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Original Article

Construction of a stroke green channel process based on the PDCA cycle management model and its impact on stroke prognosis

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Abstract: Objective: To evaluate the impact of implementing a stroke green channel process (GCP) based on the PDCA (Plan-Do-Check-Act) cycle on stroke prognosis. Methods: A retrospective analysis was conducted at the Second Affiliated Hospital of Guizhou Medical University by reviewing data of 259 stroke patients from January 2021 to December 2023. Patients were divided into two cohorts: 114 patients managed by the PDCA-based GCP and 145 patients receiving standard care (non-green channel process, NGCP). Key metrics assessed included demographic data, rescue indicators, and prognostic outcomes - neurological function, life ability, and quality of life. Results: The GCP group demonstrated significantly reduced triage ($P = 0.009$) and computed tomography (CT) scan completion times ($P = 0.042$), leading to shorter hospital stay durations ($P = 0.022$) and fewer transfer incidents ($P = 0.001$). Neurological and cognitive functions improved in the GCP group, evidenced by lower National Institute of Health stroke scale (NIHSS) scores ($P = 0.011$) and higher Mini-Mental State Examination (MMSE) ($P = 0.008$) and Montreal Cognitive Assessment (MoCA) scores ($P = 0.032$). Functional abilities and independence also improved, with higher Activities of Daily Living (ADL) ($P = 0.007$) and Barthel scores ($P = 0.003$), alongside lower Modified Rankin Scale (mRS) scores ($P < 0.001$). Adverse reactions were less frequent in the GCP group (total incidence rate $P < 0.001$). Conclusion: Implementing a stroke GCP managed with the PDCA cycle significantly improves stroke prognosis, enhancing clinical outcomes.

Keywords: Stroke, green channel process, PDCA cycle, neurological outcomes, emergency care optimization

Introduction

Stroke is a leading cause of morbidity and mortality worldwide, presenting significant challenges to healthcare systems due to its acute onset and the urgency required in its management. The timely identification and treatment of stroke are crucial to minimizing neurological damage, enhancing recovery, and improving overall patient outcomes. Despite advancements in medical technology and therapeutic strategies, the implementation of efficient stroke management protocols remains suboptimal in many areas, significantly impacting patient prognosis [1-3].

In recent years, the concept of the "stroke green channel" has emerged as a promising approach to streamlining stroke care. This process was designed to expedite the evaluation, diagnosis, and treatment of stroke patients, minimizing the time from symptom onset to therapeutic intervention. The green channel protocols often incorporate comprehensive and coordinated efforts between various hospital departments, thereby ensuring rapid patient transit through critical care pathways. However, achieving consistency and reliability in the green channel process (GCP) can be challenging without a structured management framework [4-6].

The Plan-Do-Check-Act (PDCA) cycle, also known as the Deming Cycle, is a well-established management tool rooted in principles of continuous quality improvement. Originally

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developed for industrial process optimization, the PDCA cycle has gained attraction in healthcare settings due to its systematic approach to problem-solving and process enhancement. By iteratively applying the stages of planning, implementation, evaluation, and action, healthcare providers can refine clinical protocols, reduce variability in care delivery, and enhance patient outcomes [7-9].

The integration of the PDCA cycle into the stroke GCP offers a strategic methodology for managing the complexities associated with emergency stroke care. This model not only promotes efficiency in patient management but also fosters an environment where continual assessment and process refinement are prioritized [10]. The PDCA cycle's focus on iterative improvement aligns well with the dynamic nature of clinical practice, where protocols must be adaptable to changing patient needs and advancements in medical evidence.

Current literature underscores the critical role of time in stroke management, with numerous studies highlighting the direct correlation between treatment delay and worsening neurological outcomes. Timely administration of thrombolytic therapies, such as tissue plasminogen activator (tPA), is known to significantly enhance recovery in ischemic stroke patients [11, 12]. However, delays in diagnosis, imaging, and treatment initiation remain prevalent, necessitating innovative approaches like the green channel to bridge these gaps.

Moreover, there is increasing recognition of the need for a holistic approach to stroke management that considers not only the clinical but also the operational aspects of care. Efficient management of healthcare resources, improved interdisciplinary communication, and patient-centered care planning are all critical elements that contribute to the success of stroke interventions [13, 14]. Within this context, the PDCA cycle can serve as an underpinning framework for structuring the stroke GCP, ensuring that both clinical and administrative processes are aligned towards optimal outcomes.

Previous studies evaluating the effectiveness of the GCP have reported various improvements in clinical metrics such as reduced door-to-needle times and lower mortality rates [15, 16]. However, there are limited data on the integration of formal quality management models like the PDCA cycle in these protocols. Understanding the impact of structured quality management methodologies on the success of the GCP can provide valuable insights for healthcare institutions aiming to optimize stroke care delivery.

This study constructed a stroke GCP grounded in the PDCA cycle management model to explore its consequential effects on stroke prognosis.

