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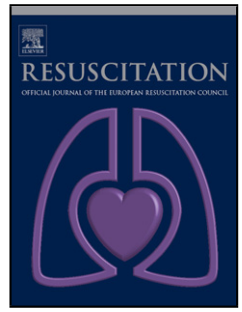

An observational study of technical and non-technical skills in advanced life support in the clinical setting

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Title page

An observational study of technical and non-technical skills in advanced life support in the clinical setting

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Abstract

Objective

Technical skills (TS) and non-technical skills (NTS) are the primary elements ensuring patient safety during advanced life support (ALS) and effective crisis resource management (CRM). Both skills are needed to perform high-quality ALS, though they are traditionally practiced separately. The evidence of the association between NTS and TS in high-quality ALS performance is insufficient. Hence, we aimed to evaluate the association between the skills in real-life in-hospital ALS situations.

Methods

We video recorded real-life in-hospital ALS situations, analyzed TS and NTS demonstrated in them with an instrument measuring TS and NTS, and tested the linear association between NTS and TS using a linear mixed model.

Results

Among 50 real-life in-hospital ALS situations that we recorded, 20 had adequate data for analysis. NTS and TS total scores were associated with one another (slope 0.48, $P<0.001$). All NTS subcategories were associated with the TS total score (slopes ranging from 0.29 to 0.39, $P<0.001$). The NTS total score and TS subcategories (*chest compression quality, ventilation quality, rhythm control and defibrillation quality*) were associated with one another (slopes ranging from 0.37 to 0.56, $P<0.01$).

Conclusions

The resuscitation teams who demonstrated good NTS also performed the technical aspects of ALS better. The results suggest that NTS and TS have an association with one another in real-life in-hospital ALS situations. NTS performance had the most evident association with chest compression quality and rhythm control and defibrillation quality; these are considered the most crucial elements affecting outcomes of ALS. The findings of the study present novel information of what and why to emphasize in ALS training.

Keywords: advanced life support; crisis resource management; non-technical skills

Clinical trial registration. ClinicalTrials.gov, NCT03017144

Introduction

Crisis Resource Management (CRM) is an emergency situation operating model adopted to the health care setting from aviation. The model consists of two sets of skills: technical skills (TS) and non-technical skills (NTS). In advanced life support (ALS), TS are procedural based psychomotor techniques, which are needed to perform the resuscitation algorithm (including chest compressions, rhythm identification and defibrillation, securing the airway and ventilation, and medication and fluid management). In contrast to TS, NTS are non-manual behavioral elements including cognitive or mental skills (e.g. decision making, planning, situation awareness), and social or interpersonal skills (e.g. team-working, communication, leadership) that contribute to safe and efficient team performance. [1-3] The individual technical proficiency alone is not enough for excellent overall performance in high-risk medical situations like ALS, so both TS and NTS are emphasized skills for managing and mastering high-quality ALS. [4]

The relationship between non-technical and technical performance is not fully understood. [5-12] Previous studies have documented a positive correlation between NTS and TS in simulated ALS scenarios by anaesthesiologist [7, 11, 12] as well as in both simulated [13] and in real-life [14, 15] situations in surgery and obstetric emergencies [16]. Even though it is known that a significant number of avoidable incidents occurring during operative procedures are linked to failures in NTS [15], there are some studies in which the correlation between these skills is only considered low [8-10], none at all [5, 6] or even negative. [17] Even less is known if a certain part of NTS impacts on the overall ALS performance, or further, if excellent NTS improve TS in ALS.

The knowledge of how these skills are related to one another can bring benefit to ALS training and research. The aim of this study was to assess NTS and TS in real-life ALS situations by professional resuscitation teams in one University Hospital.

Methods

Study design and setting

We performed this prospective observational study in a University Hospital in Finland between September 2013 and November 2014. We video recorded real-life in-hospital ALS situations handled by a resuscitation team of this hospital. The team consisted usually of an anaesthesiologist or an intensivist (team leader), accompanied by two intensive care nurses. When available, a medical technician, and in some cases also another physician, joined the resuscitation team. All resuscitation team members were experienced professionals, who received ALS simulation education regularly.

