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Simulation-based team training improves door-to-needle time for intravenous thrombolysis

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ABSTRACT

Purpose There is a clinical need for shortened door-to-needle time (DNT) for intravenous thrombolysis, but effective training methods are missing. Simulation training improves teamwork and logistics in numerous fields. Still, it is not clear if simulation improves logistics in stroke.

Methods To evaluate the efficiency of a simulation training programme, the DNT of participating centres was compared with the rest of stroke centres in the Czech Republic. Patients' data were prospectively collected from the nationally used Safe Implementation of Treatments in Stroke Registry. The outcome was an improvement in DNT in 2018 as compared with 2015 (after and before the simulation training). Scenarios were based on real clinical cases, and simulation courses were conducted in a standardly equipped simulation centre.

Findings Between 2016 and 2017, 10 courses were conducted for stroke teams from 9 of all 45 stroke centres. DNT data were available both in 2015 and 2018 from 41 (91%) stroke centres. The simulation training improved the DNT in 2018 as compared with 2015 by 30 min (95% CI 25.7 to 34.7) and as compared with 20 min (95% CI 15.8 to 24.3) in stroke centres without the simulation training (p=0.01). Any parenchymal haemorrhage occurred in 5.4% and 3.5% of patients treated in centres without and with simulation training (p=0.054), respectively.

Conclusions DNT was considerably shortened nationally. It was feasible to implement simulation as a nationwide training programme. The simulation was associated with improved DNT; however, other studies should confirm that such an association is causal.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Acute stroke management can be optimised using simulation training to initiate thrombolysis as soon as possible.

WHAT THIS STUDY ADDS

⇒ The effect of simulation training in acute stroke care was reflected in the shortened door-to-needle time and better patient outcomes, and including hospitals without training makes the data valuable.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Simulation training should be applied in all stroke centres nationally.

⇒ Improvement in acute stroke management is feasible, and better patient outcomes reduce treatment costs.

INTRODUCTION

Both intravenous thrombolysis and mechanical thrombectomy provide greater benefits to patients if administered earlier after symptom onset.[1] Despite such theoretical knowledge and the fact that it has been clearly demonstrated that intravenous thrombolysis could be initiated within 20 min after the patient's arrival to the hospital,[2–4] time from symptom onset to treatment in real life remains frequently too long.[1 5 6]

Fast provision of recanalisation treatment depends on a proper sequence of logistical steps, but also requires good teamwork and communication. Understanding of these elements is much less straightforward than it seems. Without the necessary experience, healthcare professionals, even those from high-volume stroke centres, may frequently experience difficulty in understanding how things could be done differently in order to initiate intravenous thrombolysis faster than their current clinical practice.

Simulation provides a training opportunity to experience 'ultrashort' delivery of intravenous thrombolysis in a high-fidelity simulated environment, thus providing motivation, reassurance and guidance on how to change their current practice. Our simulation programme was established in 2015. So far, more than 1200 healthcare professionals from 23 countries have underwent training in stroke logistics and provision of recanalisation treatments. The goal of this study was to establish if and how a half-day simulation training session can change the logistics of intravenous thrombolysis in a long-term perspective.

This is a cohort study of all patients who had a stroke treated with intravenous thrombolysis with or without mechanical thrombectomy from all stroke centres in the Czech Republic. A change of logistics measured as time from admission to initiation of

intravenous thrombolysis (door-to-needle time, DNT) in stroke centres that passed simulation training was compared with all other stroke centres in the Czech Republic during the study period between 2015 and 2018. We hypothesised that after passing the half-day simulation training in 2016 or 2017, the participating stroke centres would have shortened their DNT for intravenous thrombolysis more than the stroke centres that did not participate in the simulation training. The improvement was measured as a change of DNT in each stroke centre in 2018 as compared with 2015. We also hypothesised that shortening the DNT would not compromise the safety of treatment, measured as an occurrence of any intracerebral haemorrhage (ICH) or any parenchymal haemorrhage (PH).

