ORIGINAL ARTICLE

# An expedited stroke triage pathway: the key to shortening the door-to-needle time in delivery of thrombolysis


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Brain ischemia; Emergency medical services; Recombinant proteins; Stroke; Tissue plasminogen activator

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**Objectives** To assess time management of stroke thrombolysis triage and functional outcomes in patients receiving recombinant tissue plasminogen activator for hyperacute stroke, and identify bottlenecks in delivery of the treatment.

**Design** Prospective study.

**Setting** A university teaching hospital in Hong Kong.

**Patients** Patients with suspected hyperacute stroke referred to the stroke thrombolysis team during October 2008 to September 2009.

**Main outcome measures** Time performance records including door-to–stroke team, door-to-needle, and onset-to-thrombolysis times. Functional outcomes by modified Rankin Scale score at 3 months, and thrombolysis-related complications including haemorrhagic transformations and mortality.

**Results** During the 12-month period, 95 thrombolysis calls were received; recombinant tissue plasminogen activator was given intravenously to 17 (18%) of the patients and intra-arterially to 11 (12%). The mean (standard deviation) door-to–stroke team and the door-to-needle times for intravenous recombinant tissue plasminogen activator patients were 33 (25) and 80 (25) minutes, respectively; both were about 20 minutes longer than that recommended by the National Institute of Neurological Disorders and Stroke. The mean National Institute of Health Stroke Scale score for patients received intravenous recombinant tissue plasminogen activator was 16 (standard deviation, 7). The mean (standard deviation) onset-to-treatment time was 144 (42) minutes. Nine (53%) patients who received intravenous recombinant tissue plasminogen activator achieved favourable outcomes at 3 months, with a modified Rankin Scale score of 0 to 1. Symptomatic haemorrhage and mortality occurred in one (6%) patient.

**Conclusion** A dedicated stroke triage pathway is essential to ensure efficient and safe delivery of thrombolysis therapy. Improvements in door-to–stroke team time through integration with emergency medicine staff and neuroradiologists may improve thrombolysis eligibility.


## Introduction

Thrombolysis with alteplase—a recombinant tissue plasminogen activator (rtPA)—remains the only proven effective drug treatment for acute ischaemic stroke.[1] The treatment benefit with intravenous (IV) rtPA is substantial, with a relative risk reduction of 9.8%, an absolute risk reduction of 5.5%, corresponding to a number-needed-to-treat of 18. Despite recent evidence suggesting that the beneficial effect of IV rtPA extends up to 4.5 hours after stroke onset, only 5% or less of patients worldwide have been able to receive such treatment.[1,2] In Hong Kong, there is no uniform territory-wide government policy on thrombolysis in stroke, although several major public hospitals have implemented in-house hyperacute stroke triage programmes for thrombolysis.

"Time is brain", as advocated by Saver,[3] every minute counts in delivering rtPA. Meta-analysis has shown that the earlier rtPA is given from symptom onset, the better

## 加快中風患者的分流途徑：在血栓溶解治療過程中縮短由入院到下針時間的關鍵

**目的** 評估分流血栓溶解治療中風患者的時間分配，以及接受合成組織胞漿素原活化劑（rtPA）的高急性中風患者的神經功能狀況，並找出阻礙救援過程中的障礙物。

**設計** 前瞻性研究。

**安排** 香港一所大學教學醫院。

**患者** 2008年10月至2009年9月期間，轉送往中風血栓溶解小組的被懷疑患有高急性中風的病人。

**主要結果測量** 入院到中風小組人員到達時間、入院到下針時間，和病發到接受血栓溶解治療時間的紀錄；用修正版任金量表（mRS）評估病人中風三個月後的神經功能狀況；與血栓溶解治療有關的併發包括腦梗塞後的出血變化及死亡。

**結果** 在12個月的研究期間，共接到95宗與血栓溶解治療有關的病例；其中17名（18%）患者接受靜脈注射rtPA，另11名（12%）患者接受動脈注射rtPA。入院到中風小組人員到達時間平均為33分鐘（標準差：25分鐘），入院到下針時間平均為80分鐘（標準差：25分鐘）；兩者都比美國國立神經病與中風協會（NINDS）所建議的多約20分鐘。接受靜脈注射rtPA的病人，其美國國家衛生研究院腦中風量表（NIHSS）分數為16（標準差：7）。病發到接受治療時間平均為144分鐘（標準差：42分鐘）。9名接受靜脈注射rtPA的病人三個月後達至滿意結果，其mRS分數為0至1。1名病人（6%）出現症狀性出血及死亡。