Ethics approval

The study was approved by the Ethics Committee of the Hospital District (statement number 14/2012, date of approval 19.6.2012), the administrative approval was given by the hospital research authorities (research number T70/2012, statement O43/12) and the study was registered in ClinicalTrials.gov (ID NCT03017144).

All the participants had to unanimously agree to filming the event before turning the camera on. To avoid the influence of the peer pressure, any participant could demand the removal of the video immediately or at any time during the study, if an individual decided to withdraw consent to participate.

Videoing was performed without an informed consent from patients by permission based on Finnish law Med. Res. 488/1999 and approval of ethical committee and authorities. Names and identity codes of patients or resuscitation team members was not collected. The data concerning resuscitation alarms was collected according to the Utstein model [18].

Conduct of the study

We used a GoPro®-camera fixed on top of the resuscitation trolley. The camera was asked to be turned on by the resuscitation team whenever an emergency alarm was activated. During the study period, the resuscitation team handled 181 emergency situations. Of these, 110 were ALS situations and 71 were other medical emergencies. 50 of the ALS situations were filmed. We excluded those, which were technically impossible to analyze, and after this, 20 were included in the analysis. (Fig. 1). We did not exclude any of the videos due to team performance or patient related factors.

We edited the videos using the Pinnacle 14 editing software and we removed the non-relevant content e.g. most of the time when the team was moving from the ICU to the ALS situation and most of the aftermath. The aim of the editing was to make the videos more comfortable for the raters to evaluate. We left all the parts showing ALS intact. We transferred the edited videos to a password protected folder on the hard drive of the hospital. The authors could watch the videos via the secure remote access in which - to ensure full security - the log in was using two factor authentication; first by a personal password and then by a code sent to the author's personal mobile phone for each log in attempt.

Data handling

We analyzed NTS and TS from the videos with a validated ALS performance evaluation instrument, which the research group has developed and published for research purposes [19]. The instrument consists of 69 items, which are grouped into adherence to guidelines (28 items), clinical decision-making (5 items), workload management (12 items), team behaviour (8 items), information management (6 items), patient integrity and consideration of laymen (4 items), and work routines (6 items). As considered inessential matters for this study, patient integrity and consideration of layman were evaluated but not taken in as part of the analysis. Adherence to guidelines is divided into recognition of the need for cardiopulmonary resuscitation (5 items), chest compression quality (9 items), ventilation quality (4 items), rhythm quality and defibrillation quality (6 items), and medication and fluid therapy (4 items).

The first group, adherence to guidelines (28 items in total), is devoted to the measurement of TS, while the rest of grouped items (clinical decision-making, workload management, team behaviour and information management, 31 items in total) measure NTS. The instrument is valid and reliable in this context (content validity index of the instrument is 0.96, Cronbach α's are 0.83 for TS and 0.82 for NTS). A rating scale from +2 to -2 is used for each item in the instrument. [19] The scale is presented in table 1.

Two authors V.P. (specializing physician in anaesthesiology) and M.T (senior anaesthesiologist) analyzed the videos independently with the instrument. They both had a vast experience of performing ALS and they were also trained simulation instructors.

The raters familiarized themselves with the usage of the instrument by first evaluating simulated ALS situations. Thereafter, they evaluated real-life ALS situations for several hours to make sure a consistent evaluation process. To avoid a bias, the raters were told to evaluate only what really happened in the videos and not to make any inferences. After this training the evaluators discussed the evaluation experiences to make a considered and deliberated consensus of the assessment criteria. Then the raters evaluated independently the ALS videos for this study one at a time. During the evaluation process the raters arranged themselves video meetings to ensure congruence in assessments. They discussed the evaluation criteria based on individual examples of the decisions in order to standardize the grading. Additionally, we determined the hands-on time (time with chest compressions) visually from the ALS videos.

The majority of the items in the tool could be evaluated from the videos. However, actions concerning ALS initiation and planning of further treatment after ROSC were only visible in a few videos. In addition, it was often impossible to verify the correctness of the rhythm recognition due to the placement of the defibrillator that hindered visibility of the monitor on the recorded videos as well as defibrillator pad placement. On item level, the percentages of successful evaluations varied from 20 to 100 % - eight items were below 50 %. The percentages of successful evaluations from the video-recorded ALS situations per measurement tool item and subgroup are presented in table 2.

