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Research Article

Emergency reflex action drill for traumatic cardiac arrest in a simulated pre-hospital setting; a one-group pre-post intervention study

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ABSTRACT

Background: Emergency Reflex Action Drills (ERADs) are meant to decrease stress-associated cognitive demand in high urgency situations. The aim of this study was to develop and test an ERAD for witnessed traumatic cardiac arrest (TCA), an event in which potentially reversible causes need to be systematically addressed and treated in a short period of time. We hypothesize that this ERAD (the TCA-Drill) helps ground Emergency Medical Services (EMS) nurses in overcoming performance decline during this specific high-pressure situation.

Methods: This was a prospective, experimental one-group pre-post intervention study. Ground EMS nurses participated in a session of four simulated scenarios, with an in-between educational session to teach the TCA-Drill. Scenarios were video recorded, after which adherence and time differences were analyzed. Self-confidence on clinical practice was measured before and after the scenarios.

Results: Twelve ground EMS nurses participated in this study. Overall median time to address reversible causes of TCA decreased significantly using the TCA-Drill (132 vs. 110 s; $p = 0.030$) compared with the conventional ALS strategy. More specifically, participants adhering to the TCA-Drill showed a significantly lower time needed for hemorrhage control (58 vs. 37 s; $p = 0.012$). Eight of 12 (67 %) ground EMS nurses performed the ERAD without protocol deviations. Reported self-confidence significantly increased on 11 of the 13 surveyed items.

Conclusions: The use of an ERAD for TCA (the TCA-Drill) significantly reduces the time to address reversible causes for TCA without delaying chest compressions in a simulated environment and can be easily taught to ground EMS nurses and increases self-confidence.

Implications for clinical practice: The use of an ERAD for TCA (the TCA-Drill can significantly reduce the time to address reversible causes for TCA without delaying chest compression. This drill can be easily taught to ground EMS nurses and increases their self-confidence in addressing TCA-patients.

Introduction

Patients with prehospital traumatic cardiac arrest (TCA) have a poor prognosis with reported overall survival rates ranging between 2 % and 7.5 % (Barnard et al., 2017; Prentice et al., 2018; Lockey et al., 2006; Zwingmann et al., 2012; Vianen et al., 2022). Favorable neurological outcome rates have been reported in up to half of surviving patients. A recently published retrospective cohort study conducted in the

List of abbreviations: ALS, Advanced Life Support; ATLS, Advanced Traumatic Life Support; ERC, European Resuscitation Council; ERAD, Emergency Reflex Action Drill; HEMS, Helicopter Emergency Medical Services; HOTT, Hypovolemia, Oxygenation, Tension pneumothorax, Tamponade; ICU, Intensive Care Unit; IV/IO, Intravenous/intra-osseous; MREC, Medical Research Ethics Committee; OHCA, Out-of-Hospital-Cardiac-Arrest; PHTLS, Prehospital Trauma Life Support; SBME, Simulation Based Medical Education; TCA, Traumatic Cardiac Arrest; TCA-Drill, Traumatic Cardiac Arrest Drill.

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Netherlands showed an overall survival rate of 4 % of which 47 % of the patients had favorable neurological outcome (Houwen et al., 2021).

The probability of survival and a favorable neurological outcome after TCA are highly dependent on early recognition of this severe condition and swift treatment of potentially reversible causes (hypovolemia, hypoxia, tension pneumothorax and cardiac tamponade) together with rapid initiation of chest compressions (Konesky and Guo, 2018; Truhlar et al., 2015; Dunford et al., 2002; Lott et al., 2021; Salway et al., 2019; Savary et al., 2021). Current protocols and guidelines are clear on what should be done in a patient with traumatic cardiac arrest, but usually do not take into account the difficulties of turning thought into action (Houwen et al., 2021; Truhlar et al., 2015; Lott et al., 2021; Savary et al., 2021). Time-pressure, ambient noise and the chaotic characteristics of the prehospital environment may add up to stress experienced by ground EMS nurses when encountering a severely injured patient going into cardiac arrest. This can cause cognitive and motoric abilities to decline, resulting in suboptimal performance of previously learned skills (Salway et al., 2019; Bandura, 1986; Burns et al., 2007; Anderson et al., 2018).