**結論** 要有效率和安全地為病人施予血栓溶解治療，必須要有一個專為中風患者而設的分流途徑。透過與急症室人員及神經放射科醫生的整合來改善入院到中風小組人員到達時間，有助進一步改善適用於病人身上的血栓溶解治療。


the probability of achieving a favourable outcome at 3 months.[4] Therefore, rtPA delivery in hyperacute stroke should be performed as swiftly as possible rather than merely complying to the 3- or 4.5-hour therapeutic window. Back in 1997, the National Institute of Neurological Disorders and Stroke (NINDS) recommended that thrombolysis treatment should be initiated to all eligible stroke patients within 60 minutes of their presentation to the emergency department; in other words, starting from the triage station, assessment by emergency physician, stroke physician, a non-contrast computed tomographic (CT) brain scan and its interpretation, and evaluation of eligibility for thrombolysis should all be performed within a door-to-needle time of 1 hour.[5]

In our hospital, once the emergency physician suspects the diagnosis of hyperacute stroke and activates the thrombolysis team by paging the on-call stroke nurse, he/she would then immediately review the patient in the emergency department with a portable 'lysis-box' containing all the essential equipment and medications. Emergency department staff check for and rule out hypoglycaemia using capillary blood testing as soon as possible, send routine blood tests (including glucose and coagulation screen) and arrange a non-contrast CT scan of the brain, a chest X-ray and an electrocardiogram, while the stroke team is en route to the emergency department. The stroke nurse clarifies the stroke onset time, quantifies the neurological deficit by the National Institute of Health Stroke Scale (NIHSS), and liaises with the duty stroke neurologist who leads the thrombolysis team. The stroke neurologist also reviews the patient in the emergency department, obtains informed consent for investigation and treatment from the patient and family, and arranges an urgent cranial multimodal CT scan where necessary with the on-duty neuroradiologist while simultaneously reviewing the non-contrast CT brain scan. The neurologist and neuroradiologist interpret the CT brain scan on-site together and decide on the patient's eligibility to receive IV or intra-arterial (IA) rtPA, or to withhold thrombolysis treatment. The neurologist also coordinates with the emergency physician, intensivist, and neurointerventionist to formulate a treatment plan. The multimodal CT study includes a non-contrast brain scan, an angiogram and a perfusion study,[6] with a view to understanding the pathophysiology of any given stroke. It gives valuable information for evaluating patients who might stand a lower success rate of recanalisation and a higher risk of haemorrhagic complications with IV rtPA. Such patients include: (1) those who have internal carotid artery (ICA) occlusion or carotid T-junction (ICA bifurcation) occlusion, implying a lower chance of recanalisation, and (2) those with an Alberta Stroke Program Early CT Score (ASPECTS) of 7 or less despite presenting within the 3-hour window.[7,8] In patients presenting between 3 and 6 hours from symptom onset, IA thrombolysis was only indicated when the CT angiogram showed a relevant arterial occlusion.

In this study, we examined the performance of our thrombolysis triage model. In particular, we compared our time management, functional outcomes at 3 months, and complication rates in comparison with international recommendations and standards. We aimed to identify any bottlenecks in thrombolysis delivery and identify methods to improve the system.

## Methods

We analysed data collected in the Prince of Wales Hospital Stroke Thrombolysis Registry from October

