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Research Paper

Stroke nurse-led intravenous thrombolytic therapy strategy for ischemic stroke based on timeline process: A quality improvement program from China

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A B S T R A C T

Objective: Early thrombolytic therapy for ischemic stroke within the therapeutic window is associated with improved clinical outcomes. This study investigated whether optimizing intravenous thrombolytic (IVT) therapy strategies for stroke could reduce treatment delays.

Methods: To reduce delays in IVT therapy for ischemic stroke, a series of quality improvement measures were implemented at a tertiary hospital in Hangzhou, Zhejiang Province, from June 2021 to August 2023, which included developing a timeline process management system, forming a nurse-led stroke process management team, providing homogeneous training, standardizing the IVT therapy process for ischemic stroke, and introducing an incentive policy. During the pre- (from June 2021 to February 2022, group A) and post- (from March to November 2022, group B1; from December 2022 to August 2023, group B2 [implementation of an additional incentive policy]) of the implementation the strategy, the door-to-computed tomographic angiography (CTA) time (DCT), CTA time, neurology consultation to consent for IVT, CTA-to-needle time (CNT), and door-to-needle time (DNT), the percentage of people who underwent CTA within 20 min, 15 min, and 10 min and DNT within 60 min, 45 min, and 30 min were collected and compared.

Results: Following the implementation of the standardized IVT process management strategy for stroke, the DNT for group B1 and group B2 were 30 (24, 44) min and 31 (24, 41) min, respectively, both significantly lower than the 46 (38, 58) min in group A ($P < 0.001$); the median DCT were both 13 min in group B1 and B2 lower than 17min in group A ($P < 0.001$); the median CTA were 12 min in Group B1 and 9 min in Group B2 lower than 14 min in group A ($P < 0.001$); similar results were observed during the neurology consultation to obtain consent for IVT and CNT. Compared with group A, the proportion of DCT $\leq$ 20 min, 15 min, and 10 min was higher in groups B1 and B2 ($P < 0.05$), and the same result was observed at DNT $\leq$60 min, 45 min, and 30 min ($P < 0.05$). However, the additional incentive policy did not significantly differ between Group B2 and Group B1.

Conclusions: Optimizing IVT therapy for ischemic stroke is a feasible approach to limit the DNT to 30 min in ischemic stroke, significantly reducing delays within the therapeutic window and increasing the number of patients meeting target time segments. Additionally, generating a timeline for the IVT therapy process by scanning positioning quick response codes was a significant breakthrough in achieving the informatization of IVT quality management for stroke.

What is known?

- With the establishment of stroke centers in China, the time for intravenous thrombolytic (IVT) in ischemic stroke is decreasing, but limited cooperation occurs among the emergency, neurology, radiology, and other departments.
- National medical quality control indicators for neurological diseases have confirmed the importance of information technology in enhancing the collection, analysis, and feedback of information on indicators and guiding medical institutions to continuously improve the quality of medical care.

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What is new?

- A nurse-led stroke management strategy for IVT therapy in ischemic stroke is recommended.
- The use of positioning quick response (QR) codes for the informative collection of process-time data to generate a timeline for IVT can provide reliable data for improving the quality of care.
- Conduct IVT therapy conversations using a standardized introduction, situation, background assessment, and recommendation (ISBAR) communication mode, which is beneficial for patients and their families to understand and decide on treatment quickly.

