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Quality improvement project to improve patient outcomes by reducing door to CT and door to needle time and increasing appropriate referrals for endovascular thrombectomy.

Jennifer Hennebry ,[1] Sinead Stoneman,[2] Breda Jones,[2] Nicola Bambrick,[3] Andreea Stroiescu,[1] Ian Crosbie,[1] Riona Mulcahy[2]

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[1]Radiology, University Hospital Waterford, Waterford, Ireland
[2]Gerontology, University Hospital Waterford, Waterford, Ireland
[3]Emergency, University Hospital Waterford, Waterford, Ireland

Correspondence to
Dr Jennifer Hennebry;
jennifer8h@gmail.com

ABSTRACT

This paper describes a stroke quality improvement (QI) project in a primary stroke centre in a 431-bed hospital serving a local population of 114 000 people. Approximately 170 acute strokes are treated each year in a seven-bed stroke unit managed by three geriatricians with a subspecialty interest in stroke. 24-hour CT radiology service is available. Endovascular thrombectomy (EVT) is performed by neuro-interventional radiology at one of two comprehensive stroke centres located 90–120 min away. In 2018, as part of a national collaborative QI initiative a new national thrombectomy referral pathway was introduced with an aim that all eligible patients be referred for EVT. This initiative included maximising timely access to CT and thrombolysis. Review of local data highlighted significant deficits in these areas.

A local QI team convened and a multidisciplinary approach was employed to map the existing process for CT access and time to thrombolysis decision.

We describe how focused timesaving interventions such as; new emergency and radiology department 'pre-alerts', dedicated acute stroke pagers, new 'FAST' registration by clerical staff, new CT ordering codes and new 'FAST packs' (including tissue plasminogen activator, paper National Institute of Health Stroke Scale scoring tools, consent forms and EVT patient selection tools) were created and incorporated into a multidisciplinary detailed clinical stroke care pathway.

We describe how we achieved our SMART aims; to reduce our door to CT time and to reduce our door to needle time to the national target of less than 30 min. A third aim was to increase the number of patients referred for EVT from our centre.

This project is an accurate description of how a multidisciplinary approach combined with teamwork and effective communication can create sustainable improved patient care and is generalisable to all institutions that require timely referral to external centres for EVT.

INTRODUCTION

Problem description

University Hospital Waterford is a primary stroke centre (PSC) within a 431-bed hospital serving a local population of 114 000 people. Approximately 170 acute strokes are treated in a seven-bed stroke unit each year. Dedicated stroke services are provided by three geriatricians with a subspecialty interest in stroke and one stroke clinical nurse specialist from 09:00 to 18:00 Monday to Friday with out of hours care provided by acute medical physicians. Our institution operates a 24-hour CT radiology service.

In 2018, we enrolled in a national collaborative quality improvement (QI) initiative steered by the national thrombectomy service in conjunction with the Royal College of Physicians, Ireland and the Royal College of Surgeons, Ireland. A new national thrombectomy referral pathway was commenced with an aim that all suitable patients presenting with acute signs of stroke (termed 'FAST positive') and evidence of large vessel occlusion (LVO), be referred to one of two neuro-interventional radiology centres in Ireland as timely as possible (travel time by ambulance 90–120 min, respectively).

On analysis of retrospective data, we identified that our 'door to CT' and 'door to needle' (DNT) times were unacceptably long with a median of 38 min (range 14 min–211 min) and 105 min (range 54 min–233 min), respectively in 2017. Two patients were referred for endovascular thrombectomy (EVT) in 2017 and six patients in the first 6 months of 2018.