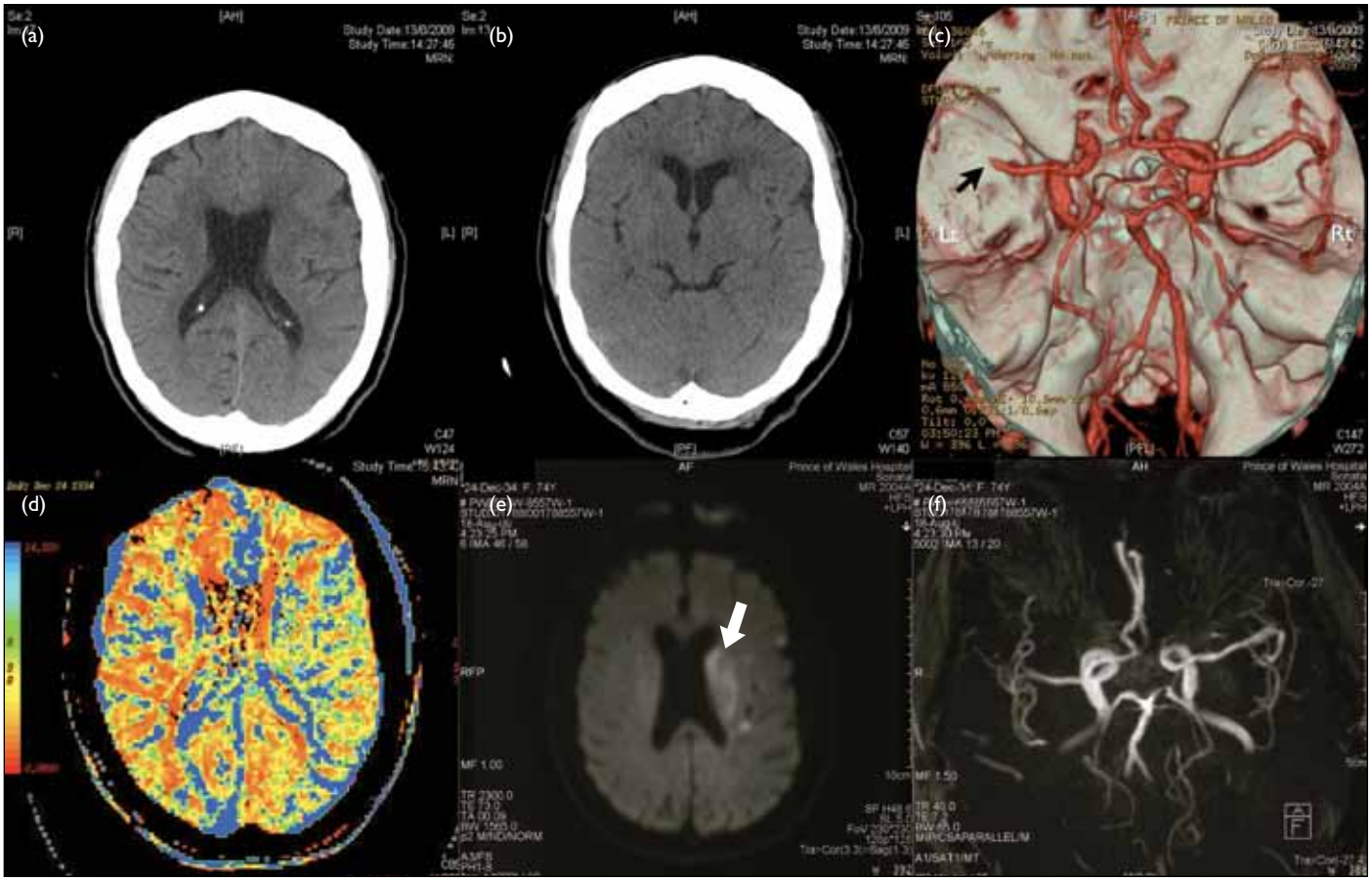


**FIG 1. Successful recanalisation and a good functional outcome in a patient who received intravenous recombinant tissue plasminogen activator (rtPA) for acute left middle cerebral artery occlusion from cardioembolism**

A 74-year-old Chinese woman presented 34 minutes after an acute onset of right hemiplegia and global aphasia. (a, b) A non-contrast computed tomographic (CT) brain performed in 15 minutes after arrival (door-to-CT) showed no evidence of haemorrhage or obvious early signs of infarction. Assessment by the stroke team in 46 minutes (door-to–stroke team) revealed atrial fibrillation and an National Institute of Health Stroke Scale (NIHSS) score of 15. (c) A CT angiogram showed an abrupt occlusion of left middle cerebral artery (black arrow) and (d) there was a corresponding extensive perfusion deficit in a perfusion study (prolonged mean transit time). She received rtPA 45 mg intravenously at 113 minutes (door-to-needle), ie 147 minutes after symptom onset (onset-to-treatment). (e) Four days later, a diffusion-weighted magnetic resonance imaging brain shows residual acute infarcts of smaller volume (white arrow) compared with the pre-thrombolysis hypoperfused region in the CT study. (f) A magnetic resonance angiogram shows recanalisation of the left middle cerebral artery. The patient was discharged on day 8 with an NIHSS score of 0. Three-month modified Rankin Scale score was 0, indicating a full functional recovery. She was put on warfarin for long-term stroke prophylaxis

