Simulation-based training improves process times in acute stroke care (STREAM)

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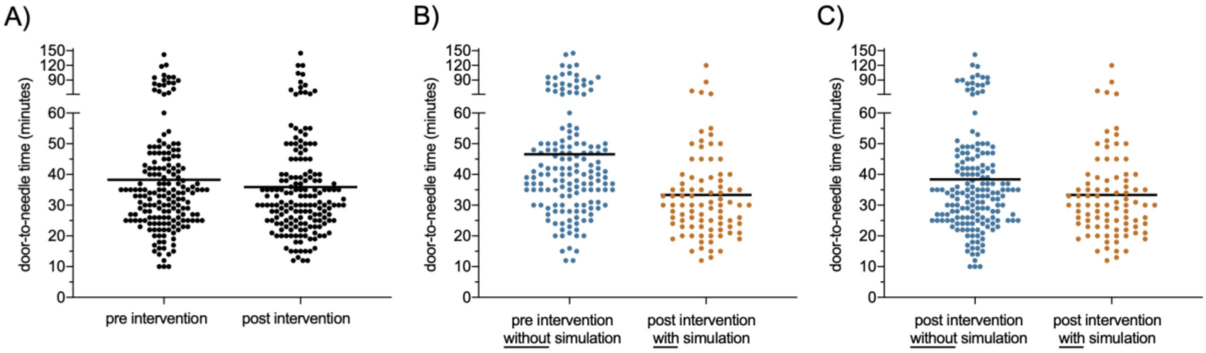
Supplemental Materials

Figure I: Influence of the STREAM trial intervention on door-to-needle times as primary and secondary analyses



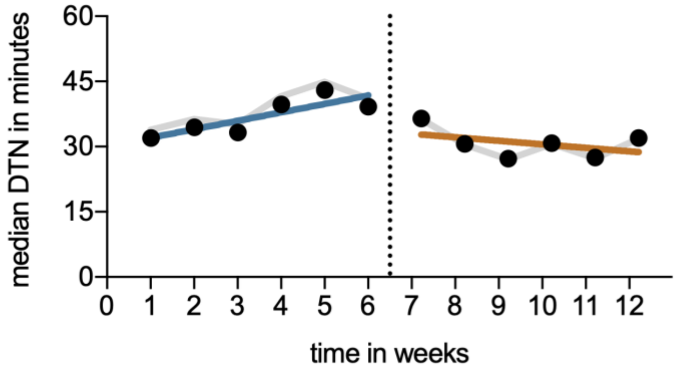
A) Primary analysis: comparing all patients in the pre- vs. all patients in the post-observational phase captures the effect of all five components of the intervention as planned in the trial protocol, but is susceptible to an incomplete penetration of the trial-specific *in situ* simulation trainings to the entire workforce of clinicians involved in acute stroke care at each center. Mean DTN was not altered significantly in the primary analysis (38 min, IQR 25 – 43 min vs. 36 min, IQR 25 – 40 min, p = 0.282).

B) Secondary analysis: comparing the combined effect of workflow adaptation and simulation training in the setting of optimal adherence to the trial intervention by comparing process times of simulation-naive teams in the pre-interventional phase with teams of whom at least one member had participated in the STREAM simulation training in the post-interventional phase. The reduction of the DTN by 5 minutes in the post-interventional phase was significant (38 min, IQR 25 – 43 min vs. 33 min, IQR 23 – 39 min, p = 0.033).

C) Secondary analysis: evaluating the isolated simulation training effect by comparing the operations of simulation-naive teams vs. simulation experienced teams exclusively in the post-interventional phase. The reduction of the DTN by 6 minutes in the post-interventional phase was significant (39 min, IQR 25 – 44 min vs. 33 min, IQR 23 – 39 min, p = 0.051).

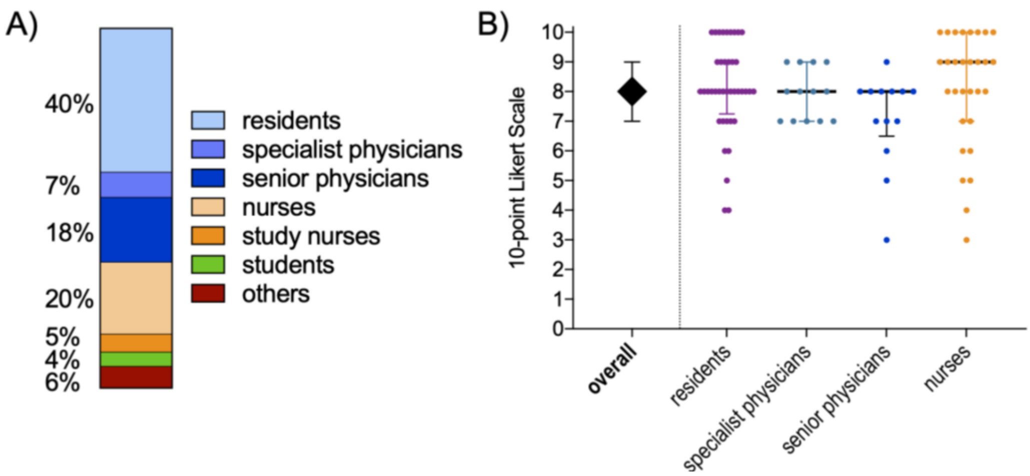
Individual DTN is given as a dot and means are presented. Normal distribution was confirmed by quantile-quantile plots. Statistical significance was tested with Student’s two-tailed t-test.