METHODS

Simulation programme

The stroke programme at St Anne's University Hospital Brno has started the simulation training in stroke management in 2016 with the main objective of providing advanced training for stroke centres in the Czech Republic in the 'ultrashort' delivery of thrombolysis. All stroke centres in the Czech Republic received an invitation for the simulation training as open call. In 2017, the programme was also extended internationally and became one of the tools within the European Stroke Organisation: Enhancing and Accelerating Stroke Treatment (ESO EAST) programme, which aims to improve the quality of stroke care in Eastern Europe.[7 8] In this study, we present the national results from the Czech Republic. Data from other countries that attended the simulation programme were not included because the information on stroke logistics has only been systematically collected from all patients who had a stroke treated with intravenous thrombolysis in the Czech Republic. Moreover, the Czech Republic had relatively the highest number of stroke centres trained in the simulation programme.

Simulation scenarios were conducted in a usual format (briefing–simulation–debriefing–conclusion) and included minimally two rounds of simulation. Reflecting on clinical practice in the Czech Republic, the following roles were assigned: treating physician (in most cases a neurologist), nurse, paramedic, patient and sometimes radiologist. Scenarios were based on real thrombolytic cases adapted if needed for educational purposes. Relevant information on each case was given to a paramedic and to a patient. Originally, a trained neurology nurse portrayed a patient who had a stroke, as in another simulation programme,[9] but this was changed after realising what value it had for trainees themselves to experience a patient role, especially in terms of understanding the importance of effective communication. Moreover, it has been shown how easy it is to train neurologists or other health professionals to depict focal neurological symptoms care.

The structure of the scenarios was the same as in standard clinical practice, with the following main steps: each case was initiated by prenotification from Emergency medical services (EMS) (ie, a phone call between a paramedic and a stroke neurologist), continued by transferring a patient (played by one of the trainees) to the CT scanner (in reality the patient is transferred directly from the ambulance car to a CT scanner), obtaining the patient's history, neurological examination, performance and interpretation of CT results, indication and performance of thrombolysis, and indication for mechanical thrombectomy.

Simulation courses were conducted in a standardly equipped simulation centre (hospital bed, stretcher, simulation monitor, artificial CT scanner, audio-visual equipment, software for simulation training, etc). A neurologist with 20 years of experience in thrombolytic treatment (RM) led all simulation sessions together with at least two other members of the stroke team (a simulation technician and a simulation methodologist/lecturer).

Learning objectives were grouped into four elements: logistics=workflow, decision-making, teamwork and communication with a patient. Teamwork followed the principles of crew resource management, especially closed loop communication, situational awareness, workload management and leadership. Debriefing followed the recommendations of three phases (description, analysis and application)[10] to analyse the non-technical aspects of a simulated scenario.

Four attendees in the auditorium were assigned the role of observers. They focused on teamwork, communication with a patient, time loss and patient safety during the simulation, and provided their comments based on checklists during debriefing.

The simulation training was available to any stroke centre within the country. If the stroke centre decided to participate, they were instructed that any healthcare professional involved in the logistics pathway (neurologists, radiologists, emergency physicians, nurses, technicians, etc) should participate. We strongly encouraged the heads of neurology departments and/or stroke programme directors to participate as well because decision-making power is usually needed to facilitate the change of workflow of patients who had a stroke in a hospital.

The set-up of the simulation training is shown in figure 1. The simulation centre is equipped with a hospital bed, a patient monitor which allows for manipulation of the values of vital functions, an artificial CT scanner, and an audio-visual equipment which allows for simultaneous streaming from the stage room to the audience/debriefing room and for recording. The simulation centre has a control room from where the simulation tutor controls the audio-visual equipment and sets vital functions as a response to the treatment the trainees provide to the patient.