Outcomes

Our primary outcome was the association between the items evaluating NTS and the items evaluating TS. Our secondary outcome was the association between the NTS subgroups and the TS total score. In addition, we also conducted an analysis and measured the association between the NTS total score and TS subcategories and the hands-on ratio (hands-on time divided by the total ALS time).

Statistical analysis

We calculated the mean score of the items evaluating NTS and TS and used them in the analyses to represent the NTS and TS for each assessed. We calculated the hands-on ratio by dividing the hands-on time with the total ALS time on video.

We tested the association between NTS and TS using a linear mixed model where the ALS situation was used as a random effect to consider the repetitive nature of the study design, and the rater was considered as a nuisance factor and thus was blocked by using it as a fixed effect. We quantified the results using a slope of the association with 95% confidence intervals (95% CI). A scatter plot with the slope of the association is presented for illustrative purposes. Similarly, we analyzed the association of subcategories of NTS and TS total score, and the association of NTS total score and subcategories of TS. The association between NTS total score and hands-on ratio was tested using a linear mixed model where the ALS situation was used as a random and the rater as a fixed effect for the same reasons as explained above. Similarly, the slope and its 95 % confidence interval are reported.

We assessed inter-rater reproducibility of TS scores and NTS scores using an intraclass correlation coefficient (ICC). ICC reflects both the degree of correlation and agreement between raters and is calculated by dividing the subject variation with the total variation. We calculated ICC estimates and their 95 % bias corrected bootstrap (B = 2000) confidence intervals based on a mean-rating (k = 2), absolute-agreement, 2-way mixed-effect model.

We checked the residuals for justification of the analyses. P-values less than 0.05 were considered statistically significant. We used R version 3.6.0 for statistical analyses.

Results

After editing, the videos were 2:12–44:50 minutes long and the median length was 9:39 min with an interquartile range of 6:26–14:13.

The distribution of the skills

TS and NTS were generally rated on high level, but the deviation of NTS was greater than that of TS: the median of TS was 0.68 and the interquartile range (IQR) was 0.89–0.21. For NTS, the median was 0.66 and the IQR 1.10–0.03. The median for TS for the rater one was 0.70 (IQR 0.89–

0.21) and for the rater two 0.66 (IQR 0.84–0.18). The median for NTS for the rater one was 0.68 (IQR 1.14–0.03) and for the rater two 0.63 (IQR 1.00–0.06).

Association between non-technical and technical skills

The ICC was excellent for the NTS total score (ICC=0.96; 95% CI 0.889–0.987) and for the NTS subgroups (ICC ranging from 0.91–0.97). The ICC was excellent for TS total score (ICC=0.98; 95% CI 0.951–0.991) and for the subgroups (ICC ranging from 0.90–1.0). The association between the NTS and the TS total scores was evident (slope 0.48; 95% CI 0.34–0.61, $P<0.001$). This means that when an NTS total score is increased by 1 unit, the TS total score is increased by 0.48 units. (Table 3 and Fig. 2.). All NTS subcategories were associated with the TS total score. The NTS total score was associated with all TS subcategories except *recognition of the need for cardiopulmonary resuscitation* and *medication and fluid therapy* (Table 3) and the hands-on-ratio (slope 2.24, P=0.056).

Discussion

This study presents a novel finding that there may be an association between NTS and TS performance in real-life in-hospital ALS situations. The findings suggest that the resuscitation teams that showed a good NTS performance, also performed technical aspects of ALS better. In contrast, the resuscitation teams with poorer NTS showed inferior technical performance during ALS.

The NTS total score had an evident association with the TS total score. Further, all NTS subcategories were associated with the total TS performance. Different NTS subcategories showed similar associations with the total TS performance. However, two TS subcategories, chest compressions, and rhythm control and defibrillation quality showed the strongest association with the total NTS performance, and the teams with higher NTS total scores seemed to perform better hands-on time than the teams with lower scores.