2008 till September 2009. All thrombolysis calls initiated to the stroke team were recorded. The team currently provides a thrombolysis service during office hours only due to limitations in resources. The data contained time records of symptom onset, arrival time at the emergency department, thrombolysis call initiation and stroke nurse attendance time, CT brain scan and interpretation time, thrombolysis team decision time, and rtPA initiation time. For patients receiving IV thrombolysis, the time of rtPA bolus injection was marked as 'needle-time', which was also the rtPA delivery time (Fig 1). For patients receiving IA thrombolysis, the puncture of the femoral artery marked the 'needle-time'; and the thrombolysis delivery time was the moment when rtPA was first delivered through a microcatheter perched adjacent to the culprit clot.

Baseline demographics—including age, gender, and risk factors (hypertension, diabetes mellitus, atrial fibrillation, prior stroke, and smoking history)—were collected. The NIHSS score was recorded by certified stroke nurses or neurologists. The reasons for exclusion from thrombolysis were classified into: minor stroke (NIHSS 0-5), massive stroke (NIHSS >25), contra-indication based on medical history and/or laboratory results, presentation beyond the thrombolysis window (including wake-up strokes), intracerebral haemorrhage (ICH), stroke mimics, and patient refusal. The cases in which the decision to undertake IV or IA thrombolysis altered by multimodal CT imaging were recorded.

## Outcome measures

The mode of discharge (direct to home, discharge to

TABLE 1. Demographics of patients who received thrombolytic therapy for acute stroke in our study and in previously reported studies; data from the National Institute of Neurological Disorders and Stroke (NINDS) and European Cooperative Acute Stroke Study (ECASS) III trials are shown for comparison*

| Demographics | IV rtPA (n=17) | IA rtPA (n=11) | NINDS[9] | ECASS III[2] |
|---|---|---|---|---|
| Age (years) | 71 ± 11 | 62 ± 14 | 67 ± 10 | 65 ± 12 |
| Male gender | 7 (41%) | 6 (55%) | 58% | 63% |
| NIHSS | | | | |
| Mean ± SD | 16.4 ± 7.0 | 16.0 ± 7.1 | - | 10.7 ± 5.6 |
| Median | 16 | 14 | 14 | 9 |
| Diabetes mellitus | 3 (18%) | 3 (27%) | - | 14.8% |
| Hypertension | 7 (41%) | 6 (55%) | - | 62.4% |
| Atrial fibrillation | 8 (47%) | 7 (64%) | 42% | 12.7% |
| Prior stroke | 1 (6%) | 1 (9%) | - | - |
| Smoking history | 2 (12%) | 1 (9%) | - | - |

* IV denotes intravenous, rtPA recombinant tissue plasminogen activator, IA inter-arterial, NIHSS National Institute of Health Stroke Scale, and SD standard deviation

TABLE 2. Time management of patients according to thrombolytic therapy received*

| | Time (minutes), mean ± standard deviation | | |
|---|---|---|---|
| | IV rtPA | IA rtPA | No rtPA |
| Symptom-to-door | 64 ± 42 | 91 ± 42 | 181 ± 21 |
| Door-to–stroke team | 33 ± 25 | 33 ± 25 | 73 ± 20 |
| Door-to–CT brain | 30 ± 14 | 33 ± 14 | 43 ± 15 |
| Door-to-decision | 80 ± 25 | 51 ± 16 | 142 ± 17 |
| Door-to-needle | 80 ± 25 | 84 ± 25 | - |
| Onset-to-thrombolysis | 144 ± 42 | 237 ± 42 | - |