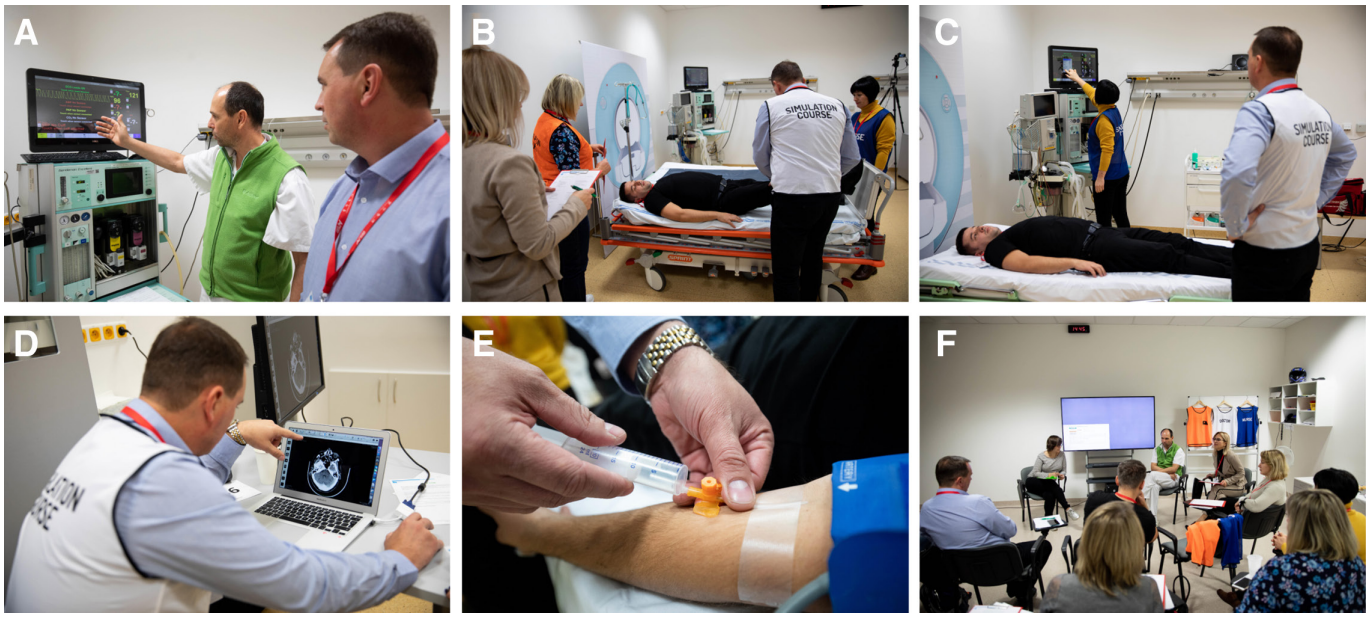

Figure 1 Simulation course. The simulation room and the equipment introduced to the attendees of the course (A); simulation started with patient arrival directly to a CT scanner (B), where the initial examination and CT were performed (C), followed by reading of the CT images (D), then initiation of thrombolysis (E) and finishing by debriefing (F).

Outcome and data collection

The primary outcome measure was DNT and secondary ICH (both as any PH and any ICH). PH and any ICH were chosen to evaluate if shorter DNT does not compromise safety of thrombolytic treatment. These data as well as other patient data were collected in the Safe Implementation of Treatments in Stroke–International Stroke Thrombolysis Registry (SITS). Participation in a registry was mandated as part of the quality improvement process by accreditation of the Ministry of Health of the Czech Republic. The SITS was used until 2018 as the only registry; therefore, it contains data from all stroke centres. Informed consent for data collection in the registry was not required because data were collected as part of clinical routine and quality improvement.