In recent resuscitation guidelines, chest compressions with minimal interruptions, rhythm control, and defibrillation quality are considered to be the most crucial elements affecting outcomes during ALS. [20] Earlier studies have shown that NTS training can reduce human errors and may improve patient outcome, [21] and our study is in line with them; improving non-technical performances in

ALS could possibly be an essential way to reduce technical errors during a crisis situation in real-life patient care. It may even maximize the outcomes from cardiac arrest. The ALS education should therefore comprise an additional focus on team related NTS training on a diverse scale aiming to the better technical performance during a crisis situation.

ALS is a time-critical and urgent medical crisis situation for healthcare professionals [22] and it could be a stressful and emotionally demanding experience. Relatively little is also known about the effects of stress on team work, group decision making, or performance, but there is some evidence that stress and overload associates with lower ALS performance on a team level [23] whereas some have found a correlation between the NTS and TS only in those simulated ALS situations where external stressors are present. [24] Stress can adversely affect cognitive functions such as attention, working memory and decision-making, [22] and this can be reflected by a deterioration of non-technical performance in simulated ALS situations [24]. Due to the unexpected nature of real-life ALS situation, there might be even more stress present than in simulation providing an explanation of the main finding of this study. We speculate that increased communication and trust within the group may lower the stress level during the crisis situation. This can improve the information management and team behaviour which can support division of labour and decision making. Studies to determine how stress impacts on the team performance in real-life ALS could bring further understanding for this question.

There are some advantages in this study. We used a validated instrument developed for the assessment of the overall performance of a resuscitation team. [19] Our instrument contained items evaluating both TS and NTS, unlike other studies, in which separate evaluation tools have been used. [5, 7, 11] The usage of one collective instrument for the evaluation of both skills might be useful in order to keep assessment of the skills as equal as possible. The structure of the instrument, the rating scale of the items, and the terminology used were planned to be homogenous. The items in the instrument are also quite specific and unambiguous in contrast to many other instruments.

In distinction to many other studies, we used the same raters evaluating the both skills to ensure the congruence of the rating process. To avoid a halo effect or spillover bias during the evaluation process, the raters were told to focus only on what they see and what they hear, not to make any inferences. Our further analysis indicating a possible association with NTS and hands-on-ratio – which is a part of technical skills and an independent variable – the presence of a significant bias seems unlikely.

The study has limitations. First, only 18 % (20/110) of the ALS situations during the study period were analyzed, and the camera was manually turned on in 45 % (50/110) of the cases, which might have had caused a selection bias. Due to the limitations regarding setting and samples the results might not be generalizable to all settings. It is also possible that the participants with more confidence in their resuscitation skills turned the camera on more easily than the others, and this could have had an impact on what was evaluated. Furthermore, we only evaluated the performance of one single hospital, so our results may not be generalizable to other settings, and different results might be found in other work environments and cultures.

Secondly, the video material consisted of real ALS situations and for this reason the material was very heterogeneous compared to simulated situations; this made the evaluation of NTS and TS occasionally challenging. The authors were aware that evaluating NTS can be challenging as many raters in other studies have faced several problems during the evaluation process e.g. when using ANTS [25, 26]. Some ALS performances took place on an inpatient-ward, in a corridor, in a narrow toilet, in an angiography room and even during the transfer of a patient from a ward to angiography. Because the filmed situations were real-life ALS scenarios, videos varied in length and content. Due to this variation some items of the measurement tool were not seen in every video. The most common areas missing were the recognition of the need for cardiopulmonary resuscitation, defibrillator rhythm interpretation, and the care plans made after ROSC. These missing areas are explained by the point of time when filming started, the location of the defibrillator, and the fact, that ROSC was not always achieved. However, the majority of the items were presented in most videos. Further, assessing chest compression quality (i.e. compression depth and chest recoil between compressions) would have been more reliable if we had used data collected by a CPR feedback device in addition to the visual evaluation. [27]

Third, the teams' knowledge of being observed is a potential source of bias, as it might affect performance. This is known as 'Hawthorne effect' or 'observers paradox', but however it is more likely the affect teams with lower rather than higher scores, [28] and further, in the absence of living observer, the researchers believe that this affect is minimal.

Conclusions

This study presents an association between NTS and TS for the first time in real-life in-hospital ALS situations. Our results suggest that NTS and TS are not independent skill sets but have a positive association with one another. This study provides novel knowledge about the association between these skills and the results reveal a deeper understanding of the association between the skills subcategories. Therefore, emphasis should be placed on both NTS and TS in health professional education and in-service training.