Figure II: Interrupted time series analysis of the STREAM trial intervention on door-to-needle times (DTN)



Median door-to-needle (DTN) time trends over the pre- and post-interventional observation phases are depicted to visualize the intervention time series analysis (ITSA) using autoregressive integrated moving average (ARIMA) modelling. Each dot represents a two-week interval. The slopes show a significant difference (p = 0.003).

Figure III: Staff participation and acceptance of *in situ* simulation training



A) Across the seven trial sites, n = 186 stroke team members from different professions and disciplines participated in the simulation trainings. A post-training questionnaire was completed by n = 110 participants.

B) The usefulness of the course was rated on a 10-point Likert scale from “not useful at all” to “extremely useful”. The training was rated as useful by 95.5 % (105/110) of all participants and this perception did not differ significantly by profession or – in the subgroup of physicians – by formative level. Most participants (93.6 %, 103/110) would welcome a regular training and the suggested interval for repetition was one year. Results were not statistically different.

Table I: Workflow and Behavioral Changes

	Pre intervention		Post intervention			Pre intervention without simulation experience		Post intervention with simulation experience		
	n=189		n=189			n=184		n=99		
	Yes %	n	Yes %	n	p [a]	Yes %	n	Yes %	n	p [a]
Direct transfer to imaging	43.4	82	53.4	101	*0.51*	44.0	81	49.5	46	*0.64*
Involvement of EMS	25.9	49	38.6	73	*0.01*	26.6	49	40.4	40	*0.02*
(Neuro-) radiologist present	69.8	132	63.0	119	*0.16*	69.0	127	66.7	66	*0.64*
IVT bolus in CT/ MRI	56.1	106	65.1	123	*0.07*	55.4	102	68.7	68	*0.02*
Do not await coagulation parameters	92.1	174	93.7	177	*0.42*	91.2	169	94.9	94	*0.20*
Patient required additional medical care	13.8	26	19.6	37	*0.14*	14.1	26	18.2	18	*0.39*

Abbreviations: EMS, emergency medical services (EMS) in the in-hospital acute stroke care workflow; IVT, intravenous thrombolysis. [a] tested via Wilcoxon-Mann-Whitney Test.

Table II - Authors' Contribution

Name	Location	Contribution
Ferdinand O. Bohmann, MD	University Hospital Frankfurt, Department of Neurology, Frankfurt am Main, Germany	Concept and design of the study; full access to all of the data and responsible for the integrity of the data and the accuracy of the data analysis; acquisition and interpretation of the data; drafted the manuscript; analyzed the data; supervised the study.
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Table III - Co-investigators

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Supplemental: CRM-based Stroke Team Training

a) **Crew Resource Management (CRM) aspects in Stroke Team Training**
b) **On-site Stroke Team Trainings**
c) **Material for Simulation Training**
d) **Teaching Material**

Crew Resource Management (CRM) aspects in stroke team training

Emergency medicine team operations such as acute stroke care are an excellent target for Crew Resource Management (CRM), a work and training philosophy that focuses on non-technical skills and strategies to prevent human error in complex procedures.[15,19,22] It is based on the fact that errors are inevitable but their consequences can be mitigated by installing safety measures. To achieve this, CRM builds on the use of checklists, decision aids and communication tools.

During the briefing as well as in the debriefing of the stroke team simulation training, we provided three main tools: 1) a stroke team pocket card, 2) an introduction into closed-loop communication and the encouragement to use it during the simulation and in clinical practice and 3) a stroke specific team timeout (termed ‘STANDARD of CARE’).[22]

Closed-loop communication is a valuable tool to improve communication and thereby patient safety in stressful situations. It acknowledges that there are many levels at which e.g. a communicated order can ‘get lost’ leading to a break of the communication loop: What is thought is not said - what is said is not heard - what is heard is not understood - what is understood is not accepted - what is accepted is not executed - what is executed is not completed.