Stroke services in the Czech Republic

All stroke centres in the Czech Republic are certified by the Ministry of Health according to published criteria.[11] In 2018, there were 13 comprehensive stroke centres (CSCs) and 32 primary stroke centres (PSCs) throughout the country. Since 2012, the EMS follows the stroke triage criteria published by the Ministry of Health in its Official Journal.[12] These criteria should guarantee that patients who had a stroke are transported to the nearest certified stroke centre, undergo intravenous thrombolysis or are transported from PSC to CSC if it is indicated, for example, for mechanical thrombectomy. EMS should prenotify stroke centres, usually through a phone call between the ambulance crew and the neurologists at the stroke centre. Details regarding organisation of stroke services in the Czech Republic have been published before.[7]

Evaluation of the simulation training

Kirkpatrick's evaluation framework was used to assess the intervention.[13] Participants' reaction (level 1) was measured using a standardised questionnaire immediately after the simulation course. Participants were asked about their opinion on the relevance of the programme to their technical and non-technical skills,[14] which are (1) indication of thrombolysis (for physicians only), (2) shortening the DNT of thrombolysis and (3) improving team communication. Behavioural changes (level 3) were assessed by changes in DNT for all patients during the study period before and after simulation courses. Patient safety outcomes (level 4) were assessed by safety of treatment, measured as an occurrence of any ICH/PH. All participants also signed written informed consent to use these data, including audio-visuals.

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting or dissemination plans of our research.

Statistical analyses

Continuous data are presented as mean±SD or median (IQR), and non-continuous variables are given as percentages. Our primary analysis was to explore the difference in DNT between centres with and without simulation training. This difference was calculated from aggregated centre statistics in 2015 and 2018. Our secondary analysis was to assess the difference in DNT in 2018 between stroke centres with and without simulation training, for which patient-level data could have been used. A t-test or Kruskal-Wallis was used for both primary and secondary analyses.

As stroke centres with longer DNT were more interested and primarily accepted for simulation training (thus biasing the baseline level of logistics between the groups), a sensitivity analysis was performed to provide a more comparable baseline level of logistics. For sensitivity analysis, all stroke centres with DNT <50 min in 2015 were excluded.

Statistical significance was achieved if p<0.05. The Statistical Package for Social Sciences (V.20.0 for Windows) was used for statistical analyses.

The data and statistical files that support the findings of this study are available from the corresponding author on reasonable request.

RESULTS

During the study period, 18 697 patients were treated in 66 hospitals in the Czech Republic. Twenty-five hospitals (the majority were not certified stroke centres and treated few patients) did not have data on DNT both for 2015 and 2018 and were therefore excluded (1563 patients). In the final analysis, data from 17 134 (92%) patients from 41 hospitals were used. All of these 41 hospitals were certified stroke centres and represent 91% of all 45 certified hospitals nationwide.

Between 2016 and 2017, 10 courses were conducted for stroke teams from nine stroke centres in the Czech Republic. These 10 stroke teams (consisting of a majority of stroke physicians from each hospital and also representatives of nursing staff) were from CSCs (2 teams) and PSCs (8 teams). All 62 physicians (neurologists, radiologists and emergency physicians) and 32 nurses attended the courses without previous simulation training experience.

Participant reaction

The questionnaire response rate was 84%. On a scale of 0%–100%, the relevance to indication of thrombolysis was 85% (95% CI 79% to 91%), and the relevance to shortening the DNT of thrombolysis was 90% (95% CI 85% to 94%) and 72% (95% CI 60% to 84%) for physicians and nurses, respectively. The relevance to improving team communication was 77% (95% CI 71% to 83%).

Behavioural changes

Demographic data of patients in stroke centres that passed and did not pass simulation training are shown in table 1. DNT from 2015 to 2018 in centres with and without simulation training is shown in figure 2. Stroke centres that passed simulation training improved their DNT in 2018 as compared with 2015 by 30 min as compared with 20 min in stroke centres that did not pass simulation training in a simulation centre (p=0.01). In 2018, DNT was 26 min (IQR 22) in centres without simulation training as compared with 24 min (IQR 18) in centres with simulation training (p=0.006).

