Medical crisis checklists in the emergency department: a simulation-based multi-institutional randomised controlled trial

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ABSTRACT

Background Studies carried out in simulated environments suggest that checklists improve the management of surgical and intensive care crises. Whether checklists improve the management of medical crises simulated in actual emergency departments (EDs) is unknown.

Methods Eight crises (anaphylactic shock, life-threatening asthma exacerbation, haemorrhagic shock from upper gastrointestinal bleeding, septic shock, calcium channel blocker poisoning, tricyclic antidepressant poisoning, status epilepticus, increased intracranial pressure) were simulated twice (once with and once without checklist access) in each of four EDs—of which two belong to an academic centre—and managed by resuscitation teams during their clinical shifts. A checklist for each crisis listing emergency interventions was derived from current authoritative sources. Checklists were displayed on a screen visible to all team members. Crisis and checklist access were allocated according to permuted block randomisation. No team member managed the same crisis more than once. The primary outcome measure was the percentage of indicated emergency interventions performed.

Results A total of 138 participants composing 41 resuscitation teams performed 76 simulations (38 with and 38 without checklist access) including 631 interventions. Median percentage of interventions performed was 38.8% (95% CI 35% to 46%) without checklist access and 85.7% (95% CI 80% to 88%) with checklist access ($p=7.5\times10^{-8}$). The benefit of checklist access was similar in the four EDs and independent of senior physician and senior nurse experience, type of crisis and use of usual cognitive aids. On a Likert scale of 1–6, most participants agreed (gave a score of 5 or 6) with the statement 'I would use the checklist if I got a similar case in reality'.

Conclusion In this multi-institution study, checklists markedly improved local resuscitation teams' management of medical crises simulated in situ, and most personnel reported that they would use the checklists if they had a similar case in reality.

INTRODUCTION

Roughly 15% of patients presenting to the emergency department (ED) require immediate or urgent interventions to decrease morbidity and mortality.[1 2] Anaphylaxis is an example of a medical crisis where fatal outcomes are associated with delayed treatment with epinephrine.[3 4] A minority of medical crises do not respond to first-line treatment, and more complex therapies are required. For example, 0.4% of patients with anaphylaxis are refractory to intramuscular epinephrine, and these cases are associated with a mortality of 26%.[5] Managing such medical crises is challenging given their high acuity, low frequency and increased complexity.

Checklists are cognitive aids that outline assessments or actions and that are designed to be carried out systematically. Cognitive aids such as checklists may help teams manage unusually severe medical crises by palliating for the unfamiliarity and stressful nature of the situation.[6–8] Given the low-frequency and high-acuity nature of crises, simulation-based trials have been used to study the impact of checklists on crisis management. One study reported that access to surgical crisis checklists decreased the rate of missed life-saving processes of care in the operating theatre from 23% to 6%.[9] Another study reported that access to checklists for emergency procedures improved the completion of critical treatment steps in the intensive care unit.[10] The aim of this randomised controlled simulation-based trial was to evaluate the impact of checklists on the management of medical crises by local resuscitation teams during their clinical shifts using simulations carried out in the ED.

METHODS

Crises

Eight crises were selected for the study: anaphylactic shock, life-threatening asthma exacerbation, haemorrhagic shock from upper gastrointestinal bleeding, septic shock, calcium channel blocker poisoning, tricyclic antidepressant poisoning, status epilepticus and increased intracranial pressure. Each of these potentially fatal conditions is an emergency in which patients can fail to respond to initial measures and for which there are established non-first-line therapies.

Checklists

A checklist was developed for each crisis through an iterative process involving specialists and residents in emergency medicine and senior nurses working in the ED. Checklist format and design was informed by the literature pertaining to emergency and abnormal checklists in the aviation industry[11–13] and by articles on medical checklists.[8 14 15] Each checklist outlined interventions to consider during the management of the crisis, based on current authoritative sources and consensus from four specialists in emergency medicine. Each intervention was associated with a popover window displaying indications, contraindications and risks, and for each medication, the medication name(s), location, dose, route and rate of administration. The checklists were customised to display the commonly used names and the locations of medications for each ED where the study was carried out (figure 1; online supplemental appendix 1 Sections I–II). The checklists were not disseminated in the EDs prior to the study.