Materials and methods

Study design and ethics statement

A retrospective analysis was performed on 259 stroke patients admitted to the Second Affiliated Hospital of Guizhou Medical University between January 2021 and December 2023. The patients were categorized into two groups based on their treatment process. The GCP group, included 114 patients who received treatment through a stroke green channel managed with the PDCA cycle. On the other hand, the non-green channel process (NGCP) group comprised 145 patients who did not undergo treatment via this PDCA-managed process. The Institutional Review Board and Ethics Committee of the Second Affiliated Hospital of Guizhou Medical University approved this study.

Inclusion and exclusion criteria

Inclusion criteria: The study included patients who underwent computed tomography (CT) examinations and met the diagnostic criteria for stroke [17]. Eligible participants were those aged 18 years or older, with complete medical records, and who completed a 3-month follow-up.

Exclusion criteria: Patients were excluded if they had malignant tumors, a history of mental illness or consciousness disturbances, diseases affecting the immune or hematopoietic systems, or abnormal liver, kidney, or other vital organ function. Additionally, individuals with a history of arteriovenous malformation, intracranial hemorrhage, or intracranial aneurysm were also excluded.

Data collection

Patient data were collected from the medical record system, encompassing demographic information, baseline disease characteristics, rescue indicators, coagulation index, neurological function scores, life ability scores, quality of life scores, and adverse reaction incidence rates. The CT scan completion time was defined as the duration from patient admission to the completion of the CT scan.

Construction of a stroke GCP based on the PDCA cycle management model

PDCA cycle: The PDCA cycle, also known as the Deming Cycle, is a scientific methodology widely employed in total quality management. This method comprises four stages: Plan, Do, Check, and Act, which are used iteratively to address problems and enhance quality incrementally.

(1) Planning stage: Before implementing the PDCA cycle, comprehensive training was provided to all medical staff in the emergency department to ensure they understood the fundamental concepts and operational processes of PDCA.

(2) Doing stage: Several measures were undertaken to improve emergency care quality: 1) Enhancing emergency skills: Regular training classes on emergency skills were organized, including education on green channel protocols, to improve the staff's ability to handle emergencies. 2) Optimizing GCPs: Existing processes were adjusted according to hospital conditions and stroke patients' specific needs. Simulations were conducted to ensure employees were adept at handling emergency procedures. 3) Promoting cross-departmental collaboration: Effective communication mechanisms were established to facilitate smooth information exchange and cooperation among departments. 4) Improving technical support: Necessary hardware facilities were added or upgraded, such as increasing the number of barcode printers for fast label printing, to enhance work efficiency and service quality.

(3) Checking stage: The PDCA team conducted comprehensive monthly evaluations of work performance of all nursing staff, assessing their emergency skills. If any weaknesses were identified during evaluations, the team provided immediate guidance and suggested specific improvements to ensure all staff met the expected skill levels and service standards.

(4) Acting stage: Following the monthly evaluations, the PDCA team held departmental meetings to thoroughly summarize and assess the evaluation results, patient feedback, and other relevant issues. For identified problems, the team proposed specific recommendations for improvement and developed detailed action plans. These recommendations were continuously implemented in subsequent work, aiming to consistently optimize the quality and efficiency of emergency care.

Green channel procedures: (1) Upon confirming a patient's need for the green channel, a specialist physician must be immediately requested to assist. The physician should arrive within ten minutes of notification. If unavailable, a qualified colleague must be dispatched as a substitute. (2) For cases included in the green channel, radiological (X-ray, CT scan) and ultrasound reports should be completed within thirty minutes. Blood transfusion, if required, must be prepared within 30 minutes. In case of supply shortage, the preparation time should not exceed 60 minutes. (3) Prescription medications for green channel patients must be prioritized by the pharmacy. (4) Regarding surgical preparation, upon receiving the surgical order, both the operating room and related equipment must be ready within 10 minutes. All relevant personnel should promptly assemble, and the anesthesiologist was responsible for conducting preoperative assessments and selecting the appropriate anesthesia method. (5) To ensure that critically ill patients receive prompt treatment, each clinical department must reserve one to two backup beds daily for emergency use. New admissions cannot be refused due to bed shortages. (6) A unified identification system should be employed for all individuals treated through the emergency green channel to streamline the process and enhance efficiency.

Detection of coagulation index

Venous blood (3 ml) anticoagulated with sodium citrate was collected from patients using vacuum blood collection tubes before and after resuscitation. The blood samples were centrifuged at 3000 rpm for 5 minutes using a low-temperature high-speed centrifuge (Mini1524, Zhuhai Hema Medical Instrument Co., Ltd., China). Levels of D-dimer (D-D) and fibrinogen (Fib) were measured using an automated coagulation analyzer (Beckman Coulter ACL-TOP, Beckman Coulter, Inc., USA).