Conflict of Interest

None

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Legends to figures and tables

Table 1. The evaluation scale

Table 2. The percentages of successful evaluations from the video-recorded ALS situations per measurement tool item and subgroup

Table 3. Associations between non-technical and technical skills (slopes with 95% confidence intervals and P-values)

Fig. 1. This figure illustrates the design of the method by which the videos were collected.

Fig. 2. Association between NTS and TS total scores

Author Contribution Statement

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Miretta Tommila: Conceptualization, Methodology, Validation, Investigation, Resources, Data Curation, Writing – Original Draft, Writing - Review & Editing, Supervision, Project administration

Table 1. The evaluation scale

Score	Meaning
+2	• Yes • Yes, always • Correct actions were taken in all of the situations • Correct actions were taken all the time • Completely correct actions were taken • Completely correct
+1	• Yes, most of the time • Correct actions were taken in most of the situations • Correct actions were taken most of the time • Mostly correct
0	This option should only be used when the question cannot be evaluated due to technical failures or to other audial or visual obstacles or hindrances. With the exception of two questions regarding the post resuscitation care.
-1	• No, most of the time • Incorrect actions were taken in most of the situations • Incorrect actions were taken most of the time • Mostly incorrect
-2	• No • No, never • Incorrect actions were taken in all of the situations • Incorrect actions were taken all of the time • Completely incorrect actions were taken • Completely incorrect
	Some questions may only be answered yes, no or not possible to evaluate. These are marked with an X in the evaluation instrument.

Table 2. The percentages of successful evaluations from the video-recorded ALS situations per measurement tool item and subgroup

TS_{1A}	n (%)
I 1	25.0
I 2	20.0
I 3	35.0
I 4	45.0
I 5	100.0
avg.(%)	45.0

TS_{1B}	n (%)
I 6	95.0
I 7	100
I 8	95.0
I 9	95.0
I 10	95.0
I 11	100.0
I 12	100.0
I 13	100.0
I 14	95.0
avg.(%)	97,2

TS_{1C}	n (%)
I 15	90.0
I 16	100.0
I 17	85.0
I 18	95.0
avg.(%)	92,5

TS_{1D}	n (%)
I 19	30.0
I 20	35.0
I 21	40.0
I 22	100.0
I 23	100.0
I 24	100.0
avg.(%)	67,5

TS_{1E}	n (%)
I 25	100.0
I 26	100.0
I 27	80.0
I 28	100.0
avg.(%)	95.0

NTS_2	n (%)
I 29	100.0
I 30	35.0
I 31	100.0
I 32	55.0
I 33	45.0
avg.(%)	67.0

NTS_3	n (%)
I 34	100.0
I 35	100.0
I 36	100.0
I 37	100.0
I 38	100.0
I 39	100.0
I 40	100.0
I 41	100.0
I 42	100.0
I 43	100.0
I 44	100.0
I 45	100.0
avg.(%)	100.0