Figure 3 demonstrates the DNT after exclusion of stroke centres with short DNT (ie, DNT <50 min) already in 2015. In 2018, DNT was 29 min (IQR 24) in centres without simulation training as compared with 25 min (IQR 18) in centres with simulation training (p<0.001).

Patient safety outcome

In 2018, any ICH occurred in 9.7% of patients treated in centres without simulation training as compared with 8.5% in centres with simulation training (p=0.35). Also, any PH occurred in 5.4% of patients treated in centres without simulation training as compared with 3.5% in centres with simulation training (p=0.054).

DISCUSSION

In our study, we assessed the efficiency of simulation training using Kirkpatrick's training evaluation model. Our results support the efficiency of the simulation programme on all documented levels, that is, participant reactions (level 1), behavioural changes (level 3) and patient outcomes (level 4).

First of all, one-fifth of stroke centres participated, which gives simulation training a nationwide impact.

Table 1 Demographics of patients in stroke centres with and without simulation training in 2015 and 2018

	n (available data) No simulation/simulation	No simulation n=14 046	Simulation n=3088
Patients' characteristics			
Age, mean±SD	14 035/3082	71±13	72±13
Sex, n (%)	14 046/3088	7395 (53)	1660 (54)
Hypertension, n (%)	12 988/2865	9570 (74)	2197 (77)
Diabetes, n (%)	12 989/2865	3667 (28)	866 (30)
Atrial fibrillation, n (%)	12 982/2865	2167(17)	551 (19)
Congestive heart failure, n (%)	12 982/2864	1067 (8)	240 (8)
Baseline NIHSS score, mean±SD	9321/2535	10±6.8	10±6.8
Baseline systolic blood pressure, mean±SD	12 026/2768	158±26	162±26
Treatment with mechanical thrombectomy, n (%)	14 046/3088	3091 (22)	414 (13)

NIHSS, National Institutes of Health Stroke Scale.

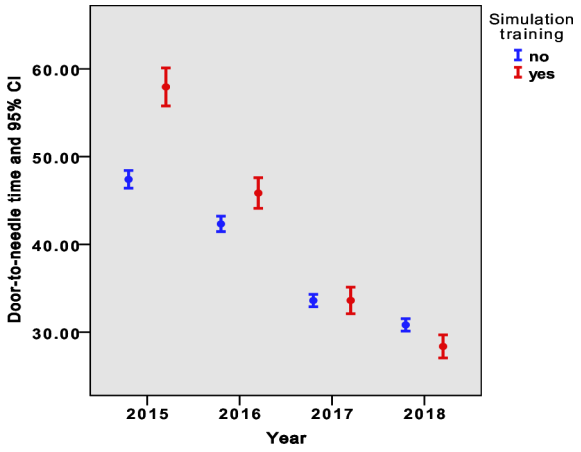

Figure 2 Door-to-needle time (DNT) before, during and after simulation training. DNT for intravenous thrombolysis in stroke centres that participated (red) and did not participate (blue) in simulation training. Before the simulation programme started, stroke centres participating in the simulation training had a longer DNT but achieved a shorter DNT at the end in 2018 when compared with stroke centres not participating in simulation training.

A broader context explaining the motivation of stroke centres to participate is explained in detail elsewhere[4] and includes reasons such as (1) certification/recertification of stroke centres by the Ministry of Health, (2) quality improvement initiatives by the Czech Stroke Society and (3) involvement of Angels Initiative.