Neurological function assessment

To evaluate patients' neurological function, we employed the National Institutes of Health Stroke Scale (NIHSS), the Mini-Mental State Examination (MMSE), and the Montreal Cognitive Assessment (MoCA). The NIHSS can assess various neurological functions, such as consciousness level, eye movements, and the ability to follow commands, with scores ranging from 0 to 42. Higher scores indicate more severe neurological impairment, while lower scores suggest milder deficits. The NIHSS demonstrated a Cronbach's alpha reliability coefficient of 0.920 [18]. The MMSE evaluates cognitive function and mental status across 30 items, covering language, delayed recall, attention, and calculation. Scores also range from 0 to 30, with higher scores representing better cognitive and mental status. The MMSE exhibited a Cronbach's alpha of 0.890 [19]. The MoCA, also scored out of 30, assesses cognitive function. Interpretation of the MoCA scores is as follows: 26 points or greater indicate normal cognitive function, 18-25 points signify mild cognitive impairment, 10-17 points represent moderate cognitive impairment, and scores lower than 10 indicate severe cognitive impairment. The Cronbach's alpha for the MoCA was found to be 0.750 [20].

Functional ability assessment

Patients' ability to perform daily activities was assessed using the Activities of Daily Living (ADL) scale, the modified Barthel Index (BI), and the Modified Rankin Scale (mRS), which collectively provide a comprehensive evaluation of functional independence and disability. The ADL scale comprises 10 items, such as dressing, eating, and grooming, with a total score ranging from 0 to 100. Higher scores indicate greater functional independence in daily activities. The ADL scale demonstrated a Cronbach's alpha coefficient ranging from 0.953 to 0.978 [21]. The modified BI assesses 10 items across two main areas: self-care activities (feeding, bathing, grooming, bowel and bladder control, dressing, and toileting) and mobility (transfers, mobility, and stair climbing). The total score ranges from 0 (complete dependence) to 100 (full independence), with higher scores signifying greater functional independence. The modified BI showed a Cronbach's alpha coefficient of 0.960 [22]. The mRS evaluates the degree of disability or dependence in patients, with a total score ranging from 0 to 6. The ratings are as follows: 0: no symptoms; 1: no significant disability, able to carry out all daily activities despite some symptoms; 2: slight disability, unable to perform all daily activities but able to manage own affairs without assistance; 3: moderate disability, requiring some help but able to walk unassisted; 4: moderately severe disability, unable to attend to own bodily needs without assistance and unable to walk unassisted; 5: severe disability, bedridden, incontinent, or requiring constant nursing care and attention; and 6: death. An mRS score greater than 2 was classified as a poor prognosis, while a score of 2 or less was considered a good prognosis [23]. The mRS demonstrated high inter-rater reliability, with a percent agreement among paired raters of 87% and a kappa (κ) coefficient of 0.840 [24].

Quality of life assessment

Patients' quality of life was evaluated using the Medical Outcomes Study (MOS) 36-Item Short Form Health Survey (SF-36). This survey assesses eight dimensions: Physical Functioning (PF), Role-Physical (RP), Bodily Pain (BP), General Health (GH), Vitality (VT), Social Functioning (SF), Role-Emotional (RE), and Mental Health (MH). Each dimension is scored from 0 to 100, with higher scores reflecting a better quality of life. The SF-36 demonstrated strong internal consistency, with a Cronbach's alpha coefficient exceeding 0.7 [25].

Statistical analysis

Data analysis was conducted using SPSS version 29.0 (SPSS Inc., Chicago, IL, USA). Categorical data were presented as [n (%)]. The chi-square test (χ^2) was employed when the sample size was ≥ 40 and the theoretical frequency (T) was ≥ 5. For sample sizes ≥ 40 with a theoretical frequency between 1 and < 5, the chi-square test was adjusted using a correction formula. When the sample size was < 40 or the theoretical frequency was < 1, Fisher's exact test was utilized. Continuous variables were first assessed for normality using the Shapiro-Wilk test. Normally distributed continuous data were expressed as the mean and standard