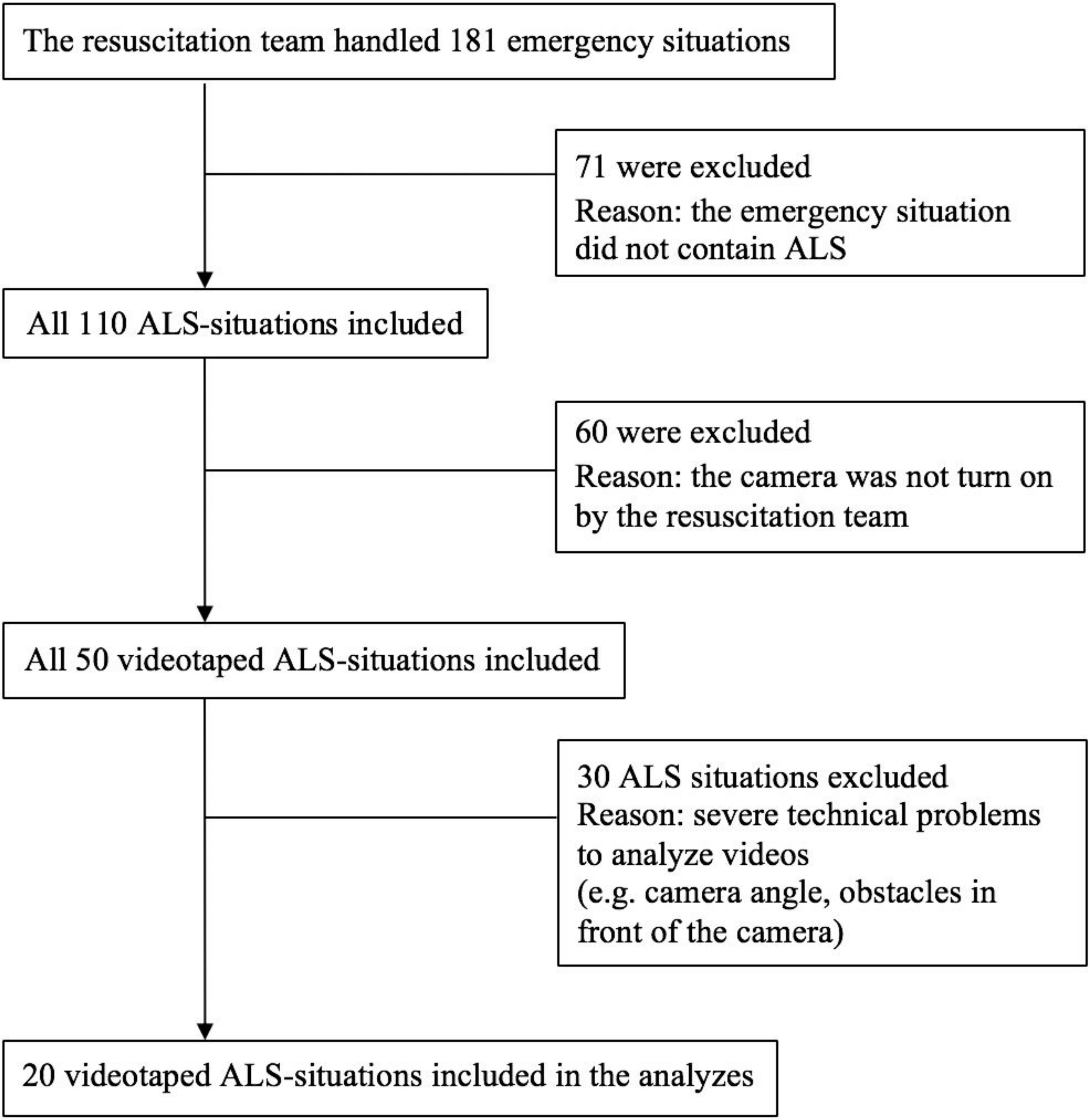
NTS_4	n (%)
I 46	100.0
I 47	100.0
I 48	100.0
I 49	100.0
I 50	100.0
I 51	100.0
I 52	100.0
I 53	100.0
avg.(%)	100.0