When compared with the rest of stroke centres that did not participate, simulation-based training improved in-hospital logistics and shortened the time from the patient's arrival to initiation of intravenous thrombolysis. There were no safety concerns related to shortened logistics: stroke centres that passed simulation training tended to have less intracerebral parenchymal haematomas (5.4% vs 3.5%, p=0.054). This is consistent with our other findings which demonstrated that longer DNT was associated with more intracerebral bleedings.[15 16]

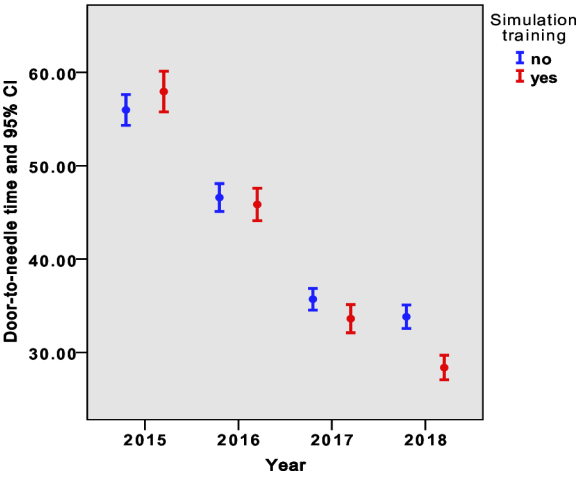

Figure 3 Door-to-needle time (DNT) changes in the sensitivity analysis. DNT for intravenous thrombolysis in stroke centres that participated (red) and did not participate (blue) in simulation training, but after exclusion of stroke centres with a DNT of less than 50 min in 2015. The DNT in 2015 was comparable; the difference in DNT in 2018 between the groups becomes more apparent.

The underlying mechanism in which simulation works was experiencing patients' workflow in a high-fidelity and controlled setting and informative feedback (rather than, for example, repetition of skills). The simulation trained the stroke teams to establish a new model of logistics before the initiation of thrombolysis. This model consisted of the direct transport of candidates from the ambulance to the CT scanner and the initiation of thrombolysis on the CT table. In our parallel study, we documented that those hospitals using this 'one-stop management' had a median DNT of 20 min, which was much shorter as compared with hospitals admitting patients outside the CT scanner and/or initiating treatment outside the CT scanner (28 respectively 37 min).[17] Simulation training most likely helped to establish this one-stop management because in 2018 one-stop management was used by 78% of stroke centres that participated in the simulation training as compared with 69% of stroke centres that did not participate in the simulation training.

On average, simulation improved DNT by 10 min compared with the control group. Therefore, the magnitude of absolute improvement was modest, although clinically still meaningful. However, it is very likely that simulation-based training would have a stronger influence on clinical practice in many centres/countries for two reasons. First, our baseline DNT was below 50 min in the control group, which is quite low and below the recommended target according to recent guidelines from 2019.[18] Second, as observed in the control group, dramatic improvement in stroke logistics occurred due to the simultaneous influence of other quality improvement measures.[7] From this perspective, a 10 min improvement is very satisfactory, and after simulation the DNT was less than half when compared with the DNT at baseline (28 min vs 58 min).

A few papers from Germany, Norway, UK and USA dealt with simulation training in stroke logistics.[9 19–21] Only a few of them measured a clinically relevant outcome and reported improvement in DNT by 10, 12 and 14 min.[9 20 21] There are additional studies using a multifaceted intervention, but not simulation training (ie, trainees acted), and they had an inconsistent effect on the decrease of DNT.[6 22–24] It is, however, difficult to compare all of these studies with our results for several reasons. First, none of the published studies had a control group and improvement was measured as pre-education and posteducation, thus not allowing the separation of the effect of simulation from an improvement due to other reasons. If we had used such a design, an improvement in DNT would have been 30 min in our study, clearly overestimating the efficiency of simulation training. Many studies were monocentric[9] and with a low number of cases.[9 21 24] In some studies, their final DNT was still quite long, for example, not less than 50 min.[9 23–25] Furthermore, only two studies

reported multidisciplinary cooperation,[9 20 21] as other studies only involved physicians. Importantly, only a few studies included safety,[21 23–25] which we considered important, especially given the fact that the final DNT was very short in both groups. Additionally, many studies performed local (in situ) simulation,[9 20] while our simulation was done centrally in an equipped simulation centre. Finally, some studies did not measure patient-relevant outcomes, but instead measured an improvement in knowledge.[19 26 27] Nevertheless, two previously published studies from Germany and Norway[20 21] and our study document that simulation training contributes to a short final DNT. DNT could reach less than 20 min, especially if patients are directed to and treated within a CT scanner, such as in our case or in Norway.[21]

