, and additional clinical management. Stroke lesion progression were detected highly in the group of NIHSS score 7–15, experienced nurses over 4 years of neurology unit, and LAA stroke subtype patients. In terms of detecting END, scheduled neurochecks and the group of LAA showed the highest detection rate. In the case of the presence of additional clinical management, factors such as heart disease, NIHSS score of 0–6, changes of alertness, and scheduled neurochecks showed a high level of influences.

Our results can serve as a basis for improving the factors related to the nursing quality of acute cerebral infarction patients. It is needed to apply systematic guidelines for the education and qualification of stroke nurses, which would be useful for an expanded study about the clinical changes of stroke patients other than their neurological changes that can be detected by nurses.

Funding statement

This research was supported by the Brain Convergence Research Program of the National Research Foundation funded by the Korean government (No. 2020M3E5D2A01084576) and the National Research Foundation of Korea grant funded by the Korean government (MSIT) (No. 2020R1A2C2100077).

Ethics and consent

- This study was reviewed and approved by the Institutional Review Board of Asan Medical Center on April 15, 2021, with the approval number: [2021-0571].
- Informed consent was not required for this study because it was conducted retrospectively using medical records of patients who underwent routine stroke treatments, so that this study was determined by the IRB to pose no risk to the subjects involved.

Data availability

All data used in the generation of the results presented in this manuscript will be made available upon reasonable request from the corresponding author.

CRediT authorship contribution statement

Jung-Hee Han: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Claire Han:** Writing – review & editing, Validation, Formal analysis. **Sunmae Park:** Resources, Project administration, Data curation. **Young-Joo Kim:** Resources, Project administration, Data curation. **Bum Joon Kim:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Funding acquisition, Formal analysis.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Bum Joon Kim reports financial support and article publishing charges were provided by the Brain Convergence Research Program of the National Research Foundation funded by the Korean government. Bum Joon Kim reports financial support and article publishing charges were provided by the National Research Foundation of Korea grant funded by the Korean government.

Acknowledgments

There are no acknowledgements.

Abbreviations

ASU	acute stroke unit
CE	cardio embolism
END	Early neurological deterioration

LAA	large artery atherosclerosis
mRS	modified Rankin Scale
NIHSS	National Institutes of Health Stroke Scale
OD	other determined
SVO	small vessel occlusion
TOAST	Trial of ORG 10172 in Acute Stroke Treatment
UD	undetermined

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e32175.

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