Armed forces have dealt with this cognitive decline associated with high stress situations, by developing so-called Emergency Reflex Action Drills (ERADs). ERADs consist of a series of split-second actions that exempt the need for cognitive processing of information and prevents decision paralysis, and are used for example when a rifle blocks during combat (Burns et al., 2007). This routine action and the need of minimal cognitive effort improves performance under stress (Bandura, 1986; Harris et al., 2015). As such, practicing action drills improves confidence and helps to prioritize the sequence of lifesaving measures in unexpected situations (Warren et al., 2016; Jabaay et al., 2020; Chan et al., 2015). Similar ERADs have already been implemented in emergency medicine, mostly in airway management related scenarios (Szekely et al., 2005; Zink et al., 2023). To our knowledge, however, an ERAD specifically designed to deal with a trauma patient going into cardiac arrest does not yet exist.

Therefore, the primary aim of this study was to examine the adherence of ground EMS nurses to an ERAD specifically developed for witnessed prehospital TCA (the TCA-Drill) in the prehospital environment and to examine the effectivity of this novel ERAD in simulated TCA scenarios. Secondary aim was to investigate if learning the TCA-Drill improves self-confidence of ground EMS nurses in addressing TCA patients.

Methods

Design

This study was a prospective, experimental one-group pre-post intervention study among Dutch ground EMS nurses and carried out according to the TIDieR guidelines (Hoffmann et al., 2014). The study was conducted in Rotterdam area, the Netherlands, between April 8, 2022 and May 6, 2022.

Population and setting

Dutch ground EMS nurses are all Advanced Life Support and Pre-Hospital Trauma Life Support (PHTLS) certified and have prior experience as certified nurse in the coronary care unit, intensive care unit, emergency department, or anesthesiology department. Ground EMS nurses of one Dutch regional ambulance care provider (AmbulanceZorg Rotterdam-Rijnmond, Barendrecht, the Netherlands) were contacted by mail and invited to participate. Participation was voluntarily and informed consent was obtained. Participants were eligible to participate if they had at least one year of experience working as Advanced Life Support (ALS) ground EMS nurse. An a priori power analysis was performed and sample size was calculated on 12 participants.

TCA-drill and scenarios

An ERAD was developed specifically for TCA (TCA-Drill) by the research team, based on available literature and clinical experience (Lockey et al., 2006; Zwingmann et al., 2012; Zink et al., 2023; Lockey et al., 2013; Leis et al., 2013; Pickens et al., 2005; Willis et al., 2006; Cera et al., 2003; Sherren et al., 2013). More detailed information about the TCA-Drill can be found in Fig. 1. Along with the TCA-Drill, a 20 min teaching module was developed, containing information about the current guidelines regarding the treatment of prehospital TCA. An instructional video showing a step-by-step approach to the TCA-Drill was made and included in the teaching module (see Supplementary materials).

In addition, four simulated scenarios of witnessed prehospital TCA were designed, starting with an Advanced Traumatic Life Support (ATLS) setting during which the patient would become apneic and unresponsive. All simulated patients had a trauma mechanism potentially resulting in tension pneumothorax, pelvic fracture, and severe bleeding from one extremity, requiring the participant to secure the airway with a temporary maneuver (jaw thrust), ventilate the patient using a bag valve mask, perform a needle thoracentesis to decompress a potentially present tension pneumothorax, initiate intra-osseous (IO) fluid therapy, and apply a pelvic binder and tourniquet and initiate chest compressions. Cardiac tamponade was not simulated, as Dutch ground EMS nurses do not have the means to diagnose or address this condition. Participants were allowed to use their own equipment during scenarios and were assisted by one of the study members to represent the ground EMS ambulance driver, who was only allowed to hand the nurse equipment or perform chest compressions.

Procedure

Participants were asked to complete the Self-Confidence in Learning-questionnaire at baseline (Jabaay et al., 2020). This instrument consists of 13 items on a five-point Likert-scale, with 5 items testing the simulation activity and 8 items testing confidence in learning (Omer, 2016). In addition, demographic variables including age, sex, years of experience, prior education, and exposure to TCA during past 12 months were collected at baseline.

Next, participants were subjected to two witnessed TCA scenario's, in which they were asked to act according to their current training and protocol knowledge. After two simulations, participants were individually and face-to-face taught on the TCA-Drill by one researcher using the teaching module. Participants were invited to rehearse the TCA-Drill during a third simulated scenario. At last, participants were asked to run a fourth simulated TCA scenario, and to act according to the newly taught TCA-Drill. All simulated scenarios were led by one researcher, who is also a certified ALS instructor. To account for knowledge activation and unfamiliarity with a simulated setting during the first scenario and the newly learned ERAD in the third scenario, only the second and fourth scenario were video recorded for analysis. After the last scenario, participants were again asked to complete the Self-Confidence in Learning-questionnaire.