The questionnaire (level 1) showed that the relevance of training for the participants was from 78% to 90% for non-technical and technical skills. A few studies that analysed the usefulness of training for participants showed that it was about 88%–90%.[20 21] However, it is difficult to compare these studies with our results because we used three specific questions. Our participants found training relevant to the improvement of team communication. This skill was found to be critical for multiprofessional teams to provide safe care.[28–30] On average, 85% of physicians found training relevant to the decision to administer intravenous thrombolysis. In terms of DNT, the training was more relevant for physicians than for nurses (90% vs 72%). This result supports previous findings.[31] One possible explanation is that nurses are in greater contact with the patients and therefore feel more problems with simulation fidelity.[31 32]

During the training of a large number of physicians, nurses and other healthcare professionals from the Czech Republic and other countries, we have observations that we could not quantify (and present as results) but are worth mentioning. In general, we noticed a large variability in the conduct of clinical practice. Even the two most essential procedures before initiation of thrombolysis, that is, neurological examination and reading the CT scans, were conducted in a hugely variable manner by different physicians. For example, it was not infrequent that a neurological examination was conducted in a way that did not allow confirming the presence of a neurological deficit. Also, we have observed consistently on many occasions that not all planes (ie, scans) were assessed on CT. It means that if the bleeding was not detected at the level of the basal ganglia, then the rest of the CT scans (usually above the basal ganglia) were not viewed, posing a substantial risk of missing bleeding in those parts of the brain where bleeding is unlikely to be expected. Finally, staff to patient and between-staff communications were hugely variable. We can conclude, based on this empirical experience, the provision of thrombolysis is done in different ways and deserves more attention to understand the magnitude of the problem and its implications, especially for patient safety and for content/quality of graduate/postgraduate education.

The limitation of our study is that stroke centres were not randomised to participate in the simulation training. A larger improvement in DNT could have been due to the fact that those stroke centres, which were more willing to improve their DNT, participated in the simulation training. However, longer DNT at baseline suggests rather the opposite because many stroke centres not participating in simulation training improved their logistics even before the start of the simulation programme. Another unlikely explanation of the results would be that stroke centres tended to improve more if their logistics were suboptimal. To eliminate this possibility, we conducted a sensitivity analysis: when only stroke centres with suboptimal logistics at baseline were considered for analysis, simulation had a bigger impact on the improvement of logistics. The last limitation is that we could not assess if simulation changed treatment with thrombolysis of stroke mimics because this information is not available in the register. However, our study documents that stroke centres after simulation training had shorter DNT, and our other studies documented that such shortening improves patient outcomes.[16] The strengths of our study are the presence of a control group, a nationwide character with a large number of patients involved, documented safety, and a reliable and prospective collection of outcome data.

CONCLUSION

In conclusion, our study documented that trainees considered simulation training as highly relevant to the improvement of their skills. We demonstrated that simulation improved clinical practice because the workflow to initiate thrombolytic therapy was faster as a result of the simulation training and regardless of other factors. The final DNT was below 30 min and did not compromise the safety of thrombolytic treatment. Simulation is a useful training method in stroke.

Contributors VS is a guarantor of this work. VS and RM are responsible for funding acquisition. VS, RM and HM developed the project methodology. VS, RM, HM and EV collaborated on data collection. RM and EV conducted the statistical analyses. All authors participated in the writing of the original draft and critically reviewed the manuscript. All authors edited and approved the final version of the manuscript for publication.

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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 This study involves human participants. In the registry, data were collected as part of routine clinical practice to assess the utilisation and quality of stroke services and in an anonymised format. Therefore, patients were not required to sign informed consent. However, the multicentre St Anne's Ethical Committee

approved the analysis of these data. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request.

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