Closed-loop communication uses self-contained verbal chains, where every order is acknowledged by its receiver who then reports back after the task is accomplished. Additionally, team members should know and address each other by name and maintain eye contact when speaking and listening to avoid misunderstandings.[22]

Standardized team timeouts, which are already widely implemented in surgical disciplines, can also be adopted to acute stroke care. The benefits are a better information footprint within the team (e.g. to navigate simultaneous actions) and the ability to identify and prevent potentially dangerous aspects early on. During the team timeout, the whole team gathers and only the team leader speaks and sums up all relevant information while all others carefully listen. Afterwards, team members address any noticed mistakes or lack of clarity, the team leader clarifies these and the team plans the next steps.

A stroke-specific team timeout may help to structure the summary of relevant facts for the whole team, to plan the following minutes and to identify missing information. The seven most relevant aspects are:

1. stroke syndrome;
2. time since onset;
3. patient age;
4. the NIHSS;
5. other diseases;
6. anticoagulation or antiplatelets;
7. red flags and contraindications to intravenous thrombolysis (e.g. recent operations, active malignancy, patient wishes).

To standardize the team timeout procedure, we developed a '10-for-10' (10 seconds to plan the next 10 min) with acronym 'STANDARD of CARE'.[22] We recommended a first '10-for-10' after the initial assessment by the neurologist and emergency department nurse, a second '10-for-10' at the CT scanner to involve the (neuro-)radiologist and technician and in case of an thrombectomy candidate a third '10-for-10' at the arrival in the angio suite to involve the neurointerventionalist and the anesthesiology team.

On-site Stroke Team Trainings

Team trainings at each trial site were led by the principal investigator's dedicated stroke team trainers, starting with a theoretical introduction focused on acute stroke therapies as well as CRM with an introduction of the specific tools closed loop-communication and 'STANDARD of CARE' team timeout. This theoretical primer was followed by *in situ* simulation for the entire interdisciplinary multiprofessional stroke team. The simulation training was structured in briefing – simulation – debriefing and lasted approximately three hours. The training was located at the emergency department, CT and angiography suite to reflect the whole treatment pathway from arrival at the hospital to groin puncture. Pre-defined scenarios (e.g. elevated blood pressure) had to be treated by the teams. A 'hot' debriefing was performed directly after the simulation with all participants, focusing on CRM-aspects and the identification of time eaters.[19]

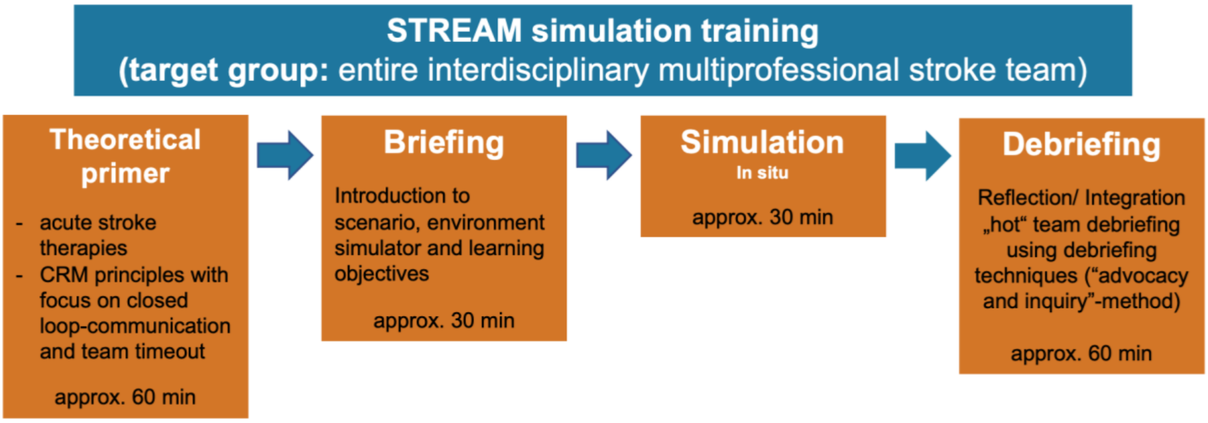

Figure III: STREAM simulation training

Material for Simulation Training

We decided to use a high-fidelity manikin (Resusci Anne, Laerdal Medical, Puchheim, Germany) with a monitoring system to on the one hand provide the usual cardiorespiratory alarms and on the other hand standardize the simulation with a focus on team communication. The manikin was controlled by a stroke team trainer and provided voice (by stroke team trainer) and vital parameters (depending on specific treatment, controlled by stroke team trainer). In addition, the standard environment of the respective emergency room was used and blood samples were provided. As routine a CT scan was performed and sample scans were presented via local radiology system to enable the assessment of acute stroke imaging for the participants of the simulation.

Teaching Materials

- Pocket Cards of an exemplary stroke team algorithm
- Exemplary sequence of a stroke team training
- Presentation for the theoretical introduction

- Scripted simulation scenarios
- Questionnaires for training evaluation
- Further information material about simulation training and theoretical aspects