1. Introduction

Despite recent advances in stroke medicine, the incidence, prevalence, mortality, and disability-adjusted life expectancy of stroke have increased in absolute terms. Stroke is a leading cause of disability and death globally [1]. According to the Global Burden of Disease Study 2019, China reported 3.94 million new stroke cases, 28.76 million prevalent cases, and 2.19 million deaths, with hospitalization costs as high as 54.8 billion yuan, placing a substantial economic burden on the healthcare system [2–4]. By 2050, the absolute numbers of incident cases, deaths, and disability-adjusted life years in China are predicted to increase by 55.58% (from 3.94 million to 6.13 million), 72.15% (from 2.19 million to 3.77 million), and 20.04% (from 45.95 million to 55.16 million), respectively [5]. Ischemic stroke is the most common type of stroke, accounting for 82.6% of all cases [6]. For acute ischemic stroke suitable for intravenous thrombolytic (IVT) therapy, treatment with recombinant tissue plasminogen activator (rt-PA) within 4.5 h of onset and IVT with urokinase between 4.5 h and 6 h of onset remains the gold standard, significantly improving patient prognosis [7,8]. Analysis of 10-year time trends for intravenous thrombolysis in acute ischemic stroke from data from the Chinese National Stroke Registry showed that the median DNT has shortened to 60 min, with 53.4% of patients having a DNT $\leq$60 min [9]. Although the DNT has met the initial recommendation of 60 min by the American Heart Association/American Stroke Association (AHA/ASA) guidelines, it is longer than the more recent guideline update suggesting 45 min [10]. Moreover, recent research has emphasized that the DNT benchmark should be 30 min [11].

The benefit of IVT in ischemic stroke is recognized as being time-dependent. Compared with later administration of rt-PA, the earlier administration is associated with a lower risk of in-hospital mortality and hemorrhagic transformation and better functional outcomes at discharge and 90 days [12]. In addition, shorter DNT was associated with lower all-cause mortality and all-cause readmission rates at one year [13]. Therefore, reducing the delay in IVT in patients with ischemic stroke remains a focus of research. In previous studies, improvement measures for stroke care quality, such as establishing in-hospital stroke centers, optimizing fast green channels, and creating dedicated stroke teams, can be crucial in expediting patient assessment and treatment, thereby reducing IVT delays [14–16]. Among these, the model of trained stroke nurses coordinating care in a multidisciplinary team to manage the entire ischemic stroke treatment process, tightly control critical time points, and reduce human-caused treatment delays has been shown in numerous studies to improve IVT rates and reduce DNT [17,18].

Implementing a multilevel strategic approach to minimize DNT is critical. Unfortunately, because of the lack of timely and accurate data collection to provide excellent patient care and continuous quality improvement, substantial time and effort are required to identify patient records and the manual assessment of metrics in charts has been neglected in efforts to reduce in-hospital time delays [19]. Therefore, our study was based on the national quality management standards for stroke and the requirements for using information technology to enhance performance indicators' collection, analysis, and feedback [20]. We divided the IVT treatment process for ischemic stroke to improve the existing process into several key time points. Stroke nurses collected data on these key points by scanning quick response (QR) codes, which generated the corresponding nursing records and visualized the process timeline. This approach aimed to reduce the workload of emergency nurses, provide data for the quality management of stroke centers, and support continuous process optimization.

2. Methods

2.1. Identification and analysis of problems

Previous studies have identified the lack of a dedicated stroke team, efficient multidisciplinary stroke services, and effective communication, as well as delays in treatment decisions and laboratory tests, as key factors contributing to delays in IVT therapy for stroke patients [21]. Researchers have generally adopted strategies to reduce delays, such as the establishment of stroke units and multidisciplinary teams [14], optimization of fast green channels [15], and standardized nursing cooperation workflow [16]. The IVT therapy management process involves the collaboration of several departments, such as emergency, neurology, and radiology, but there is a lack of cohesion among these departments. Inconsistent communication between doctors and nurses results in patients and their families spending more time understanding the information provided by all parties, which affects the IVT decision-making process. Additionally, although there is now a consensus on the IVT process, the delineation of key time points and quality control of the IVT process have not been given sufficient attention, and stroke nurses are only documenting the stroke process checklist and are not actively taking the lead in promoting the IVT process. Manual recording is not as convenient as scanning the positioning QR code, and the accuracy of data recording cannot be guaranteed. To address these issues, a series of quality improvement measures were implemented.