Scenarios

Scenarios were developed for each of the eight medical crises based on actual cases that had presented to one of the EDs. The nature of the medical crisis was readily apparent from the scenario introduction read out prior to each simulation and the clinical findings provided during the primary survey. For example, teams were informed that the patient had vomited a mixture of fresh blood and coffee grounds throughout the night prior to the upper gastrointestinal haemorrhage scenario (online supplemental appendix 1 Section III).

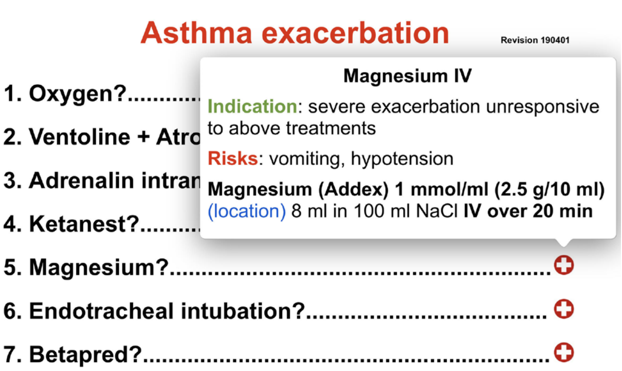

Figure 1 Sample checklist and popover window.

For each scenario, 7–10 emergency interventions were identified as indicated (online supplemental appendix 1 Section III).

Study sites

Sample size calculations based on results from a pilot study[16] indicated that performing each scenario twice (with and without checklist access) in three EDs would be sufficient to detect a clinically meaningful difference of 20% in performed emergency interventions with a power of 0.80 and a type I error probability of 0.05 (online supplemental appendix 1 Section IV). Since the feasibility of performing simulations in situ in busy resuscitation rooms was unclear, we aimed to perform the study in four EDs. These EDs cater primarily to adult patients, with a yearly number of patient visits of 85 000, 80 000, 65 000 and 35 000. Two of these EDs belong to an academic centre (a tertiary care university hospital), one to a large community hospital and one to a rural community hospital.

Study participants

Study participants consisted of the medical personnel on clinical duty composing a resuscitation team assigned to manage priority 1 patients. In two of the EDs, an additional resuscitation team was scheduled to work during the mornings of the study week to ensure that both teams could partake in the simulations without having to manage actual priority 1 patients. Study participants were not informed in advance of the nature of the scenarios.

Allocation to scenario and checklist access

The sequence according to which the eight scenarios were carried out at each ED was predetermined through permuted block randomisation. Whether the first simulation in each ED was run with checklist access (+) or without (−) was alternated between EDs. Checklist access was alternated thereafter within each ED. For example, if the randomly generated scenario sequence was 53284617 and the first scenario was run with checklist access, the following sequence was generated: 5+, 5−, 3+, 3−, 2+, 2−, 8+, 8−, 4+, 4−, 6+, 6−, 1+, 1−, 7+, 7−. This sequence can be thought of as a stack of 16 cards, with the top card representing scenario 5 with checklist access and the bottom card scenario 7 without checklist access.

For a given team, the allocated scenario was the highest card in the stack representing a scenario that none of the team members had performed previously. This feature ensured that no participant performed the same scenario more than once. Once a team had successfully carried out a whole simulation, the corresponding card was discarded. When a given team could perform a second simulation, the allocated scenario was the highest card in the stack representing a scenario that none of the team members had performed previously and with a different checklist access than during the first simulation. This feature ensured that teams that could perform two scenarios performed one with and one without checklist access. If the team had to interrupt the scenario prior to its completion, the card was left in the stack at its original position, until a team consisting of different personnel could perform the scenario, and the incomplete simulation was excluded from the study.