Table 1. Comparison of demographic characteristics between the two groups

Parameters	NGCP group (n = 145)	GCP group (n = 114)	t/χ^2	P
Age (years)	64.54 ± 4.25	65.27 ± 4.83	1.297	0.196
Female/Male	90 (62.07%)/ 55 (37.93%)	72 (63.16%)/ 42 (36.84%)	0.032	0.857
Ethnicity (Han/Other)	129 (88.97%)/ 16 (11.03%)	98 (85.96%)/ 16 (14.04%)	0.531	0.466
BMI (kg/m^2)	25.63 ± 2.27	25.51 ± 2.78	0.388	0.699
Smoking history (Yes/No)	83 (57.24%)	54 (47.37%)	2.497	0.114
Drinking history (Yes/No)	20 (13.79%)	17 (14.91%)	0.065	0.798
Hypertension (Yes/No)	76 (52.41%)	55 (48.25%)	0.444	0.505
Diabetes (Yes/No)	46 (31.72%)	45 (39.47%)	1.682	0.195
Coronary heart disease (Yes/No)	50 (34.48%)	35 (30.7%)	0.414	0.520
Abnormal lipid metabolism (Yes/No)	89 (61.38%)	68 (59.65%)	0.080	0.777
Educational level (Elementary school and below/Middle school/College and above)	36 (24.83%)/ 60 (41.38%)/ 49 (33.79%)	26 (22.81%)/ 50 (43.86%)/ 38 (33.33%)	0.205	0.902
Marital Status (Married/Unmarried or Divorced)	49 (33.79%)/ 96 (66.21%)	37 (32.46%)/ 77 (67.54%)	0.051	0.821
Insurance mode (Have health insurance/Without health insurance)	72 (49.66%)/ 73 (50.34%)	64 (56.14%)/ 50 (43.86%)	1.076	0.300
Living condition (Live with family members/Live alone)	117 (80.69%)/ 28 (19.31%)	95 (83.33%)/ 19 (16.67%)	0.300	0.584

Notes: GCP: green channel process; NGCP: non-green channel process; BMI: Body Mass Index.

deviation (X ± s). For non-normally distributed data, the Wilcoxon rank-sum test was applied, with results presented as [median (25th percentile, 75th percentile)]. A *P*-value of less than 0.05 was considered statistically significant.

Results

Demographic characteristics

Demographic characteristics were compared between the NGCP group and the GCP group to assess their comparability (**Table 1**). The mean age was 64.54 ± 4.25 years in the NGCP group and 65.27 ± 4.83 years in the GCP group, with no statistically significant difference (t = 1.297, P = 0.196). Gender distribution was similar in both groups, with the NGCP group consisting of 62.07% females and 37.93% males, compared to the GCP group's 63.16% females and 36.84% males (χ^2 = 0.032, P = 0.857). Ethnicity distribution, BMI, history of smoking and drinking, hypertension, diabetes, coronary heart disease, and abnormal lipid metabolism also showed no significant differences between the two groups (P > 0.05). Educational levels, marital status, insurance mode, and living conditions were comparable between the NGCP and GCP groups (P > 0.05). These findings indicate that demographic variables were well-matched across the two groups, minimizing potential confounding factors in the analysis of stroke prognosis related to the implementation of the GCP.

Dizziness was reported in 54.48% of the NGCP group and 53.51% of the GCP group (χ^2 = 0.024, P = 0.876) (**Table 2**). Hemiplegia was present in 42.07% of NGCP group compared to 43.86% in the GCP group (χ^2 = 0.084, P = 0.773), while partial numbness was reported in 34.48% and 32.46% of the patients in the NGCP and GCP groups, respectively (χ^2 = 0.118, P = 0.732). Instances of slurred speech were noted in 35.86% of the NGCP group and 38.6% of the GCP group (χ^2 = 0.205, P = 0.651). The distribution of lesion types was similar, with ischemic lesions in 64.83% of the NGCP group and 70.18% of the GCP group (χ^2 = 0.828, P = 0.363). Finally, lesion side statistics indicated no significant difference, with left-side lesions found in 43.45% of the NGCP cohort and 51.75% of the GCP group (χ^2 = 1.767, P = 0.184). These data suggest a bal-

Table 2. Comparison of baseline disease characteristics between the two groups

Parameters	NGCP group (n = 145)	GCP group (n = 114)	X^2	P
Clinical manifestation				
Dizziness	79 (54.48%)	61 (53.51%)	0.024	0.876
Hemiplegia	61 (42.07%)	50 (43.86%)	0.084	0.773
Partial numbness	50 (34.48%)	37 (32.46%)	0.118	0.732
Slurred speech	52 (35.86%)	44 (38.6%)	0.205	0.651
Lesion type (ischemic/hemorrhagic)	94 (64.83%)	80 (70.18%)	0.828	0.363
Lesion side (left/right)	63 (43.45%)	59 (51.75%)	1.767	0.184

Table 3. Comparison of rescue indicators between the two groups

Parameters	NGCP group (n = 145)	GCP group (n = 114)	t/χ^2	P
Triage time (min)	3.33 ± 1.54	2.92 ± 0.96	2.641	0.009
CT scan completion time (min)	29.55 ± 4.27	28.52 ± 3.64	2.046	0.042
Family decision-making time (min)	20.52 ± 5.37	19.06 ± 3.56	2.627	0.009
Emergency resuscitation time (min)	33.34 ± 11.63	30.53 ± 6.38	2.478	0.014
Length of hospital stay (d)	10.13 ± 1.67	9.77 ± 0.77	2.310	0.022
Incidence of transfer accidents (%)	25 (17.24%)	5 (4.39%)	10.299	0.001

Note: CT: computed tomography.

anced distribution of baseline disease attributes in the two groups, reducing potential bias in evaluating the effects of the stroke GCP.