2.2. Procedures

2.2.1. Development of a timeline process management system

The development team for the timeline process management system comprises ten members, including emergency department directors, nurse managers, emergency physicians, stroke nurses, neurologists, imaging physicians, and systems engineers. They tackled issues within the acute stroke process, specifically focusing on IVT in ischemic stroke, and created QR codes for critical milestones such as patient arrival, neurologist arrival, computed tomographic angiography (CTA), consent to thrombolytic treatment, head CTA review, and transfer to the department. Following the national quality management standards for stroke and the nursing guidelines for intravenous thrombolysis in acute ischemic stroke [20,22], the emergency department's head nurse and stroke nurse developed six templates for nursing records: admission, vascular access opening, blood collection, neurology consultation, radiology examination, return to the rescue room post-examination, and IVT. Responsibilities for template input and design fell to the systems engineer, who also considered QR code positioning and placement while considering department layout and hospital stroke process flow. Recording is completed by scanning the positioning QR code and generating the IV thrombolytic therapy timeline in the system.

2.2.2. Composition and responsibilities of the nurse-led stroke process management team

The emergency department has six relatively fixed nurse-led stroke process management teams, each consisting of a stroke nurse, an emergency department physician, a neurologist, a head nurse, a bedside nurse, and a triage nurse. Three of these teams rotate daily to ensure a 24-h schedule. Before implementing a standardized process management strategy for IVT in ischemic stroke, explicit definitions of each member's responsibilities were established. Physicians in the emergency department conducted rapid physical and neurological examinations. Triage nurses facilitated the subsequent stroke process by selecting a fast green channel in the emergency triage system. A nursing team leader promptly contacted neurologists and radiologists via phone. After the assessment, the neurologist communicated the IVT plan. Vital signs were monitored by the bedside nurse, who also established intravenous access and personalized the nursing record template as required. The stroke nurse provided assistance and guidance to the bedside nurses, utilizing the standardized introduction, situation, background, assessment, and recommendation (ISBAR) communication model to report the status upon the neurologist's arrival and accompany the patient to the radiology department for CTA. If informed consent for IVT was obtained from the radiology department, IVT was administered promptly. As a core member of the stroke team, the stroke nurse assumes responsibility for communication and coordination with all parties involved in the thrombolytic process. Stroke nurse was accountable for assisting in overseeing the quality of the nurses' work, inspecting and filing the medical records of the patient with ischemic stroke, and analyzing and summarizing the quality analysis of the stroke process while on duty in the emergency department resuscitation room before the arrival of the patient with ischemic stroke in the emergency department.

2.2.3. Training and assessment of nurse-led stroke process management teams

All nurse-led stroke management team members participated in a two-week training session covering theoretical expertise, standardized ISBAR communication, and three scenarios of the standardized IVT process for ischemic stroke. Theoretical topics included ischemic stroke etiology, history collection, general physical and neurological examinations, National Institute of Health stroke scale (NIHSS), diagnostic criteria, general management principles, specific treatments (IVT therapy and endovascular therapy), indications and contraindications, IVT dosage calculation and administration, observation points, and emergency management of post-IVT complications. Nurses also received training in intravenous infusion skills. ISBAR is a standardized communication method endorsed by the WHO and includes (I) brief self-introduction; (S) patient's general vital signs, NIHSS score, and initial diagnosis; (B) relevant ischemic stroke treatment history and medication; (A) comprehensive assessment and ischemic stroke treatment plan; and (R) presentation of the IVT treatment plan, including the risks and benefits of thrombolytic treatment, and allowing time for patient and family decision-making under strict time constraints [23,24]. Following the training, all members underwent an examination to ensure competency.