Available knowledge

Stroke is one of the worldwide leading causes of morbidity and mortality with negative effects on individual quality of life and huge economic cost to society.[1]

Rapid administration of intravenous tissue plasminogen activator (tPa) in appropriate patients remains the mainstay intervention for early treatment of ischaemic stroke[2]

and treatment within 4.5 hours improves outcomes at 3–6 months.[3] A meta-analysis of nine randomised trial comparing alteplase with placebo/open control performed by Emberson *et al* highlighted that alteplase significantly improves the overall odds of a good stroke outcome when delivered within 4.5 hours. Reducing the time to administration of tPA has been associated with proportional benefits on clinical outcomes.[3]

HERMES meta-analysis of six trials (Mr. Clean, ESCAPE, REVASCAT, EXTEND 1A, SWIFT and PRIME) looked at the effect of EVT in restoring perfusion at different time windows and successfully established EVT as the optimal intervention for anterior circulation stroke with the number needed to treat of 2.6 to reduce long-term disability and morbidity (based on modified Rankin score (mRS)).[4]

European Stroke Organisation guidelines state that in addition to intravenous tPA within 4.5 hours, EVT should be considered within 6 hours of symptom onset in patients with anterior circulation LVO.[5]

The American Heart/Stroke Association has also recommended EVT within 6 hours of symptom onset for patients suffering from acute ischaemic stroke who meet specific selection criteria.[6]

More recent studies have focused less on definitive time windows but on patients individual imaging findings, which reflect individual pathophysiology and collateral blood supply. Ischaemic cores in patients with better collateral blood supply have been shown to progress more slowly and may benefit from thrombectomy and reperfusion at longer time intervals from symptom onset.[7]

The thrombectomy service in Ireland currently accept patients up to 12 hours for anterior circulation stroke and 24 hours for posterior circulation stroke in those appropriate by imaging criteria. The Irish national DNT target including CT imaging is 30 min.

Many hospital improvement strategies to reduce DNT have been described and the most effective interventions include pre-alerting of stroke patient arrival by ambulance staff, rapid registration process, single call activation of stroke teams, rapid transfer to CT and administration of alteplase while still in the CT scanner.[8]

A study by Meretoja *et al* showed interventions while the patient is being transported (such as pre-alerting emergency department (ED) staff and radiology, pre-ordering scans, pre-mixing of tPA and administration of tPA in the CT suite), to be more time effective than in hospital interventions. However they acknowledge that significant results in reducing delays are never achievable by single interventions but require improvement of the whole system, as was the case in our hospital.[9]

Xian *et al*'s study of 5460 patients receiving tPA within 3 hours of symptom onset reported rapid triage/stroke team notification, single call activation system and tPa stored in the ED to be the most strongly associated with shorter DNT. However, they noted that out of hospital strategies were applied less frequently.[10] A later study of 888 hospitals, performed by the same group, again highlighted pre-hospital interventions to be the most effective at time saving. They also reported that the more DNT time-saving strategies applied (both pre-hospital and in hospital) the lower the DNT.[11]

In hospital strategies were analysed by Kamal *et al*, who reported taking the patient to CT on the hospital stretcher, registering the patient as unknown and administering alteplase on the scanner to be most effective in reducing DNT.[12]

A cumulative approach incorporating as many of the described strategies as possible was adopted in our QI initiative.

Rationale

The availability of EVT in two centres in Ireland prompted the national QI project and the national thrombectomy service encouraged all hospitals to update their local stroke care pathways to include timely referral for thrombectomy in suitable patients. This combined with the knowledge of avoidable delays in our door to CT time and DNT provided the rationale for this QI initiative.

Specific aims

The SMART aims for this QI project were to reduce our door to CT time and to reduce our DNT to the national target of less than 30 min. A third aim was to increase the number of patients undergoing EVT from our centre.

METHODS

Context

We created a QI team consisting of the hospital stroke consultant lead, a stroke clinical nurse specialist, a stroke care registrar, ED clinical nurse specialist and a radiology specialist registrar. We retrospectively analysed patient's (who had received intravenous thrombolysis) charts and radiology records from the previous year in 2017 and extrapolated the median door to CT time was 38 min and the median DNT was 105 min in these patients. Only two patients had been referred to neuro-interventional radiology for EVT.

An inclusive interdepartmental meeting was held with representation from members of staff involved in every step of the patient journey including; paramedics, switch telephone staff, ED registration clerical staff, laboratory staff, ED doctors and nurses, porters, radiographers, radiologists, general medical doctors and care of the elderly/stroke physicians. A large process map was created on a whiteboard by mapping out the existing steps to CT access and thrombolysis in a sample patient who had a stroke attending our hospital. Multidisciplinary discussion provided input at every step in the patients' journey, which allowed us to identify exactly where delays were occurring. We marked the delays with red stickers on the board. Every department suggested ways to streamline the patients' journey in their area and time saving suggestions were recorded.