* IV denotes intravenous, rtPA recombinant tissue plasminogen activator, IA inter-arterial, and CT computed tomography

rehabilitation hospital, or death) and the modified Rankin Scale (mRS) score at 3 months were recorded. A favourable outcome was defined as a mRS score of 0 or 1, that is, no residual symptoms or residual symptoms without disability, respectively. A follow-up CT scan was performed at least 24 hours after receiving rtPA to detect ICH, if any. Any ICH was classified into asymptomatic or symptomatic according to the criteria used in the European Cooperative Acute Stroke Study III (ECASS III) trial[2]; symptomatic haemorrhage was defined as any extravascular blood in the brain or within the cranium that was associated with clinical deterioration, as measured by an increase of 4 points or more in the NIHSS score, or that led to death and was identified as the predominant cause of neurological deterioration. These outcome measures were also employed in the NINDS and ECASS III trials.[2,9]

### Statistical analyses

Statistical analysis was performed using the Statistical Package for the Social Sciences (Windows version 16.0; SPSS Inc, Chicago [IL], US). The mean symptom-to-door, door-to–stroke team, door-to–CT brain, door-to-decision, door-to-needle, and onset-to-thrombolysis times measured in minutes over the 12-month period were calculated by dividing the period into two 6-month segments and the difference in mean time-to–stroke team, time-to-CT, and door-to-needle time for IV rtPA patients.

## Results

From October 2008 to September 2009, we received 95 thrombolysis calls and administered IV rtPA to 17 (18%) patients and IA rtPA to 11 (12%) patients. The thrombolysis calls were predominantly from the emergency department (n=82, 86%), followed by the medical wards (n=7, 7%), the cardiac catheterization laboratory (n=4, 4%), and the intensive care unit (n=2, 2%). Table 1 shows the baseline characteristics of patients given rtPA. The time profiles of patients who received IV, IA, or no rtPA treatment are shown in Table 2.

### Patients receiving intravenous recombinant tissue plasminogen activator

Of the 17 patients who received IV rtPA, 15 (88%) were referred from the emergency department and 2 (12%) from medical wards. The mean age of patients who received IV rtPA was 71 years, and seven (41%) were male. Their median NIHSS score was 16. The two most common risk factors were atrial fibrillation (47%) and hypertension (41%). Three (18%) patients had diabetes mellitus and one (6%) had had a prior stroke. The mean symptom-to-door, door-to–stroke team, door-to–CT brain, and door-to-needle times were 64, 33, 30, and 80 minutes, respectively. The mean onset-to-thrombolysis time was 144 minutes.

### Patients receiving intra-arterial recombinant tissue plasminogen activator

The mean age of the patients who received IA rtPA was 62 years, and six (55%) were male. Their median NIHSS score was 14. Atrial fibrillation (64%) and hypertension (55%) were also the two commonest risk factors. Three patients (27%) had diabetes mellitus and one (9%) had had a prior stroke. The mean symptom-to-door, door-to–stroke team, door-to–CT brain, and door-to-needle times were 91, 33, 33, and 84 minutes, respectively. The mean onset-to-thrombolysis time was 237 minutes.

Decisions to use IA thrombolysis were predicated by: (1) onset of symptoms between 3

TABLE 3. Time management of patients receiving intravenous recombinant tissue plasminogen activator, as compared with the National Institute of Neurological Disorders and Stroke (NINDS) benchmark and trends over the 12-month study period*

| | Mean time (mins) | | | Mean time (mins) | | |
|---|---|---|---|---|---|---|
| | NINDS | IV rtPA | Difference† | IV (Oct 2008 to Mar 2009) | IV (Apr to Sep 2009) | Difference‡ |
| Symptom-to-door | 60 | 64 | – | 57 | 69 | – |
| Door-to–stroke team | 15 | 33 | +18 | 39 | 31 | -8 |
| Door-to-CT | 25 | 30 | +5 | 35 | 27 | -8 |
| Stroke team–to-treatment | – | 47 | – | 51 | 43 | -8 |
| Door-to-needle | 60 | 80 | +20 | 90 | 74 | -16 |
| Onset-to-treatment | 180 | 144 | – | 147 | 143 | – |

* IV denotes intravenous, rtPA recombinant tissue plasminogen activator, and CT computed tomography
† Difference as compared with benchmark of NINDS
‡ Difference between 6-month periods (Oct 2008 to Mar 2009 vs Apr to Sep 2009); values did not reach statistical significance

and 6 hours with CT angiogram evidence of major artery occlusion (n=7, 64%); (2) stroke secondary to cardiac catheterization (n=2, 18%); and (3) high risk of haemorrhagic complication from IV rtPA (n=2, 18%). These 'high-risk' patients presented within 3 hours of symptom onset but had low ASPECTS (≤7) and carotid T-junction (n=1, 9%) or ICA occlusion (n=1, 9%) revealed by CT angiogram. They were presumed to be at higher risk of haemorrhagic transformation and lower rate of recanalisation, if IV rtPA was to be given.