2.2.4. Standardized IVT process for ischemic stroke implemented

To shorten the IVT time, we implemented a comprehensive quality improvement program based on the existing IVT therapy process and eventually formulated a standardized IVT process for ischemic stroke (Appendix A). Upon arrival at the emergency clinic, a patient with a suspected stroke was immediately placed in a stroke-specific bed. Patients initially diagnosed with ischemic stroke after a rapid physical examination and neurological assessment by an emergency physician were promptly admitted to the fast green channel, enabling treatment before payment. The stroke nurse assisted the bedside nurse in monitoring vital signs, establishing intravenous access, conducting a rapid glucose check, sending all blood samples for testing, and performing electrocardiography. The neurologist arrived at the emergency department within 5 min of receiving the notification for the ischemic stroke consultation to evaluate the patient's consciousness, gaze, visual field, facial palsy, limb movement, sensation, speech, and articulation using the NIHSS score. Meanwhile, the stroke nurse reported the patients' status using the standardized ISBAR mode. With a portable thrombolysis kit including rt-PA, urapidil hydrochloride, nicardipine hydrochloride, syringes, extension tubes, and tee tubes, the stroke nurse accompanied the patient to the CTA with the neurologist so that IVT could be initiated immediately after completion of the CTA and informed consent was obtained. During transit, the neurologist explained the IVT therapy plan to the patient and family. If IVT was indicated after CTA, consent for thrombolytic treatment was obtained immediately, and the stroke nurse arranged for IVT in the radiology department without waiting for a formal imaging report. If the patient or family did not agree to IVT therapy or were hesitant, the neurologist would again communicate about IVT therapy and simultaneously return to the emergency room. Notably, as leaders in the stroke process, stroke nurses participated in the entire IVT treatment process and generated the IVT timeline for ischemic stroke by scanning the positioning QR code (Appendix B), thus completing the collection of stroke quality management data. Simultaneously, nursing record templates were generated, and bedside nurses were required to make personalized changes to reduce the nursing writing workload.

2.2.5. Incentive strategy

To further diminish DNT, meetings and interviews were held with the stroke process management team, and an incentive policy was developed. Under this policy, the top three groups with the shortest IVT of ischemic stroke during the monthly review would be awarded 200 RMB, 100 RMB, and 50 RMB, respectively. During the quarterly review, the top three groups with the shortest IVT of ischemic stroke would be awarded 300 RMB, 200 RMB, and 100 RMB, respectively. In addition, all team members were standardized before implementing the ischemic stroke standardized IVT process, eliminating the impact of occasional personnel changes. During the monthly review, we captured data on all standardized IVT processes for ischemic stroke implemented by the six nurse-led stroke process management teams over one month in the timeline process management system and then calculated the average DNT for each team. This process was also adhered to during our quarterly review.

2.3. Data collection

This historical, controlled study enrolled patients with ischemic stroke who received IVT between June 2021 and August 2023 at a tertiary stroke center. Those who met the diagnostic criteria for ischemic stroke in the Chinese guidelines for diagnosing and treating acute ischemic stroke 2018 [25]. Patients under 18 years of age and those diagnosed with ischemic stroke but not treated with IVT were excluded. Quality improvements for IVT led to a retrospective analysis of patients pre-intervention in group A (June 2021 to February 2022). After standardizing the IVT process, 78 patients with ischemic stroke from March to November 2022 were included in Group B1. To further reduce DNT, an incentive policy was implemented from December 2022 to March 2023, and an additional 65 ischemic stroke patients with intravenous thrombolysis were recruited in group B2. Basic information about all patients, including age, gender, blood pressure on admission, past medical history, stroke prodromal symptoms, and Activity of Daily Living (ADL), was collected through the emergency information system and the electronic medical record system. The intravenous thrombolytic therapy timeline was derived from the timeline process management system. Main measures: Door-to-CTA time (DCT), CTA time, neurology consultation to consent for IVT, CTA-to-needle time (CNT), and Door-to-needle time (DNT). Secondary measures: DCT compliance (percentage of people who underwent CTA within 20 min, 15 min, and 10 min) and DNT compliance (percentage of people who received IVT therapy within 60 min, 45 min, and 30 min) [10,11]. All data had been meticulously organized and verified by two researchers.

2.4. Data analysis

This study used SPSS 26.0 for data analysis. The Probability-Probability Plot was used to assess the normality of the data distribution. Continuous variables normally distributed were expressed as mean and standard deviation, while those not normally distributed were presented as medians. Categorical variables were presented as the frequency and percentage. Data comparison about the patients' characteristics, main outcomes, and secondary outcomes among the three groups was performed using the one-way ANOVA and Post Hoc Multiple Comparisons for normally distributed data, the Kruskal-Wallis, and Bonferroni's post hoc test for non-normally distributed data, and the Fisher's exact test and chi-square test for categorical variables. $P < 0.05$ was considered to indicate statistical significance.