Following this, a formal process map was created (figure 1) and reviewed by all staff involved. This process was conducted incorporating multidisciplinary opinion and previous expert

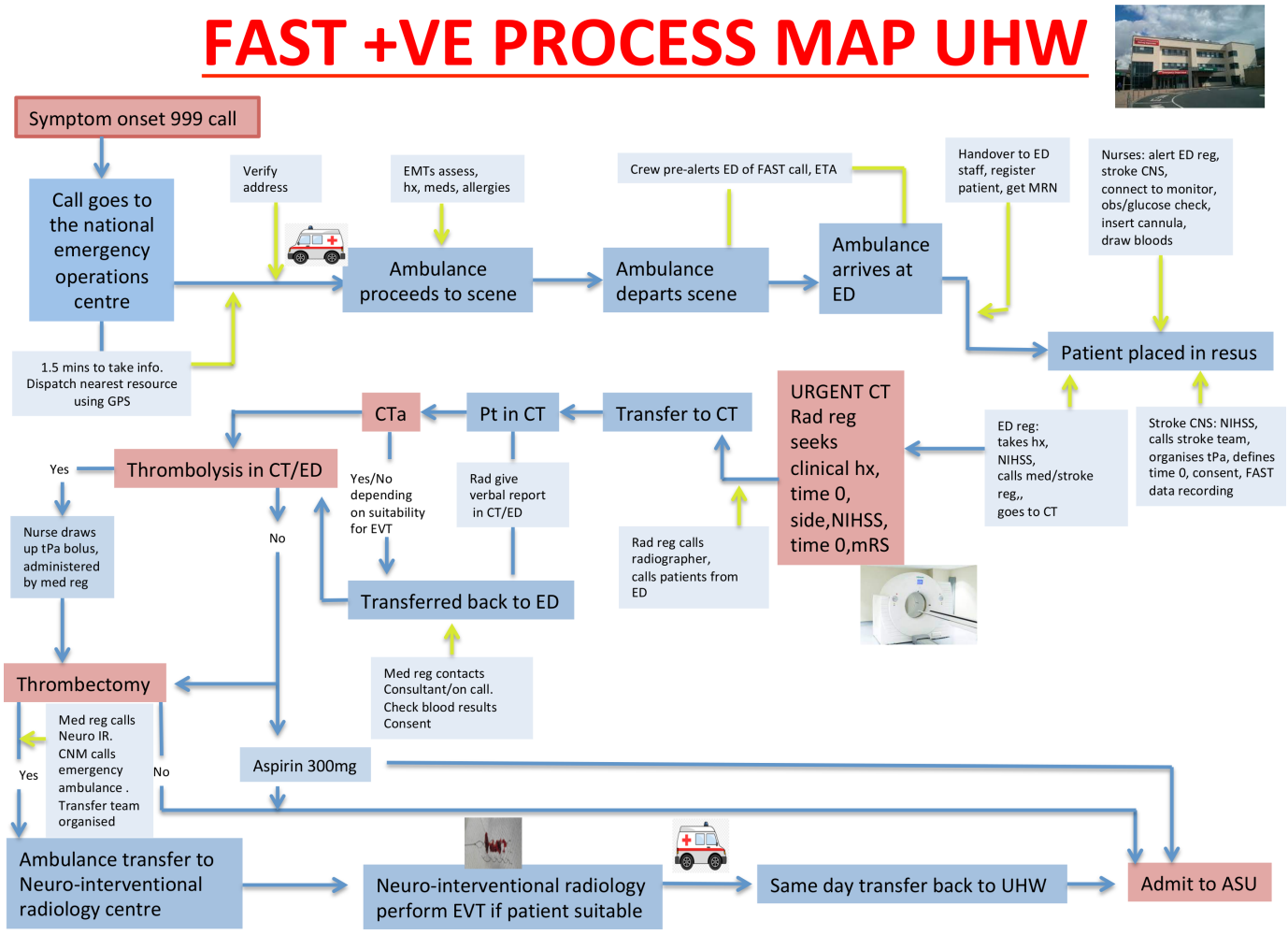

Figure 1 FAST positive stroke patient process map UHW.