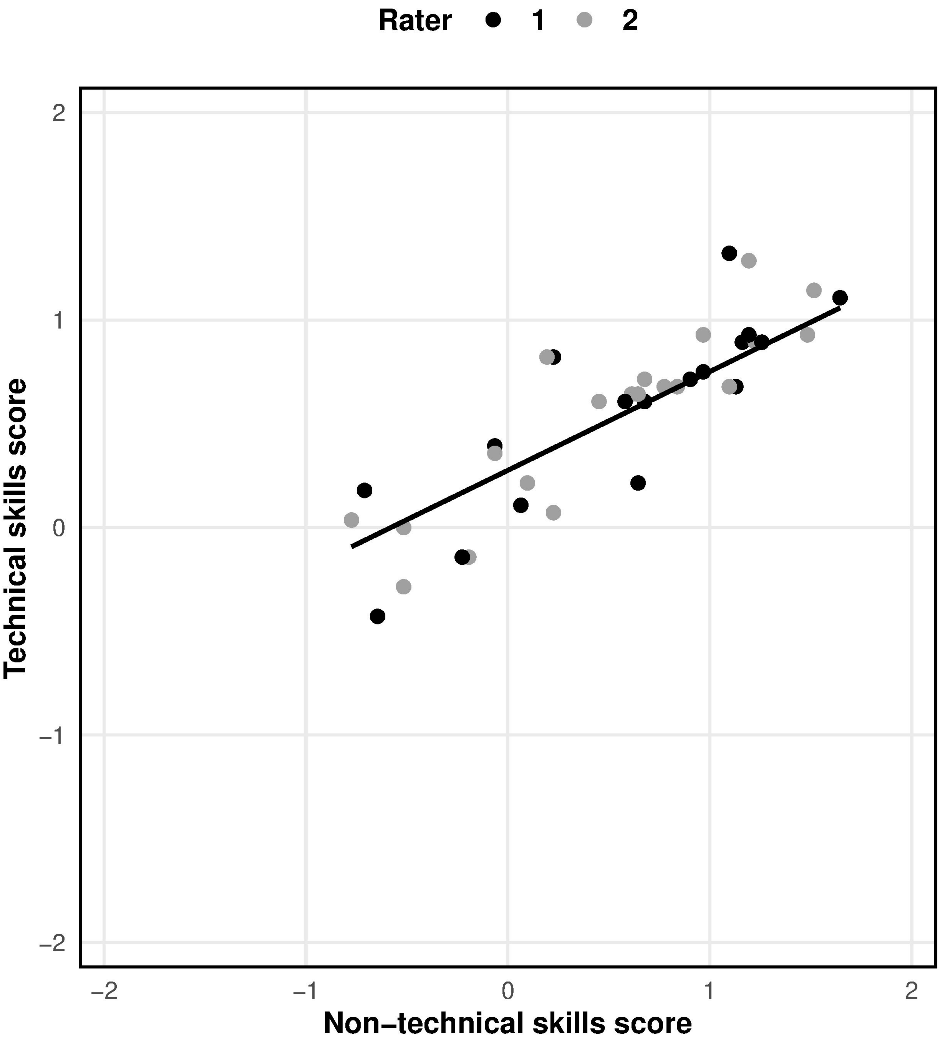
NTS_5	n (%)
I 54	100.0
I 55	100.0
I 56	90.0
I 57	100.0
I 58	95.0
I 59	100.0
avg.(%)	97.5

TS_{1A} = Recognition of the need for cardiopulmonary resuscitation, TS_{1B} = Chest compression quality, TS_{1C} = Ventilation quality, TS_{1D} = Rhythm control and defibrillation quality, TS_{1E} = Medication and fluid therapy, NTS_2 = Clinical decision making, NTS_3 = Workload management, NTS_4 = Team behaviour, NTS_5 = Information management, I 1– I 59 = Measurement tool items, n (%) = the percentage of successful evaluation per item, avg.(%) = the average percentage of successful evaluation per subgroup

Table 3. Associations between non-technical and technical skills (slopes with 95% confidence intervals and P-values)

	$TS_{total\ score}$	95 % CI	P-value
$NTS_{total\ score}$	0.48	0.34–0.61	<0.001
Clinical decision making	0.39	0.23–0.54	<0.001
Workload management	0.29	0.17–0.40	<0.001
Team behaviour	0.33	0.15–0.51	<0.001
Information management	0.30	0.15–0.45	<0.001
	$NTS_{total\ score}$	95 % CI	P-value
Recognition of the need for cardiopulmonary resuscitation	0.37	-0.01–0.76	0.056
Chest compression quality	0.56	0.27–0.85	<0.001
Ventilation quality	0.37	0.15–0.58	0.002
Rhythm control and defibrillation quality	0.54	0.20–0.88	0.004
Medication and fluid therapy	0.32	-0.09–0.73	0.12


The resuscitation team handled 181 emergency situations
71 were excluded
Reason: the emergency situation did not contain ALS
All 110 ALS-situations included
60 were excluded
Reason: the camera was not turn on by the resuscitation team
All 50 videotaped ALS-situations included
30 ALS situations excluded
Reason: severe technical problems to analyze videos
(e.g. camera angle, obstacles in front of the camera)
20 videotaped ALS-situations included in the analyzes



Rater
1
2
Technical skills score
Non−technical skills score
2
1
0
−1
−2
−2
−1
0
1
2