2.5. Ethical consideration

This study was approved by the Zhejiang Hospital Ethics Committee [Approval No. 2023: Clinical Audit No. (4K)]. The patients involved in this study were fully informed of all aspects relevant to their decision to participate before confirming their willingness to participate and providing informed consent.

3. Results

3.1. General baseline information

A total of 228 patients were enrolled between June 2021 and August 2023, with the age of 64 (53,72) years, 75 (32.9%) females, 94 (41.2%) ambulance arrivals, and a median time from onset to arrival at the hospital of 90 (60,120) min. Table 1 summarizes the patient characteristics. No significant differences were present among the three groups in terms of general information, such as age ($P = 0.400$), gender ($P = 0.491$), and mode of arrival ($P = 0.555$), indicating that no differences were present among the included patients with ischemic stroke, as shown in Table 1.

3.2. Main outcomes

After implementing the standardized IVT process management strategy for ischemic stroke, the median (IQR) of DCT in group B1 was 13 (10, 17) min, which was lower than the 17 (13, 21) min in group A ($P < 0.001$). However, the difference in group B2, which had a median DCT of 13 (10, 16.5) min, was not significant between B1 and B2 ($P > 0.05$). The median CTA times were observed to be 14 (11, 17), 12 (10, 15), and 9 (6, 12) min in groups A, B1, and B2, respectively, with pairwise differences except between groups A and B1 ($P < 0.001$). For the neurology consultation to consent for IVT, the median were 26 (18, 35), 19 (11.5, 28), and 16 (9, 26) min in groups A, B1, and B2, respectively, again showing differences among the three groups ($P < 0.001$). Further analysis using Bonferroni's post hoc test revealed that groups B1 and B2 had differences compared to group A, but no significant difference was found between groups B1 and B2. Similar results were observed for the CNT. Regarding the DNT, the median in group B1 was 30 (24, 44) min lower than the 46 (38, 58) min in group A ($P < 0.001$). A similar effect was noted when comparing group B2 to group A. No significant differences were observed between groups B1 and B2 ($P > 0.05$). (Table 2).

3.3. Secondary outcomes

Before the intervention, the compliance rate for DNT ≤60 min in Group A was 82.4%. After the intervention, the compliance rates in Groups B1 and B2 increased to 93.6% and 95.4%, respectively. The compliance rates in Groups B1 and B2 were higher than that in Group A ($P < 0.05$), although there was no significant difference between Groups B1 and B2 ($P > 0.05$). The DNT ≤45 min of group B1 was 88.5%, slightly above 83.1% of group B2 ($P = 0.355$), and both were higher than the 47.1% in group A ($P < 0.001$). A similar trend was observed for DNT ≤30 min. For DCT ≤20 min, the compliance rates for groups B1 and B2 were 87.2% and 92.3%, respectively ($P = 0.230$), both of which were significantly higher than the 72.9% compliance in group A ($P < 0.05$). Regarding DCT ≤15 min, groups B1 and B2 achieved 65.4% and 73.9% compliance rates, respectively ($P = 0.275$), significantly higher than the 38.8% observed in group A. A similar effect was noted for DCT ≤10 min (Table 3).

The results are presented as a bar chart to observe DNT more intuitively before and after the intervention and the three main factors affecting DNT (Appendix C). The median times for DNT, DCT, CTA, and CNT were reduced compared to group A in groups B1 and B2. However, the differences between groups B1 and B2 were not statistically significant. We analyzed trend plots of DNT, DCT, CTA time, and CNT over three quarters for continuous changes in groups A, B1, and B2. After the intervention, the DNT continued to decline, with the shortest median time recorded in the last quarter for group B1. In contrast, DNT in group B2 did not show further reduction despite implementing an additional incentive policy (Appendix D).