Data collection

Time intervals between the moment of becoming apneic and the moment a specific reversible cause was completely addressed were measured in seconds by two researchers based on video recordings of the simulated scenarios for each ground EMS nurse. Hemorrhage control was reached after applying both the T-pod and the tourniquet. IV/IO access was reached after both inserting the intraosseous needle and the start of fluid therapy. Airway management was reached after both inserting a Mayo tube and the first ventilation with the bag valve mask. Relief of a tension pneumothorax was reached after performing bilateral needle thoracenteses and lastly, the first chest compression was the

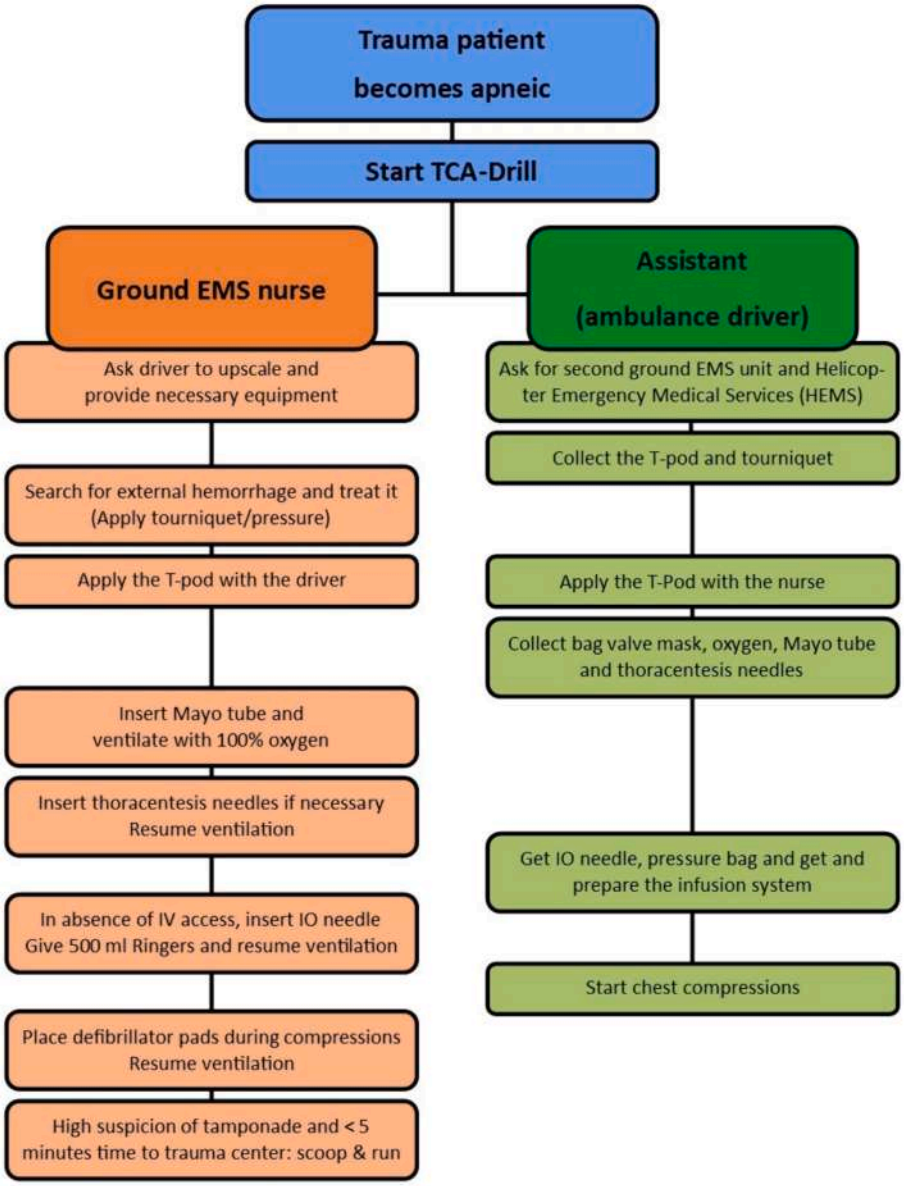

Fig. 1. The TCA-Drill. EMS, Emergency Medical Services, HEMS, Helicopter Emergency Medical Services, IO, intra-osseous, IV, intravenous.

measuring point for the start of compressions.