## Patients excluded from thrombolysis

Sixty-seven (71%) of the patients were excluded from rtPA. The most common reason was minor stroke, with NIHSS score of 0 to 5 (n=21, 32%). The second most common reason was the patients being beyond the 'safe thrombolysis time' window (n=19, 28%), which included 'wake-up' strokes (n=10, 15%). Wake-up strokes refer to neurological deficits noted upon awakening without a definite onset time. The onset time for triage in these patients could only be referred to the last-seen-well time. In 11 (16%) of the patients, rtPA therapy was not indicated because of poor premorbid functional status and medical co-morbidities, such as significant anaemia, severe renal impairment, or active malignancies. Stroke mimics, such as hypoglycaemia, cervical myelopathy and hypoxic brain damage, accounted for eight (12%) of the patients being excluded. Five (8%) patients had ICH. Massive strokes (NIHSS score >25) were noted in two (3%) of the patients, and one (1%) did not consent to thrombolysis treatment.

Notably, for patients who were not given rtPA presented to hospital later (181 minutes after symptom onset), the stroke team was informed later (73 minutes after arrival at hospital), or had a longer door-to–CT brain time (43 minutes).

## Time management

On average, the stroke team was notified 33 minutes after the patient arrived at the emergency department, or 18 minutes later than that recommended by NINDS. The door-to-needle time of 80 minutes was 20 minutes longer than the NINDS benchmark of 60 minutes (Table 3).

When time performance across the first half year was compared with the second half, we see an improving trend. On average the stroke team was notified 8 minutes earlier and the door-to-CT time was 8 minutes shorter. The stroke team–to-treatment time, which is a measurement of the stroke team's triage efficiency, also improved by 8 minutes. These contributed to an overall shortening of 16 minutes in the door-to-needle time. In the later half year, the door-to-needle time was shortened from 90 to 74 minutes, though it was still 14 minutes longer than recommended.

In patients having IA thrombolysis, the mean time from symptom onset to presentation was 91 minutes, which was longer than for those given IV rtPA. In two patients, stroke occurred during cardiac catheterization, and therefore, the door-to–stroke team time was rapid and the door-to-needle time was significantly shorter.

## Favourable functional outcome

In patients having IV rtPA, 53% attained a favourable outcome at 3 months, which included seven (41%) with a mRS score of 0, and two (12%) with a mRS score of 1 (Fig 2). For IA thrombolysis, one (9%) of the patients had a mRS score of 1, and two (18%) had a mRS score of 2. This corresponds to a favourable outcome (mRS 0-2) in 27% of the patients based on the criteria used in the Prolyse in Acute Cerebral Thromboembolism II trial.[10]

One interesting observation was that five (29%)