4. Discussion

Shortening the DNT is a recognized key factor in achieving a favorable outcome after stroke, with each minute of delayed DNT decreasing the chance of survival by 0.6%, increasing the chance of cerebral haemorrhage by 0.3%, and decreasing the ability to perform activities of daily living by 0.4% [26]. To reduce delays in IVT for ischemic stroke, we developed a timeline process management system and implemented a series of quality improvement measures. Previous surveillance data have shown a median DCT of 20 min for IVT in ischemic stroke, indicating a significant delay between admission and access to imaging, which may be related to stroke recognition and the initiation of the thrombolytic process [27]. In our study, the emergency stroke team was on standby 24 h a day, and once the patient with ischemic stroke arrived at the hospital, the triage nurse quickly triaged them and entered the stroke process, initiating the stroke team and the fast green channel, thereby shortening the response time of the stroke team. The bedside nurse was responsible for immediately establishing the intravenous access, and the stroke nurse prepared a portable thrombolytic box for the CTA. These interventions shortened the median DCT to 13 (10,17) min, significantly lower than 17 (13,21) min before the intervention. More than 85% of patients had a DCT of <20 min, and almost one-third had a DCT of <10 min. Therefore,

Table 1
Baseline characteristics of the participants ($n = 228$).

Characteristics	Total	Group A ($n = 85$)	Group B1 ($n = 78$)	Group B2 ($n = 65$)	H/χ^2	P
Age (years)	64 (53, 72)	66 (54, 74)	63 (52, 71)	63 (52, 71)	1.83	0.400
Gender						
Female	75 (32.9)	32 (37.6)	24 (30.8)	19 (29.2)	1.43	0.491
Male	153 (67.1)	53 (63.4)	54 (69.2)	46 (70.8)		
Medical transportation						
By ambulance	94 (41.2)	35 (41.2)	29 (37.2)	30 (46.2)	1.18	0.555
By self-transport	134 (58.8)	50 (58.8)	49 (62.8)	35 (53.8)		
Time of onset to arrival at hospital (min)	90 (60, 120)	90 (60, 135)	60 (60, 150)	90 (30, 120)	1.42	0.492
Comorbidity						
High blood pressure	124 (54.4)	42 (49.4)	45 (57.7)	37 (56.9)	1.71	0.425
Diabetes	38 (16.7)	15 (17.6)	17 (21.8)	6 (9.2)	4.12	0.127
Atrial fibrillation	19 (8.3)	10 (11.8)	5 (6.4)	4 (6.2)	2.09	0.351
Coronary atherosclerotic heart disease	20 (8.9)	7 (8.2)	8 (10.3)	5 (7.7)	0.34	0.844
Self-care after onset of illness						
Heavy dependence	69 (30.3)	26 (30.6)	19 (24.4)	24 (36.9)	7.86	0.249
Moderately dependent	46 (20.2)	20 (23.5)	13 (16.7)	13 (20.0)		
Mildly dependent	87 (38.2)	31 (36.5)	32 (41.0)	24 (36.9)		
No need to be dependent	26 (11.4)	8 (3.5)	14 (17.9)	4 (6.2)		
Bleeding after IVT	49 (21.5)	24 (28.2)	31 (39.7)	18 (27.7)	3.78	0.151

Note: Data are *Median* (P_{25}, P_{75}) or n (%). IVT = intravenous thrombolytic. Group A: 1 cerebral haemorrhage, 2 nasal haemorrhages and the rest gingival haemorrhages; Group B1: 2 cerebral haemorrhages, 1 nasal haemorrhage and the rest gingival haemorrhages; Group B2: 2 nasal haemorrhages and the rest gingival haemorrhages.

Table 2
Comparison of DCT, CTA time, neurology consultation to consent for IVT, CNT and DNT among the three groups.