EMT, emergency medical technician; ED, emergency department; ETA, estimated time arrival; MRN, medical record number; EVT, endovascular thrombectomy; CNS, clnical nurse specialist; mRS, modified Rankin score; NIHSS, National Institute of Health Stroke Scale; tPa, tissue plasminogen activator; CNM, clinical nurse manager; UHW, University Hospital Waterford; ASU, acute stroke unit.

reports in the literature on how to reduce door to CT and DNT.

The specific areas identified in order to improve our patients door to CT and DNT included; faster assessment and registration with a medical records number in ED, faster transfer to CT, immediate interpretation of CT imaging, faster administration of tPA on the CT table in appropriate patients and faster referral and selection of appropriate patients for EVT.

	First 9 months median time (min)	Second 9 months median time (min)	IQR (min)
Door to CT time	27	32	27.5
Door to needle time	35	50	22

Interventions

A new clinical guideline/pathway was created for all patients who had an acute stroke attending our institution and each team members' role was clearly outlined (figure 2A).

Based on the previous process delays identified, a number of new interventions were commenced including:

A pre-alert system to ED staff and radiology from paramedics through switchboard.
A new stroke pager for stroke and general medicine physicians.
FAST registration by clerical staff.
New ED 'pit-stop' clinical evaluation.
New CT ordering codes.
New mobile thrombolysis packs (for tPa administration in the CT department in appropriate patients).

New CT ordering codes and referral guidelines to allow rapid image interpretation were also created. Clinical and imaging criteria were outlined to medical and emergency clinicians, guided by the national thrombectomy service to facilitate appropriate patient selection for EVT (figure 2B).

Continuous education and feedback was given to clinicians to include four key information points to allow rapid image interpretation and patient selection for CT