Rescue indicators

The GCP group demonstrated a reduced triage time, averaging 2.92 ± 0.96 minutes compared to 3.33 ± 1.54 minutes in the NGCP group (t = 2.641, P = 0.009) (**Table 3**). The time to complete a CT scan was also significantly shorter in the GCP group (28.52 ± 3.64 minutes), compared to 29.55 ± 4.27 minutes in the NGCP group (t = 2.046, P = 0.042). Family decision-making time decreased from 20.52 ± 5.37 minutes in the NGCP group to 19.06 ± 3.56 minutes in the GCP group (t = 2.627, P = 0.009). Emergency resuscitation time was also reduced in the GCP group, averaging 30.53 ± 6.38 minutes, compared to 33.34 ± 11.63 minutes in the NGCP group (t = 2.478, P = 0.014). Furthermore, the average length of hospital stay was significantly shorter in the GCP group (9.77 ± 0.77 days) than in the NGCP group (10.13 ± 1.67 days; t = 2.310, P = 0.022). Most notably, the incidence of transfer accidents was significantly lower in the GCP group at 4.39%, compared to 17.24% in the NGCP group (χ^2 = 10.299, P = 0.001). These findings indicate that the stroke GCP effectively streamlines various aspects of patient management, contributing to improved outcomes in stroke treatment.

Coagulation index

In the comparison of coagulation indices between the NGCP and GCP groups, no significant differences were observed in D-D or Fib levels before rescue (D-D: P = 0.230; Fib: P = 0.711) (**Table 4**). Post-rescue, there was a trend towards increased D-D levels in both groups, but this increase did not reach statistical significance (P = 0.065). Similarly, Fib levels showed a slight decrease after rescue in both groups, yet this change also lacked statistical significance (P = 0.140). The results suggest that while there was a tendency for D-D to increase and Fib to decrease post-rescue, these changes did not significantly differ between the NGCP and GCP groups, indicating that the GCP did not have a differential impact on coagulation parameters.

Prognostic outcome scores

The NIHSS scores were significantly lower in the GCP group, with an average of 5.66 ± 1.21, compared to 6.27 ± 2.53 in the NGCP group (t = 2.567, P = 0.011), indicating better neuro-

Table 4. Comparison of coagulation indices between the two groups

Parameters	NGCP group (n = 145)	GCP group (n = 114)	t	P
Before rescue				
D-D (μg/ml)	0.64 ± 0.15	0.66 ± 0.16	1.204	0.230
Fib (g/L)	4.93 ± 0.75	4.96 ± 0.53	0.371	0.711
After rescue				
D-D (μg/ml)	1.57 ± 0.22	1.64 ± 0.35	1.859	0.065
Fib (g/L)	4.38 ± 0.63	4.29 ± 0.37	1.482	0.140

Notes: D-D: D-dimer; Fib: Fibrinogen.

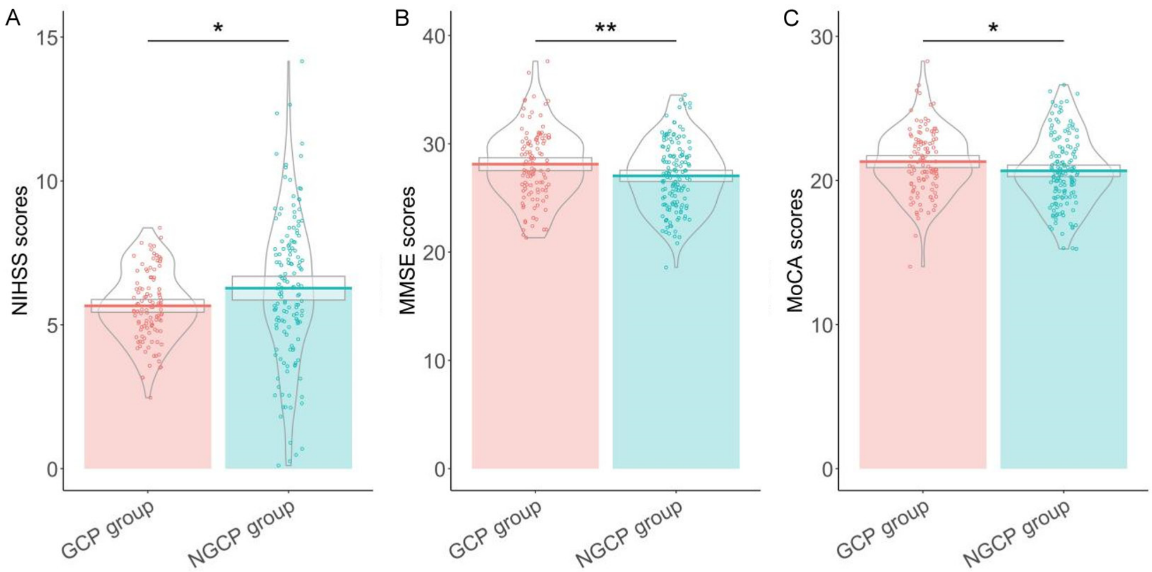

Figure 1. Comparison of neurological function scores between the two groups. A. NIHSS score; B. MMSE score; C. MoCA score. Notes: GCP: green channel process; NGCP: non-green channel process; NIHSS: National Institute of Health stroke scale; MMSE: Mini-Mental State Examination; MoCA: Montreal Cognitive Assessment. *: $P < 0.05$; **: $P < 0.01$.