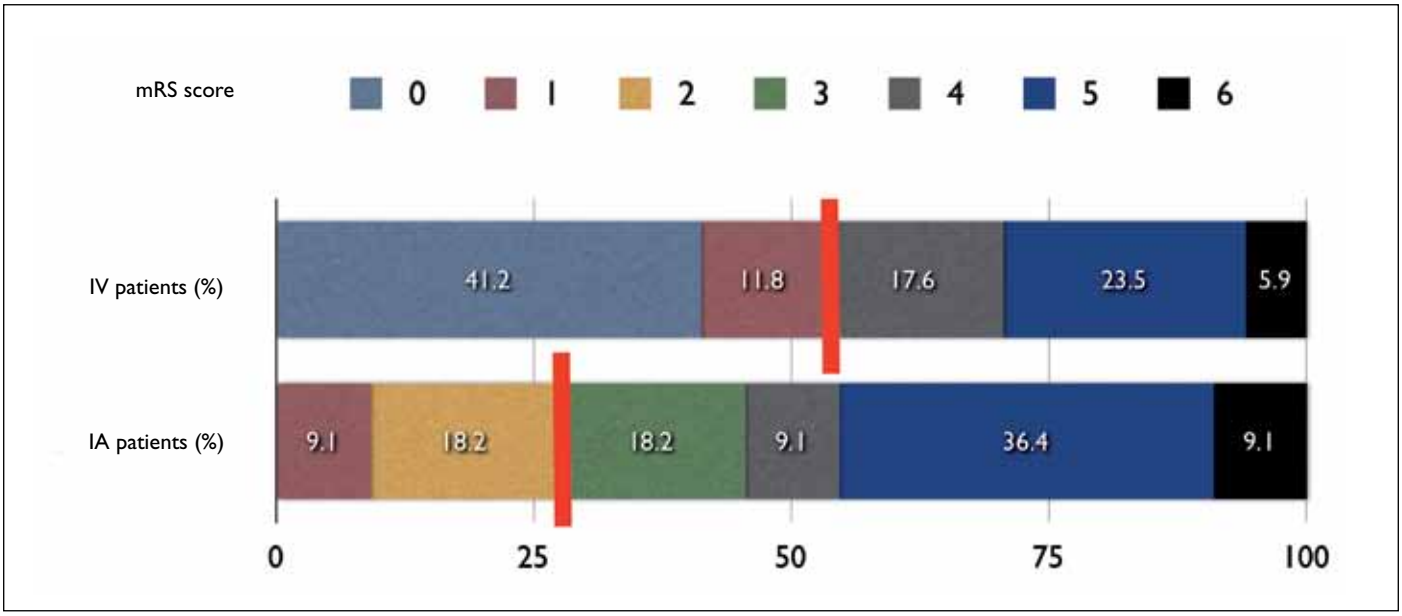


FIG 2. Three-month modified Rankin Scale (mRS) score
Good functional outcomes defined by red bars; mRS 0-1 for patients receiving intravenous (IV) recombinant tissue plasminogen activator (rtPA), and mRS 0-2 for patients receiving intra-arterial (IA) rtPA

of the patients who received IV rtPA could be directly discharged home from the Acute Stroke Unit after a mean stay of 9 (standard deviation, 3) days despite an initial median NIHSS score of 11, indicating a moderate neurological disability.

### Haemorrhagic transformation and mortality after receiving recombinant tissue plasminogen activator

One (6%) of the patients died shortly after receiving IV thrombolysis. This 70-year-old woman had a massive stroke and died shortly after receiving rtPA treatment before a CT brain scan could be repeated. There were no other obvious medical complications and her death was presumed to be due to a symptomatic haemorrhage. Six (35%) of the patients had asymptomatic haemorrhage, namely mild petechial haemorrhages within the infarct core but without any clinical or mass effects.

Two (18%) of the patients developed symptomatic haemorrhages after IA thrombolysis. One underwent decompressive craniectomy for malignant middle cerebral artery syndrome and the other was treated conservatively. Both were totally dependent (mRS score, 5) at 3 months. One (9%) of the patients who had IA thrombolysis during cardiac catheterization died of pneumonia during rehabilitation.

## Discussion

To ensure a safe and efficient delivery of thrombolysis and achieve a door-to-needle time within 60 minutes, a chain of events have to occur smoothly, similar to the 'chain of survival' required for successful outcomes from cardiopulmonary resuscitation.[11] Close collaboration between paramedics, nurses, emergency physicians, neurologists, neuroradiologists, and neurointerventionists is of paramount importance. Our data suggest that these are achievable through a dedicated team with a commitment to deliver rtPA within the shortest possible time following a patient's arrival in hospital. Overall, the stroke team–to-treatment time constituted most of the door-to-needle time (approximately 45 minutes at present). As time is needed for clinical assessment, informed consent, CT arrangement and interpretation, further shortening of the stroke team–to-treatment time may not be feasible. On the other hand, there is an opportunity to improve the door-to-needle time further by shortening the door-to–stroke team time. Our experience suggests that an early involvement of the stroke team even before exclusion of ICH may effectively shorten the subsequent CT-to-treatment time in eligible patients. After all, only a small percentage (8%) of patients who had a thrombolysis call initiated turned out to have haemorrhagic stroke. As stroke is a treatable medical emergency, the stroke team should be informed as soon as a diagnosis of hyperacute stroke has been made in a patient with a reasonably good premorbid state. At the moment, this task is the responsibility of the emergency physician. It is envisaged that with proper training,

this important gate-keeping task could be delegated to the emergency department triage nurse, as well as to ambulance paramedics.