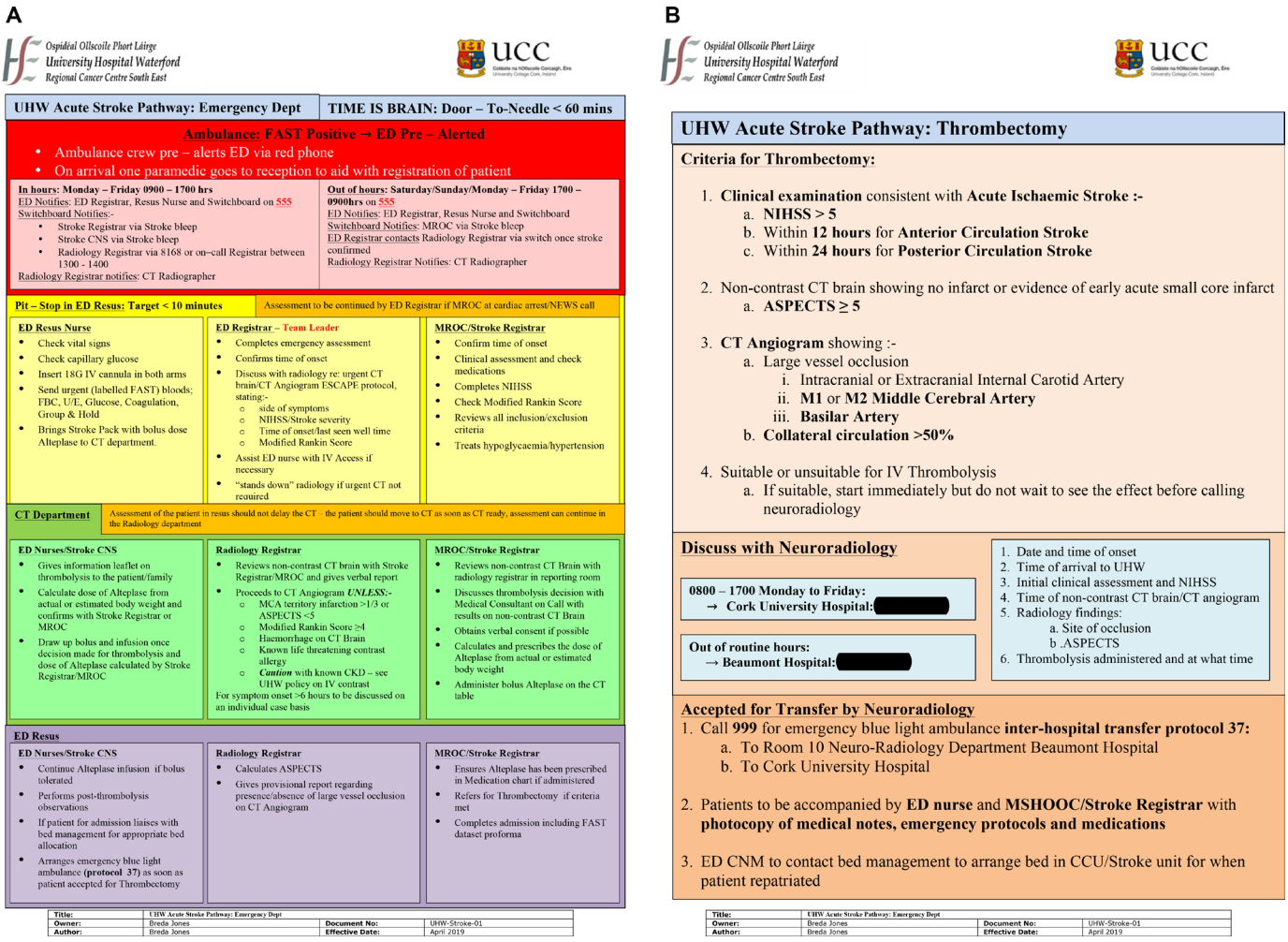

Figure 2 UHW clinical pathway for acute stroke patients.
ED, emergency department; NHSS, National Institute of Health Stroke Scale.

intracranial angiogram/EVT referral. These included: time of onset, location of neurological deficit, National Institute of Health Stroke Scale score and mRS.

Designated stroke proformas were created for stroke patient clinical records with specific headings including; decision time, time EVT centre contacted and time of patient transfer (if appropriate for EVT) to improve data recording.

Measures

We prospectively measured door to CT time and DNT in every FAST acute stroke as both times were clearly recorded in patients' radiology and clinical records. These measurements reflected the most pertinent steps to avoid delays in acute stroke management.

A subset of measurements including; time of ED arrival to CT department arrival, CT department arrival to time of non-contrast CT brain, time between non-contrast CT brain and CT intracranial angiogram, time to decision regarding patient suitability for thrombolysis/EVT and door in door out (DIDO) time in those accepted for EVT were also recorded in patients radiology reports and clinical records. This allowed us to pinpoint other sites of delay in the process for ongoing improvement.

Unfortunately these time intervals were not previously recorded so we have no comparison to pinpoint exactly which of the new interventions employed were most effective at reducing our door to CT and DNT. Therefore, the overall reduced times we report are a cumulative result of all interventions performed.

Analysis

The radiology data from each FAST (facial droop, arm weakness, speech disturbance, time) stroke call was collated each month and combined with the clinical records of times measured for treatment decision and administration of tPa. Our QI team examined the measured times and could easily track the improvement in times at each step of the patient pathway.

All interventions described were commenced simultaneously at the time of launch of the new pathway. Data and results were reviewed at monthly meetings and arising barriers preventing improvement were discussed.

After 3 months, departmental feedback sessions and a hospital grand rounds presentation took place

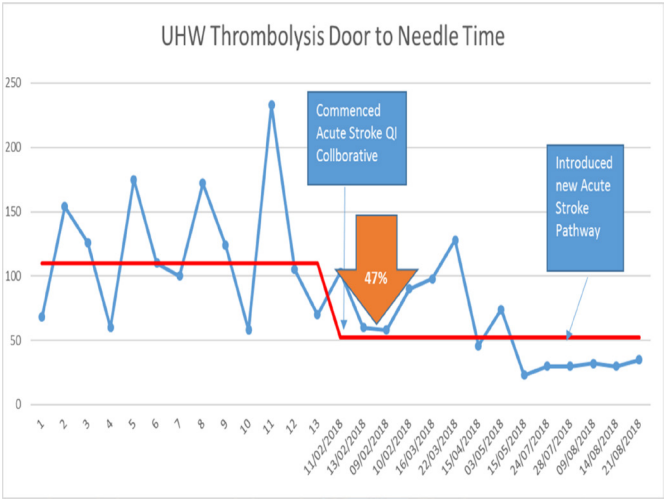

Figure 3 Door to needle time prior to and at time of launch of new stroke pathway.
QI, quality improvement.

to communicate the positive results and highlight the improved clinical patient outcomes. The positive results boosted staff morale and engendered a sense of achievement by highlighting the benefit of teamwork and effective communication, a key component in making the continued efforts sustainable.