logical function (**Figure 1**). The MMSE scores in the GCP group was 28.12 ± 3.26, which were higher than 27.04 ± 3.16 in the NGCP group, reflecting improved cognitive function (t = 2.692, P = 0.008). Similarly, MoCA scores were significantly higher in the GCP group, averaging 21.31 ± 2.27 versus 20.67 ± 2.44 in the NGCP group (t = 2.160, P = 0.032). These results suggest that the implementation of the stroke GCP, grounded in the PDCA cycle management model, positively impacts neurological and cognitive outcomes in stroke patients.

The ADL scores were higher in the GCP group, with a mean of 76.94 ± 3.62, compared to 75.77 ± 3.26 in the NGCP group (t = 2.743, P = 0.007), indicating enhanced functional capacity (**Figure 2**). The Barthel scores, which assess independence in basic activities, were also significantly higher in the GCP group, averaging 58.95 ± 4.75 versus 57.37 ± 3.21 in the NGCP group (t = 3.037, P = 0.003). Furthermore, the mRS scores, reflecting the degree of disability or dependence, were significantly lower in the GCP group at 1.13 ± 0.44, compared to 1.38 ± 0.21 in the NGCP group (t = 5.594, P < 0.001), suggesting a better prognosis. These results support the effectiveness of the stroke GCP in improving functional ability outcomes for stroke patients.

In terms of quality of life, the PF scores were higher in the GCP group, with a mean of 68.05 ± 7.45 compared to 65.43 ± 7.34 in the NGCP group (t = 2.837, P = 0.005) (**Table 5**). RP scores also demonstrated improvement, with the GCP group scoring 69.18 ± 6.37 versus 66.73 ± 6.37 in the NGCP group (t = 3.069, P =

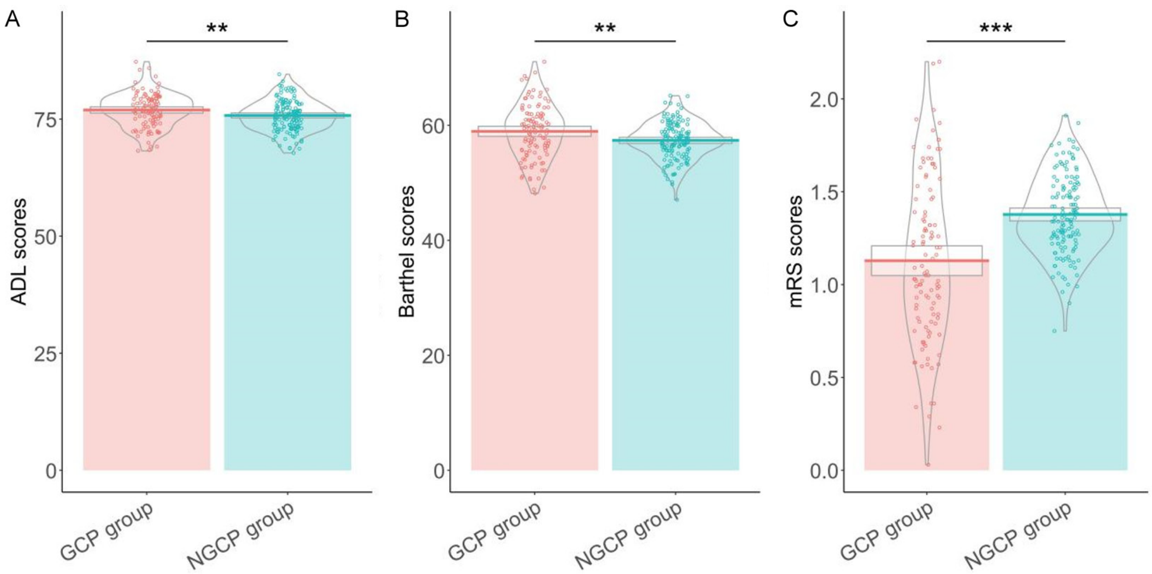

Figure 2. Comparison of functional ability scores between the two groups. A. ADL score; B. Barthel score; C. mRS score. Notes: ADL: Activities of Daily Living; mRS: Modified Rankin Scale. **: *P* < 0.01; ***: *P* < 0.001.