Simulations

All simulations were run between 08:00 and 11:00 when the lead nurse and physician in the ED deemed that the timing was suitable. The lead nurse and physician in the ED had the mandate to interrupt the study at any time to ensure patient safety in the ED. The resuscitation team was gathered in the resuscitation room, team members were enrolled in the study and signed an informed consent form, and scenario and checklist access was determined as described above. Personnel were instructed to locate actual equipment and medications during the simulations in order to receive training equipment and clearly marked placebo medications, and instructed to treat the manikin as they would a real patient. All teams were informed that the diagnosis would be readily apparent from the scenario introduction and that the simulations would focus on treatment (online supplemental appendix 1 Section IV). Personnel were explicitly allowed to use their usual cognitive aids (eg, pocketbooks, internet) but not allowed to request help from other personnel during the simulation.

Simulations were performed using an adult manikin (Laerdal Extri Kelly) that could quickly be wheeled out of the resuscitation room if necessary. Computer-generated vital signs were displayed on the screen used during actual clinical practice or on a screen of similar size placed in a similar location. All simulations were video recorded using two cameras. Simulations were terminated when all indicated emergency interventions had been performed, when the team expressed that they could not think of any other intervention to perform or when 15 min has elapsed, whichever came first.

Each scenario was simulated at least twice, once with and once without checklist access, in each of the four EDs. Each team performed two separate scenarios, one with and one without checklist access, unless precluded by actual emergencies. Simulations that had to be interrupted were repeated with a team consisting of other personnel. No personnel participated in a given scenario more than once. In one ED, all 16 scenarios were performed over the course of 3 weeks. In the other three EDs, all scenarios were performed during five consecutive weekdays, with a target of four simulations per day and the possibility of performing additional simulations on the fifth day.

Checklist display

The checklists were stored on a tablet computer. The tablet computer was connected to a screen large enough to be seen by all team members during the simulation (online supplemental figure 1). Two of the four resuscitation rooms were equipped with large wall-mounted screens that are routinely used to display information to the whole team, and the checklists were displayed on these screens. In the other two resuscitation rooms, the checklists were displayed on a large television mounted on a trolley. When teams were allocated to checklist access, a demonstration checklist was presented to the team prior to simulation, and the nurse or medical secretary assigned the task of managing the checklist familiarised himself or herself with the popover window function. The investigator running the simulation selected the relevant checklist once the simulation had begun. The investigator was not allowed to encourage personnel to use the checklist during the simulation. Personnel who had run a simulation with checklist access were subsequently asked to fill out a survey evaluating the checklist.

Statistical analysis

Video recordings of all scenarios were independently reviewed by two emergency physicians. In addition, a random sample of two scenarios with, and two without, checklist access from each site was reviewed by an outside emergency physician unaware of the study hypothesis. Reviewers independently recorded whether the predefined indicated emergency interventions were performed on the manikin (as opposed to just ordered) using a yes/no coding, and when these interventions were performed. The primary outcome measure was the percentage of interventions carried out by the team within 15 min from simulation start. The order according to which interventions were performed did not impact on the primary outcome measure. In our primary analysis we used bootstrapping to determine how the median percentage of interventions performed varied between teams that did, or did not, use checklists.[17] In a secondary analysis using a mixed-effects ordinal logistic regression model,[18] we assessed how the number of interventions performed varied among teams that did, and did not, use checklists. This model included random intercepts for EDs, and teams nested within EDs, in order to determine whether the effect of checklist access on number of interventions performed varied between teams or between EDs. The importance of these random effects was assessed by the magnitude of their SEs when the model's likelihood function was maximised and by a likelihood ratio test. Using similar models, we separately regressed the number of interventions against senior physician's experience, whether the senior physician was a specialist, senior nurse's experience and scenario type. To explore whether these variables and the use of local cognitive aids acted as effect modifiers, we also ran models that included checklist access, the variable of interest and the interaction between checklist access and the variable of interest.