In addition, adherence to the ERAD in the fourth scenario was scored by two researchers. In case of disagreement, videos were reviewed by two reviewers to achieve consensus.

Data analysis

All analyses were performed using IBM's Statistical Package for the Social Sciences (SPSS), Version 28 (SPSS, Chicago, Illinois, USA). Categorical variables are presented as frequencies with percentages. Normality of data was tested using the Shapiro-Wilk Test. Continuous outcomes are presented as median with percentiles (P_{25} and P_{75}). Time intervals from the second scenario and the fourth scenario as well as Likert scores of the Self-Confidence in Learning-questionnaire before and after the scenarios were analyzed as continuous data and compared using the Wilcoxon Signed Ranks Test.

Ethics statement

The study was exempted by the Medical Research Ethics Committee Erasmus MC (registration nr. MEC-2022-0139).

Results

Sample and baseline characteristics

A total of 30 ground EMS nurses were approached to participate, 12 ground EMS nurses were eventually included in the study (Table 1). Invitations were declined for various reasons, being time related (n = 4), stress-related (n = 6), health-related (n = 3), or no response to invitation (n = 5). Participants had a median age of 35 years and various background experience. A majority (n = 10; 83 %) had an exposure of less than five TCAs in the previous year.

TCA-drill adherence

Full adherence to the TCA-Drill was achieved by 8 (67 %) participants. Four participants did not adhere to the TCA-drill with each nurse making four to five deviations from the TCA-Drill in their simulated scenario. There was no significant difference in age, prior education, or

Table 1
Baseline characteristics of study participants (n = 12).

Characteristic		Total group
Male sex		10 (83 %)
Age (in years)	25–35	6 (50 %)
	35–45	3 (25 %)
	45–55	3 (25 %)
Medical education prior to ground EMS nursing*	Intensive Care Unit	5 (42 %)
	Emergency department	6 (50 %)
	Coronary Care Unit	4 (33 %)
	Anesthesiology department	3 (25 %)
Experience as ground EMS nurse (in years)	< 2	0 (0 %)
	2–4	6 (50 %)
	5–9	2 (17 %)
	10–14	1 (8 %)
	15–19	1 (8 %)
	20–24	1 (8 %)
	≥ 25	1 (8 %)
TCA patients in previous year	None	1 (8 %)
	< 5	9 (75 %)
	5–10	2 (17 %)

Data are shown as n (%).
TCA, traumatic cardiac arrest.
* Medical education prior to ground EMS nursing exceeds 100 % as some participants have had multiple previous professions.

years of experience between ground EMS nurses adhering and nurses not adhering to the TCA-Drill.

Time needed to address reversible causes of TCA and initiate chest compressions

Total duration of the simulated scenarios of all twelve participants showed non-significant median decrease of 18 s to address all reversible causes of TCA (139 vs. 120 s; p = 0.083) after being taught the TCA-Drill (Table 2). However, a sub analysis of the eight TCA-Drill adherent nurses showed a significant decrease in median time of 22 s to perform all interventions (132 vs. 110 s; p = 0.030).

Median time needed to reach hemorrhage control decreased for all participants after the TCA-Drill teaching module (58 vs. 37 s; p = 0.021), including the TCA-Drill adherent group (58 vs. 37 s; p = 0.012). There was no significant decrease in time needed to gain IV/IO access, with a median decrease of 31 s (120 vs. 89 s; p = 0.084) for all participants and a median decrease of 28 s (117 vs. 89 s; p = 0.069) for the TCA-Drill adherent group in favor of the TCA-Drill approach. Time to reach airway management was not significantly different for both approaches; 55 vs. 47 s (p = 0.929) for all participants and 53 vs. 47 s (p = 0.498) in the TCA-Drill adherent group. Analysis of the median time needed to relief a tension pneumothorax showed no significant increase in the TCA-Drill adherent group (43 vs. 59 s; p = 0.092), but analysis of median times of all participants showed a significant increase of 14 s (44 vs. 58 s; p = 0.010) until a needle thoracentesis was performed. Median time to the start of chest compressions did not significantly decrease in the TCA-Drill adherent group (81 vs. 79 s; p = 0.441), and median times of all participants showed a non-significant increase of 7 s (75 vs. 82 s; p = 0.077) to the start of chest compressions.