The continuous analysis of process times in individual patient cases allowed appropriate changes to be implemented and communicated by the QI teams to relevant departments.

RESULTS

Time improvements were observed from the initial inter-departmental planning meeting. This meeting highlighted the importance of each individual's role, including clerical staff, porters, emergency doctors, radiographers and medical physicians in reducing the time to diagnosis and treatment. The awareness of the existing points of delay, highlighted in the process map, initiated time saving improvements in each department. As a result, a decrease in door to CT and door to decision times were observed even prior to launching the clinical pathway in July 2018 (figure 3).

Door to CT time

Baseline door to CT time was extrapolated from retrospective analysis of patients who received thrombolysis in 2017. Median door to CT time was calculated as 38 min.

Eighteen consecutive months of data post implementation of the new clinical pathway was analysed. These data were split into two comparable 9-month periods. These time periods contain the same number of major medical staff changeovers, a recognised challenge for any specific clinical pathway.

In the first 9 months post implementation of the pathway, the door to CT median time fell to 27 min, an overall improvement of 11 min on measured times in 2017 (figure 4A).

The median door to CT time in patients subsequently treated with intravenous tPa±EVT was 17 min, representing a 21 min decrease (figure 4B).

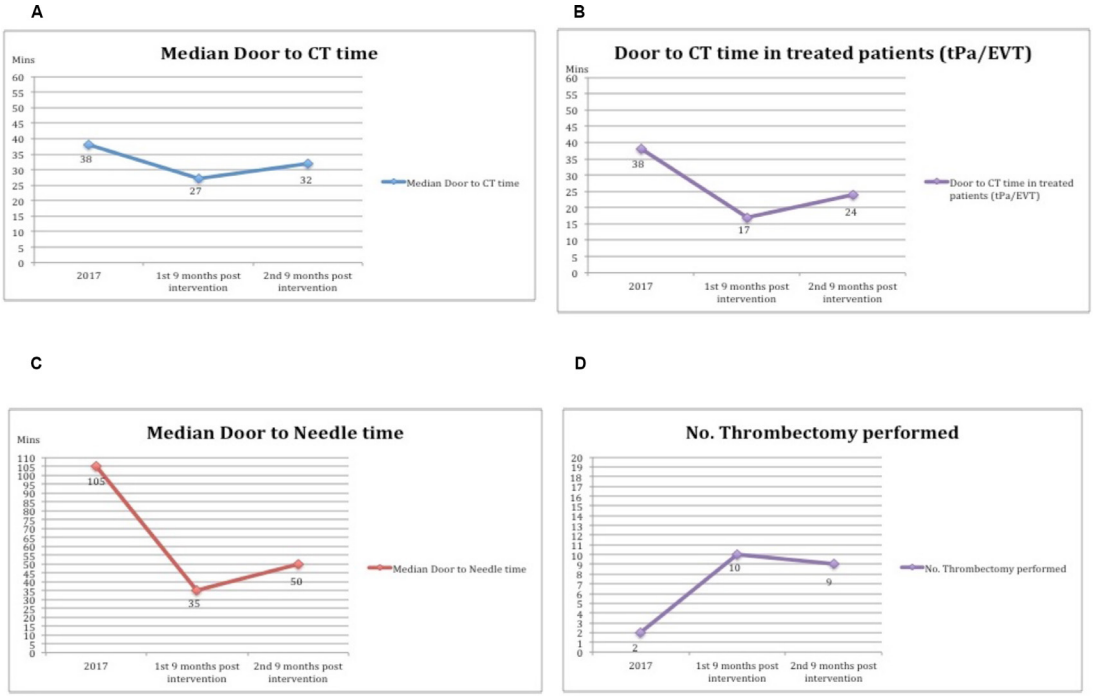

Figure 4 (A) Results: Median door to CT time. (B) Results: Median door to CT time in treated patients (tPa/EVT). (C) Results: Median door to needle time. (D) Results: Number of EVT performed.
EVT, endovascular thrombectomy; tPa, tissue plasminogen activator.