The door-to-needle time is composed of door-to–stroke team time and stroke team–to-treatment time. Our study showed that both times warrant improvement by tackling potential delays. The door-to–stroke team time could be improved by changing the triage category for hyperacute stroke patients in the emergency department. At present, acute stroke is triaged as category 3, to be seen within 30 minutes of presentation (target 90%). This should be revised if patients presenting with acute-onset neurological deficits within the therapeutic time frame could be triaged as category 1 or 2, followed by swift assessment and treatment by senior emergency physicians and nurses. Early activation of thrombolysis calls by trained paramedics and triage nurses at dedicated thrombolysis centres would also expedite the rapid mobilisation of the thrombolysis team to evaluate the patient. Paramedic stroke recognition and hospital pre-notification has been associated with shorter pre-hospital times and time to first medical assessment.[12] Rapid assessment tools by paramedics and physicians, such as the Cincinnati Prehospital Stroke Scale and Los Angeles Prehospital Stroke Screen, have been successfully used to identify patients with acute stroke in the field.[13,14] To improve stroke team–to-needle (treatment) time, an urgent CT scan is an essential priority. The ideal service would see dedicated stroke neurologists, emergency physicians with experience in dealing with stroke patients, and neuroradiologists working in a concerted team to provide the safest and quickest delivery of thrombolysis.[11] This inevitably requires additional resources for the emergency department, neurology staff, and neuroradiology support.

Thrombolysis treatment is not without risk; the most-feared complication being symptomatic ICH. It is prudent to administer rtPA to patients only after carefully balancing risks and benefits. We therefore do not give rtPA to patients with minor strokes in whom potential risks outweighing benefits, or to those with very severe stroke with high haemorrhage risks. Moreover, in our system it was a requirement that the urgent CT brain be read by a stroke neurologist or neuroradiologist. This assessment paradigm demands resources and expertise, but our data suggest that efficiency and safety can both be achieved, with acceptable rates of haemorrhagic transformation and mortality. Thus, 53% of our IV rtPA patients achieved a favourable outcome at 3 months, compared to 39% and 52% in the NINDS and ECASS III trials, respectively.[2,9] The death rate of 6% was lower than that reported in the NINDS (17%) and ECASS III (7%) trials although our overall patient numbers were small. Symptomatic haemorrhage occurred in 6% of our IV rtPA patients, compared to 6% and 2% in the NINDS and ECASS trials, respectively (Table 4). Regarding limitations of our study, as our results were from a single centre, they may not be easily generalised to other acute hospitals in Hong Kong. Moreover, in a few patients (n=2) eligible for IV rtPA, the treatment decisions were altered based on unfavourable multimodal CT findings, which may have led to a lower haemorrhagic transformation rate.

TABLE 4. Functional outcomes and complications of patients who received thrombolytic therapy for acute stroke in our study and in previously reported studies*

| Outcome/complication | PWH IV rtPA (No. [%]) | NINDS[9] | ECASS III[2] |
|---|---|---|---|
| Favourable outcome | 9 (53) | 39% | 52% |
| Death (3 months) | 1 (6) | 17% | 8% |
| Asymptomatic haemorrhage | 6 (35) | 3% | 27% |
| Symptomatic haemorrhage | 1 (6) | 6% | 2% |
| Direct discharge home | 5 (29) | - | - |

* PWH denotes Prince of Wales Hospital, IV intravenous, rtPA recombinant tissue plasminogen activator, NINDS National Institute of Neurological Disorders and Stroke, and ECASS III European Cooperative Acute Stroke Study III

In conclusion, a neurologist-led stroke thrombolysis triage model is feasible, and rapid triage is the key to shortening door-to-needle times. Close collaboration between emergency department and radiology colleagues is essential for a safe and efficient delivery of thrombolytic therapy for ischaemic stroke. International benchmarks are achievable although to date our data are based on a small number of patients. Ultimately, an extension of these services to 24 hours a day, 7 days a week would require a significant investment in neurology, emergency medicine, and radiology service provision.

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