Table 5. Comparison of SF-36 scores between the two groups

Parameters	NGCP group (n = 145)	GCP group (n = 114)	t	P
PF	65.43 ± 7.34	68.05 ± 7.45	2.837	0.005
RP	66.73 ± 6.37	69.18 ± 6.37	3.069	0.002
BP	64.48 ± 5.95	66.22 ± 5.78	2.359	0.019
GH	62.57 ± 5.37	64.36 ± 6.32	2.465	0.014
VT	69.02 ± 6.23	71.54 ± 7.07	3.045	0.003
SF	63.98 ± 6.37	66.56 ± 6.82	3.130	0.002
RE	62.35 ± 6.78	64.33 ± 7.16	2.271	0.024
MH	63.89 ± 7.27	65.74 ± 7.15	2.044	0.042

Notes: SF-36: the Medical Outcomes Study (MOS) item short form health survey; PF: Functioning; RP: Role-Physical; BP: Bodily Pain; GH: General Health; VT: Vitality; SF: Social Functioning; RE: Role-Emotional; MH: Mental Health.

0.002). For BP, the GCP group scored 66.22 ± 5.78 compared to 64.48 ± 5.95 in the NGCP group (t = 2.359, P = 0.019). GH scores were likewise better in the GCP group at 64.36 ± 6.32, compared to 62.57 ± 5.37 in the NGCP group (t = 2.465, P = 0.014). VT scores were 71.54 ± 7.07 in the GCP group, higher than the NGCP group's 69.02 ± 6.23 (t = 3.045, P = 0.003). SF scores improved to 66.56 ± 6.82 in the GCP group compared to 63.98 ± 6.37 in the NGCP group (t = 3.130, P = 0.002). RE and MH scores were also significantly higher, with RE at 64.33 ± 7.16 versus 62.35 ± 6.78 (t = 2.271, P = 0.024), and MH at 65.74 ± 7.15 versus 63.89 ± 7.27 (t = 2.044, P = 0.042) in the GCP and NGCP groups, respectively. These results indicate that the stroke GCP is associated with substantial improvements in overall health-related quality of life in stroke patients.

Adverse reactions

Notably, the incidence of neurological sequelae was significantly lower in the GCP group at 1.75%, compared to 9.66% in the NGCP group (χ^2 = 6.874, P = 0.009) (**Table 6**). Although the rates of urinary tract infection and pulmonary infection were lower in the GCP group, with incidences of 3.51% and 5.26%, respectively, these differences were not statistically significant when compared to the NGCP group, which had incidences of 7.59% (χ^2 = 1.945, P = 0.163) and 10.34% (χ^2 = 2.212, P = 0.137), respectively. Importantly, the total incidence rate of

Table 6. Comparison of incidence of adverse reactions between the two groups

Parameters	NGCP group (n = 145)	GCP group (n = 114)	χ^2	P
Neurological sequelae	14 (9.66%)	2 (1.75%)	6.874	0.009
Urinary tract infection	11 (7.59%)	4 (3.51%)	1.945	0.163
Pulmonary infection	15 (10.34%)	6 (5.26%)	2.212	0.137
Total incidence rate	40 (27.59%)	12 (10.53%)	11.576	< 0.001

adverse reactions was significantly reduced in the GCP group at 10.53%, compared to 27.59% in the NGCP group (χ^2 = 11.576, $P < 0.001$). These findings indicate that the integration of the stroke GCP can significantly minimize the overall risk of adverse reactions in stroke patients.

Discussion

In this study, we explored the implementation of a stroke GCP based on the PDCA cycle management model and its impact on stroke prognosis.

One key finding of this study was the significant reduction in rescue indicators in the GCP group compared to the NGCP group. Similarly, in the study by Lu et al., the PDCA cycle management model effectively shortened the delivery interval and reduced the neonatal asphyxia rate [26]. The PDCA cycle, a structured iterative management approach, fosters continuous process improvement, ensuring that protocols are optimized to minimize delays in critical care delivery. The training and comprehensive planning stages ensured that medical personnel were not only familiar with the green channel procedures but also adept at executing them efficiently. This systematic training likely contributed to the swift identification and management of stroke cases, resulting in reduced emergency response time [27, 28].

The decreased length of hospital stay and the reduction in the incidence of transfer accidents in the GCP group further underscore the effectiveness of the PDCA-driven processes. The streamlined workflow facilitated by the green channel ensures that patients receive timely and appropriate interventions, reducing the likelihood of complications that typically prolong hospitalization. By minimizing intra-hospital transfers and associated risks, the green channel prioritizes patient stability and reduces potential for adverse events [29, 30].