We compare this to the second 9-month period, which demonstrates a door to CT median time of 32 min. The median door to CT time in those treated with tPa or EVT was 24 min for this 9-month period.

On further detailed analysis, we identified a possible reason for the longer reported median time was that 8 of the 68 FAST stroke calls were in ED for over 1 hour before the FAST call was activated. These patients did not have pre-hospital alerts activated and were not presented to ED as FAST stroke calls by paramedics. As a result these patients were not triaged in the ED as top priority for clinical evaluation. Delays in activating the FAST protocol due to delayed clinical examination occurred. Taking this into account, the median door to CT time was still lower than 2017, which suggests that once the FAST call was activated patient movement to CT was still faster than previous times when there was not a definitive patient pathway in place.

Door to needle time

The baseline median DNT in 2017 in all patients who received thrombolysis was 105 min (range 54–233 min).

In the first 9-month period postintervention the median DNT fell to 35 min. In the second 9-month period DNT was 50 min (figure 4C).

Three patients had delays in the administration of tPa due to agitation and high blood pressure, which affected the median time in this patient cohort.

Number of patients who had EVT performed

In 2017, two patients from our institution had EVT performed. This increased to 10 patients in the first 9 months following implementation of the new clinical pathway.

In the second 9-month period, nine patients were transferred for EVT.

This represents a five-fold increase in referral rate from our institution post implementation of the clinical pathway in each time period (figure 4D).

Although our study was not powered to look at length of hospital stay we noted that this was a secondary positive outcome of our project. This reduced hospital costs and also societal costs, as patients were often discharged home rather than to rehabilitation facilities.

DISCUSSION

Clearly defining every staff member's role in the new clinical pathway allowed improved teamwork and communication and subsequently resulted in faster patient times through the pathway. While it is not possible to pinpoint which individual intervention was the most timesaving we conclude that the combination of all the new interventions, rolling educational sessions, audit of outcomes and feedback to all relevant stakeholders allowed us to achieve our SMART aims.

Individual cases with delays in DNT were reviewed and had documented clinical indications such as agitation or persistent high blood pressure. The new documentation of times allowed the reasons for these delays to be clearly evident.

Data recording was largely complete with the most important times of our SMART aims recorded in 100% of cases. Recording of time of decision regarding suitability for EVT was less well recorded and continuous feedback was given to physicians to include this time in clinical notes.

All interventions employed were cost neutral to our institution and although our study was not powered to look at reduced length of hospital stay we did note this to be a secondary positive outcome. Length of stay was significantly reduced, resulting in reduced hospital costs and patients were often discharged home rather than to rehabilitation care facilities. We plan to evaluate this further in our ongoing QI project.

Lessons and limitations

All three of the primary aims of this project (to reduce door to CT time, DNT and to increase number of patients undergoing EVT) were achieved. We identified that effective teamwork, multidisciplinary communication and constant review were the key components for the success of this project.

We recognised that the initial enthusiasm and effort by all staff including clerical staff, nurses, doctors, porters, radiographers and radiologists was challenging in an already understaffed and busy emergency and radiology department. In order to maintain momentum of improvement, education sessions took place in each department, prior to launch of the pathway and at regular times of changeover of staff.

Each of our individual QI team members worked in key departments, which facilitated effective communication of positive results back to each department highlighting how the new interventions and efforts of all involved were improving patient outcomes. This was key as stakeholders became more aware of their evolving individual role in the patient pathway.

Valuable lessons were learnt as we strived for continuous improvement and sustainability. Initial time delays were identified in each department by QI team members and addressed by departmental and individual feedback sessions. The positive clinical outcomes were outlined at departmental audit and education meetings. We repeated these sessions and provided written reports to staff who were unable to attend meetings.