Self-confidence

In Table 3, the self-confidence scores of the 12 participants before and after the session are shown. Of the 13 surveyed items, an increased self-confidence was achieved on 11 items. On the remaining 2 items, there was no significant increase of reported self-confidence.

Discussion

After a short training, two-third of ground EMS nurses were able to adhere to the new-developed TCA-Drill and time needed to address potentially reversible causes of TCA was significantly lower using the TCA-Drill than with the traditional ALS approach. Also, reported self-confidence among the participating ground EMS nurses with regard to the treatment of trauma patients going into cardiac arrest increased significantly.

While the use of ERADs in (prehospital) emergency medicine is not new, this is the first study to report on the development and evaluation of an ERAD specifically for TCA (Szekely et al., 2005; Zink et al., 2023). As TCA is an extremely time-critical medical condition, neurological intact survival strongly depends on swift recognition and subsequent action to prevent further anoxic damage to the patient (Zwingmann et al., 2012; Poppe et al., 2020). However, low incidence of prehospital TCA, time-pressure, distracting injuries, and ambient noise and chaos associated with the prehospital environment can result in significant stress, cognitive impairment, and performance decline among ground EMS nurses when confronted with these circumstances and patients. Algorithms and decision support tools as provided in most guidelines are mostly not suitable for situations like these, as they often require the user to make decisions and act accordingly based on cognitive processing of complex information. ERADs, on the contrary, are designed specifically for situations such as these; individuals are taught on how to act without thinking when a certain trigger is provided (e.g. sudden oxygen desaturation, absent breathing, obstetric emergencies) (Sherren et al., 2013; LeBoeuf and Pritchett, 2020; Sheen and Goffman, 2019). By repeatedly practicing these drills, individuals may develop automatic responses that are valuable during high-stress situations (Sheen and Goffman, 2019; Jenckes et al., 2007; Sharples and Turner, 2023;

Table 2
Times observed before and after educational module on TCA-Drill.

	All participants (n = 12)			TCA adherent group (n = 8)		
	Pre	Post	p-value	Pre	Post	p-value
Total scenario duration	139 (121–152)	120 (110–140)	0.083	132 (121–148)	110 (90–129)	**0.030**
Hypovolemia: Hemorrhage control	58 (29–68)	37 (22–42)	**0.021**	58 (39–68)	37 (22–40)	**0.012**
Hypovolemia: IV/IO access & fluid supply	120 (110–130)	89 (77–109)	0.084	117 (110–124)	89 (69–102)	0.069
Hypoxia: Airway management	55 (22–78)	47 (27–69)	0.929	53 (14–80)	47 (30–60)	0.498
Tension pneumothorax: Needle thoracentesis	44 (34–53)	58 (48–67)	**0.010**	43 (33–53)	59 (48–67)	0.092
Start of chest compressions	75 (51–87)	82 (71–101)	0.077	81 (63–90)	79 (70–94)	0.441

Times are shown as median (P_{25}-P_{75}) in seconds.
Bold values denote statistical significance at the $p < 0.05$ level.
Pre, before educational module.
Post, after educational module.
IV/IO, intravenous/intra-osseous.

Table 3
Self-confidence of participants before and after educational session of TCA-Drill.

Nr.	Question	Median Likert score		p-value
		Pre	Post	
1	I am confident that I can recognize signs and symptoms of diseases	4 (4–5)	4 (4–5)	**0.046**
2	I am confident that I am obtaining the required knowledge from simulation to perform necessary tasks in a clinical practice	4 (4–4)	4 (4–5)	**0.025**
3	I am confident that I am developing the required skills from simulation to perform necessary tasks in clinical practice	4 (4–5)	5 (4–5)	0.059
4	I am confident that I can accurately assess an individual with any abnormalities	4 (3–5)	5 (4–5)	**0.011**
5	I am certain that I can accomplish my intended learning goals	4 (4–5)	5 (4–5)	0.059
6	I am confident that I am mastering the content of the simulation activity that my instructors presented to me	4 (4–5)	5 (4–5)	**0.014**
7	I am confident that I can deal efficiently with unexpected events	4 (4–5)	5 (4–5)	**0.025**
8	I am confident that I can develop appropriate nursing care plan for individuals with any abnormalities	4 (3–5)	5 (4–5)	**0.025**
9	I am confident that the simulation covered critical content necessary for the mastery of the curriculum	4 (4–5)	4 (4–5)	**0.046**
10	I can handle whatever comes my way in clinical practice	4 (3–4)	5 (4–5)	**0.020**
11	I am confident that I can always manage to solve difficult problems if I try hard enough	4 (3–4)	4 (4–5)	**0.020**
12	I am confident that I can evaluate the effectiveness of my interventions for an individual with any abnormalities	4 (4–5)	5 (4–5)	**0.025**
13	I am confident that I can appropriately intervene to meet the need of an individual with any abnormalities	4 (4–5)	5 (4–5)	**0.025**