Neurological and cognitive improvements, as reflected by the NIHSS, MMSE, and MoCA scores, provide further testimony to the efficacy of the green channel. The improved scores can be attributed to the rapid and targeted therapeutic interventions made possible by the accelerated processes under the GCP. Early administration of neuroprotective agents and thrombolytic therapy, facilitated by a reduction in treatment initiation time, likely contribute to better neurological outcomes [31, 32]. The iterative nature of the PDCA cycle allows for constant feedback and adjustments, optimizing treatment protocols to cater to individual patient needs, which could help minimize neurological damage. Chen et al. concluded that the PDCA approach could help develop a better insulin infusion protocol for critically ill patients, reducing the prevalence of hyperglycemia. They also demonstrated the effectiveness of PDCA in optimizing treatment plans and minimizing patient injury [33].

The enhancement of functional abilities, as demonstrated by higher ADL and Barthel scores, and the lower mRS scores in the GCP group, suggest an improvement in the functional independence among stroke patients receiving care through the green channel. The structured assessments and timely rehabilitation efforts, supported by cross-departmental collaboration inherent to the PDCA model, can ensure that patients are not only treated but also adequately supported after treatment to regain their functional abilities. The proactive planning of reserving emergency beds and resources likely reduces the occurrence of care delays, allowing for continuous and focused rehabilitation efforts [34, 35].

The GCP group showed significant improvements in the SF-36 health-related quality of life scores compared to the NGCP group, with statistically significant differences observed across all measured parameters. As demonstrated in the study by Huang et al. [36], patients with acute stroke who received nursing interventions under the PDCA cycle scored significantly higher than those in the conventional care group, further validating the effectiveness of the PDCA cycle. Moreover, the improvements in GH and RE scores suggest that the PDCA cycle not only enhances immediate medical outcomes but also supports long-term recovery and emotional well-being. The stroke GCP, as a comprehensive approach, ensures that patients benefit from optimized medical care and supportive services, leading to better overall outcomes and a higher quality of life [37, 38].

Another major strength of the stroke green channel lies in its ability to lower the overall incidence of adverse reactions, as evidenced by the significant reduction in neurological sequelae among GCP patients. This outcome was likely a direct consequence of the PDCA cycle's emphasis on ongoing evaluation and refinement of treatment protocols, which ensures that potential complications were anticipated and effectively addressed. By maintaining a focus on quality improvement, the green channel continually enhances patient safety and outcomes.

The latent success of the GCP can also be attributed to the cultural and systemic shifts within the hospital environment instigated by the PDCA cycle. The cycle's demand for iterative progress and reflective practice facilitates a culture of continuous learning and adaptation. Medical staff were encouraged to hone their skills and share expertise, leading to enhanced competency and confidence in managing complex cases [39, 40]. The existence of a cohesive, well-informed, and responsive medical team was instrumental in ensuring the consistent delivery of high-quality care, which was evidently realized in our study through the gains in prognostic outcomes.

Additionally, the structured nature of the PDCA cycle facilitates better resource allocation and management. By continually assessing and revising processes, healthcare facilities can optimize the use of available resources, ensuring that essential services are prioritized and potential bottlenecks are minimized [41, 42]. This strategic resource management is essential in maintaining the green channel's efficiency and effectiveness, ultimately leading to improved patient outcomes as seen in the study.

The innovation of applying the PDCA cycle to stroke in this study lies in its focus on streamlining and optimizing the acute phase of stroke management, unlike in general hospital operations. This includes rapid triage, expedited imaging, and timely initiation of treatment. Establishing a dedicated pathway for stroke patients can ensure that they receive priority treatment at every stage of their care journey. The green channel minimizes delays in critical interventions, which is crucial for improving outcomes. The PDCA cycle facilitates better coordination between different departments involved in stroke care, such as neurology, radiology, emergency medicine, and rehabilitation services. This interdisciplinary approach enhances the overall efficiency in patient care.

While the findings of this study highlight the positive impacts of implementing a stroke GCP based on the PDCA cycle, several limitations must be acknowledged. Firstly, the study was conducted in a single healthcare facility, which may limit the generalizability of the results to other settings with different resource availability and organizational structures. Additionally, the study's design did not include blinding, which could introduce bias in the assessment of outcomes. The relatively short follow-up period also limits insights into the long-term effects and sustainability of the green channel interventions on stroke prognosis. Finally, potential confounding factors such as variations in patient demographics and stroke severity were not fully accounted for, which could influence the reported results. Future studies should aim to address these limitations by incorporating multicenter trials, longer follow-up periods, and more robust control of confounding variables to validate and expand upon the presented findings.

Conclusion

In conclusion, the implementation of a stroke GCP based on the PDCA cycle demonstrates substantial improvements in stroke prognosis, underscoring the value of this management model in emergency care. The green channel not only enhances response time and clinical outcomes but also enriches the overall patient experience by fostering an environment of prompt, patient-centered care. The success of this model highlights the value of a structured approach to continuous improvement, emphasizing its potential to transform healthcare delivery and outcomes in acute medical emergencies. Future research should explore the long-term sustainability of such interventions and their applicability across various healthcare settings and demographics, aiming to generalize the benefits observed in this study to broader populations.

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Disclosure of conflict of interest

None.

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