Items	Group A ($n = 85$)	Group B1 ($n = 78$)	Group B2 ($n = 65$)	H	P	Pairwise comparison
Door-to-CTA time (DCT, min)	17 (13, 21)	13 (10, 17)	13 (10, 16.5)	23.61	< 0.001	A > B1**; A > B2**
CTA time	14 (11, 17)	12 (10, 15)	9 (6, 12)	37.01	< 0.001	A > B2**; B1 > B2**
Neurology consultation to consent for IVT (min)	26 (18, 35)	19 (11.5, 28)	16 (9, 26)	23.11	< 0.001	A > B1**; A > B2**
CTA-to-needle time (CNT, min)	27 (22, 35)	18 (13, 26.5)	18 (12, 25.5)	32.73	< 0.001	A > B1**; A > B2**
Door-to-needle time (DNT, min)	46 (38, 58)	30 (24, 44)	31 (24, 41)	47.82	< 0.001	A > B1**; A > B2**

Note: Data are *Median* (P_{25}, P_{75}). **$P < 0.001$. CTA = computed tomographic angiography. IVT = intravenous thrombolytic.

Table 3
Comparison of CTA within 20 min, 15 min, and 10 min and DNT within 60 min, 45min, and 30 min among the three groups.

Items	Group A ($n = 85$)	Group B1 ($n = 78$)	Group B2 ($n = 65$)	χ^2	P	Pairwise comparison
Door-to-CTA time (DCT, min)						
≤10	8 (9.4)	28 (35.9)	17 (26.2)	16.42	< 0.001	A < B1**; A < B2*
≤15	33 (38.8)	51 (65.4)	48 (73.9)	21.26	< 0.001	A < B1*; A < B2**
≤20	62 (72.9)	68 (87.2)	60 (92.3)	11.21	0.004	A < B1*; A < B2*
Door-to-needle time (DNT, min)						
≤30	6 (7.1)	41 (52.6)	32 (49.2)	45.73	< 0.001	A < B1**; A < B2**
≤45	40 (47.1)	69 (88.5)	54 (83.1)	40.20	< 0.001	A < B1**; A < B2**
≤60	70 (82.4)	73 (93.6)	62 (95.4)	8.66	0.013	A < B1*; A < B2*

Note: Data are n (%). *$P < 0.05$. **$P < 0.001$. CTA = computed tomographic angiography.

being prepared in advance is beneficial [28].

Notably, our study drew on patterns of previous studies in which IVT was performed directly in a CT room [29,30]. Storing rt-PA or urokinase in the pharmacy or ward delays emergency medication administration in patients with ischemic stroke [31]. Storage of spare IVT drugs in portable thrombolytic kits could enable urgent IVT therapy in the CT room without needing formal radiology reports and blood test results unless the patient takes oral anticoagulants, which would considerably reduce the delay in IVT therapy [32]. In addition, ischemic stroke requires a significant amount of time after the completion of imaging to communicate with the patient and family about the benefits and risks of IVT, which makes obtaining informed consent for treatment a key factor in prolonging DNT [33]. However, the neurologist in our study would have been required to arrive at the emergency department within 5 min and immediately evaluate the patient, using a standardized ISBAR communication mode for the IVT therapy informed consent talk so that patients and their families could quickly understand the disease and decide on treatment options, which may be the key to reducing CNT time. Hence, in this study, the median time to CNT was reduced by 9 min compared with that in Group A.

The median of DNT in this study decreased significantly from 46 (38,58) to 30 (24,42) min, with the shortest DNT after the intervention being 15 min. The number of patients treated with IVT within 60 min increased from 82.4% to 94.4% before the quality improvement measures were implemented, and the proportion of patients treated within 45 min rose from 47.1% to 86.0%. The time to DNT after the implementation of the quality improvement measures far exceeded the goals introduced by the US Stroke Guidelines of treating at least 50% of IS with rt-PA within 60 min of DNT and treating at least 50% of ischemic stroke with rt-PA within 45 min [34]. The results of this study are similar to those in a previous study [35]. The key to shortening the DNT is that our standardized IVT procedure for ischemic stroke is led by stroke nurses, who need to be nurse practitioners and above, have three or more years of clinical experience and one year in the emergency department, and have been trained by the Zhejiang Hospital stroke nurses' entry training, passing both theoretical and practical tests. As a core part of the stroke process management team, stroke nurses have extensive experience and knowledge in neurology and a high level of communication and coordination skills to coordinate all departments to improve efficiency. When the patient arrived at the emergency department, the stroke nurse followed the patient throughout the process, assisted the bedside nurse in establishing intravenous access to prepare for a CTA scan, and used the ISBAR communication model to help the neurologist obtain immediate access to the patient's status. Stroke nurses with portable thrombolytic kits accompanied the patients to the radiology department for CTA scanning so that immediate IVT could be administered after obtaining informed consent. In addition, the fast green channel for stroke patients without prepayment for the entire treatment process was an important factor in reducing delays in DNT.