Communication issues in individual cases were discussed with the individuals involved in the specific case. Difficulty in contacting the radiology department at lunch hour was addressed by allocating the on call registrar to cover lunch hour FAST calls.

A 'primary team leader' was identified for each case to ensure a senior clinician stayed with the patient in the CT department for clinical decision-making regarding thrombolysis and EVT referral.

In retrospect, a monthly or bimonthly meeting inviting all key players (rather than just QI team members) to

look at the time maps of cases could have been helpful to reinforce positive outcomes and develop a wider team approach to addressing delays caused by communication lapses. This is something we plan to do going forward. An educational YouTube video describing the steps in the pathway was created to improve communication and education particularly at time of staff change-over.[13]

Limitations of this study included the potential for positive confounding bias by clinicians and radiologists in documenting key times, including referral time and time of arrival for CT. The time of patient arrival to ED and the time that the CT scan was performed were recorded electronically and not subject to bias.

The parameters measured in this study through continuous audit including door to CT time and DNT are generalisable to all hospitals receiving patients who had an acute stroke. The methods and time saving interventions that we describe could be performed in other hospitals that do not have EVT services on-site.

Our DIDO times and door to EVT times are not generalisable to all hospitals due to difference in local ambulance protocols and distance to neuro-interventional centres however the methods we describe to reduce door to referral time could be adopted in other institutions.

The number of referrals for EVT significantly increased during this project. However once the decision was made to refer for EVT, delays were encountered due to availability of transfer ambulance impacting adversely on DIDO times.

A new faster national emergency ambulance protocol for patient transfer was created for EVT referrals ('protocol 37'), however, this still often involves a different ambulance travelling to our institution to collect the patient, which results in significant delays.

A recent study by Gaynor *et al* demonstrated that by keeping the same ambulance at a PSC until a decision is made regarding suitability for EVT at a CSC, significantly reduced DIDO and reperfusion times without adverse effects on ambulance usage time.[14]

This will require a change in local ambulance service protocol but it is something we are including in our new SMART aims for this project going forward.

Of interest, analysis of data in late 2020 and early 2021 has shown an increased door to CT time and DNT. We hypothesise that this may be secondary to altered patient flow through our ED department during the COVID-19 pandemic in Ireland. A second CT scanner (located further away in the hospital rather then next to the ED) was utilised for all patients suspected to be COVID-19 positive (all strokes were on this COVID-19 pathway). Other COVID-19 pathway delays included the time taken to put on medical personal protective equipment. We plan to analyse this development in our data collection to assess the impact of COVID-19 in the triage, diagnosis and treatment of acute stroke.

CONCLUSION

As continuous new data emerges on the benefits and improved clinical outcomes of timely treatment with thrombolysis and EVT in patients who had an acute stroke it is imperative that hospitals adjust and improve clinical pathways to aid faster diagnosis and treatment of acute stroke. Institutions which do not have a neuro-interventional radiology services are required to establish imaging protocols and referral pathways for patients suitable for EVT.

The initial SMART aims to improve door to CT time, DNT and to increase referral rates for EVT were achieved in this study and were cost neutral. Interventions implemented have proven sustainable and have become our new standard of care. Interventions commenced are also generalisable to other hospitals providing acute stroke care without on-site EVT services. Our process map has been shared with other institutions in Ireland as part of an Irish national stroke QI project.

Continuous audit by our QI team, teamwork, education and feedback to all involved departments has achieved sustainability in reducing our DNT, door to CT time and increasing the number of referrals for EVT.

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Contributors All authors listed (JH, SS, BJ, NB, AS, IC, RM) were involved in planning the project. All authors were involved in devising and implementing the new clinical pathway. BJ, JH, AS performed ongoing audit. JH took the lead in writing the manuscript. All authors provided critical feedback and helped shape the research, analysis and manuscript. JH is the guarantor for this document.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not required.

Ethics approval Our local ethics and research committee was consulted about the requirement for ethics approval. As the QI project was under the remit of ongoing audit, it was excluded from requiring formal ethics approval.

Provenance and peer review Not commissioned; externally peer reviewed.

ORCID iD

Jennifer Hennebry http://orcid.org/0000-0002-2695-3227

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