Likert scores are shown as median (P_{25}-P_{75}).
Bold values denote statistical significance at the $p < 0.05$ level.
Pre, before educational module.
Post, after educational module.

Silverplats et al., 2022; Vincent et al., 2021).

The results of the current study demonstrate that the use of a specifically designed ERAD for TCA increases confidence among ground EMS nurses to deal with these patients and improves the time needed to address reversible causes without delaying chest compressions. It should be noted that participation in multiple simulated scenarios may have improved perceived confidence in itself, as previous research supports the association between simulation training and nursing student confidence (Bowling and Underwood, 2016). We do, however, believe that the characteristics of ERAD-based training significantly contributes to the experienced rise in confidence among ground EMS nurses.

After the educational module including a video of the TCA-Drill and one simulated scenario which together took about 30 min – 67 % of ground EMS nurses were able to fully adhere to the new ERAD. We expect that repeated and more immersive training will increase this percentage. As this study only evaluated adherence directly after one training session, it is unclear how gained knowledge will be retained over time. Probably, as with all skills that are utilized with low frequency, the ability to successfully perform an ERAD depends on the frequency in which it is practiced in a simulated environment. As in the Netherlands, the average ground EMS nurses treats a TCA patient in a non-simulated setting approximately once every five year, this applies even more (Houwen et al., 2021; Info RN-VeZ, 2022).

Since for every prehospital TCA patient in the Netherlands, Dutch physician-staffed Helicopter Emergency Medical Services (HEMS) are also deployed, the effect of training the EMS nurses may be limited. However, given that the TCA-Drill mainly concerns emergency care given in the first minutes after arriving on scene – when the HEMS crew is not on-scene yet – it seems justifiable to spend time and resources on improving the emergency care in these first minutes, for example by implementing the TCA Drill.

Limitations

This study has several limitations. First and most important, the single-group pre-post intervention design could have caused an overall increased experience of the study group with addressing the reversible causes of TCA. Therefore, the decrease in time needed to address the reversible causes of TCA may not be fully attributed to the effect of adhering to the TCA-Drill, as it as it is also likely that some of the decrease in time is caused by the effect of repetition of practicing procedures. Second, the sample size was limited as some ground EMS nurses declined to participate in the study due to the experience of simulations as a stressful event. This may have led to selection bias. Third, the average Dutch ground EMS nurses treats a TCA patient about once in every five years. As the nurses included in this study have had more experience treating TCA patients in the previous year than the average Dutch ground EMS nurse, this may have influenced our findings. Lastly, the participating ground EMS nurses were all active in a unique prehospital emergency care system and the Netherlands has a unique level of training of EMS units. Therefore, extrapolating the results of this study to other EMS healthcare systems should be done with caution.

Conclusions

The use of a specifically designed TCA-Drill significantly reduces the time to address reversible causes for TCA without delaying chest compressions in a simulated environment and this TCA-Drill can be easily taught to ground EMS nurses and increases their self-confidence.

Funding

This study was not funded.

Ethics statement

The study was exempted by the Medical Research Ethics Committee Erasmus MC (registration nr. MEC-2022-0139).

CRediT authorship contribution statement

Irene Bijl: Writing – original draft, Project administration, Methodology, Investigation, Conceptualization. **Niek J. Vianen:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation. **Esther M.M. Van Lieshout:** Writing – review & editing, Visualization, Validation, Supervision, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Christian H.J. Beekers:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization. **Nancy W.P.L. Van Der Waarden:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization. **Begüm Pekbay:** Writing – review & editing, Writing – original draft. **Iscander M. Maissan:** Writing – review & editing. **Michael H.J. Verhofstad:** Writing – review & editing, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Mark G. Van Vledder:** Writing – review & editing, Visualization, Validation, Supervision, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.iccn.2024.103731.

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