Surprisingly, minimal difference was found in the time required for IVT between groups B1 and B2. DNT, DCT, CTA time, and CNT showed a decreasing trend over three quarters in groups A, B1, and B2, whereas an increasing trend was observed in the first quarter in group B2. A potential explanation for this delay could be the COVID-19 outbreak, which affected stroke care in December 2022. As in most other studies, the COVID-19 pandemic caused a general increase in the duration of IVT therapy in ischemic stroke [36,37], with an increase in the DNT from 50 (40,75) min before the COVID-19 pandemic to 65 (48,84) min [38]. Therefore, we cannot definitively state that the additional incentive policy was ineffective; the effect of the COVID-19 pandemic on stroke care counteracted that of the extra incentive policy. Future studies should control this variable to validate the impact of incentive policies on IVT treatment. Alternatively, the DNT can be further reduced by adding a process-time-consuming reminder feature.

Notably, the application of positioning the QR code timeline process management system in our model is a highlight and converts the important time nodes of the IVT treatment process of the stroke into QR codes, which scan the positioning QR code to obtain the time of the thrombolytic process and generate the timeline of the IVT, realizing the electronic information of the data of the stroke process. Thus, the lag and omission of stroke information data collection were avoided, the shortcomings of the high rate of missing data were compensated, and data quality was greatly improved [39]. Meanwhile, the nursing records of IVT patients with ischemic stroke were generated during the scanning process, and stroke nurses could make personalized modifications to the generated nursing records. This considerably reduces the burden on nurses in writing nursing records. Previous studies have applied timeline management to acute care patients with severe trauma through real-time recording of various diagnoses and treatment time points. The implementation of timeline management to obtain trauma data through a feedback mechanism to optimize the diagnosis and treatment process of trauma patients reduces the treatment time and thus improves the efficiency of treatment [40]. Therefore, timeline management could be applied to time-dependent diseases. Some researchers have added clock display timers to the stroke process to issue reminders when a predefined target time runs out, urging stroke team members to complete the task [41].

This study had some limitations. First, this was a single-center study with participants from the same hospital, which may have affected the generalizability of the findings. Second, we used the pre-intervention period as a historical control. Although group B1 can be considered a transition period, the post-intervention data may have been affected by unmeasured confounders, such as a gradual improvement in stroke care because of cumulative experience and better training. Third, because this study aimed to investigate the impact of a simple quality improvement program on DNT, several factors associated with discharge outcomes (e.g., mortality, length of stay, and inpatient costs) were excluded. Finally, our study did not develop a reminder function for the time used at different time points, and it should be added in the future.

5. Conclusions

Our study demonstrated that the DNT for ischemic stroke could be controlled within 30 min by optimizing the IVT treatment strategy. This single-center IVT strategy for ischemic stroke led by stroke nurses indicates that management is important for constructing advanced stroke centers.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

CRediT authorship contribution statement

Baiyu Li: Conceptualization, Methodology, Validation, Formal analysis, Data curation, Writing - original draft, Writing - review & editing. **Zhufeng Zhang:** Investigation, Resources, Writing - review & editing, Funding acquisition, Supervision, Project administration. **Keye Li:** Data curation, Writing - original draft, Writing - review & editing, Supervision, Project administration. **Lingdie Zhao:** Methodology, Validation, Formal analysis, Data Curation, Writing - review & editing. **Rong Niu:** Validation, Investigation, Formal analysis, Writing - original draft, Writing - review & editing.

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Declaration of competing interest

The authors declare no conflict of interest.

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Appendices. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijnss.2024.10.004.

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