Table 1 Professional characteristics of the participants

Profession	Participants (n=138)	Years of experience in profession					
		<1	1–4	5–9	10–14	≥15	Unknown
Physician*	31	2	15	9	3	2	0
Nurse	54	0	21	10	9	14	0
Nursing assistant	37	0	1	5	5	25	1
Medical secretary	16	0	0	3	0	12	1

*Five of the physicians were specialists (three specialists in emergency medicine, one double specialist in emergency medicine and surgery and one specialist in internal medicine with concurrent residency in emergency medicine). Twenty-one of the physicians were residents in emergency medicine. Four of the physicians were residents in another programme and one physician was an intern. Of the 25 residents, 5 were first year; 5 were second year; 2 were third year; 4 were fourth year; and 9 were fifth year. In Sweden, physicians carry out an 18 monthlong internship after graduating from medical school, followed by 5 years of residency.

For example, for the specialist status of the senior physician, we regressed number of interventions against checklist access, specialist status and an interaction term obtained from the product of the checklist indicator and the specialist status indicator.

Cohen's kappa was used to assess agreement between the two physicians who reviewed each of the simulations. After resolution of discrepancies, Cohen's kappa was used to assess agreement with the outside reviewer. All reported p values are two sided. Data were analysed with Stata Release V.16 (College Station, Texas: StataCorp). The data from this study are provided open source, and the codes that analysed the data and created the figures are provided in online supplemental appendix 2.

RESULTS

Characteristics of the participants

A total of 31 physicians, 54 nurses, 37 nursing assistants and 16 medical secretaries composing 41 resuscitation teams participated in the study; 25 of the 31 physicians were residents (table 1). In two EDs, the standard team consisted of one physician, one nurse, one nursing assistant and one medical secretary (18 teams), but in two teams a nurse replaced the nursing assistant. In the other two EDs, the standard team consisted of one physician, two nurses and one nursing assistant (13 teams); three teams included an additional physician, three teams an additional nursing assistant, one team an additional nurse and in one team a nurse replaced the nursing assistant (online supplemental table 5). Of the 138 participants, 114 participated in one or two scenarios, 19 in three or four scenarios and 5 in five or six scenarios (online supplemental table 6).

Simulations performed and use of cognitive aids

All eight scenarios were performed twice (once with and once without checklist access) in each of the four EDs. In each of the three EDs, it was possible to perform an additional four simulations, resulting in a total of 76 simulations including a total of 631 indicated emergency interventions. Thirty-five of the 41 teams performed two simulations, one with and one without checklist access. Six teams performed only one simulation (three with and three without checklist access). The three teams that only performed one scenario with checklist access did not differ significantly from the three teams that only performed one scenario without checklist access in regard to team size, physician and senior nurse age and experience. One simulation (upper gastrointestinal bleeding without checklist access) had to be interrupted due to an actual emergency; the scenario was subsequently rerun with another team. Scenarios were terminated because all interventions had been performed in 14 simulations with checklist access and none without; because of no further ideas in 4 simulations with checklist access and 12 without; because 15 min had elapsed in 20 scenarios with checklist access and 26 without (online supplemental table 8). There was no significant difference between the simulation durations with or without checklist access (p=0.12) (online supplemental table 9). In all but 3 of the 76 simulations, physicians had ordered diagnostic-specific first-line interventions, and when simulations were terminated at 15 min, teams were dealing with non-first-line interventions. Usual cognitive aids were used to guide treatment during 26 simulations without checklist access and in six simulations with checklist access (online supplemental table 11). In all 38 simulations without checklist access, the physician provided proof of diagnostic awareness by either stating the diagnosis or ordering diagnosis-specific interventions (online supplemental table 16).

Impact of checklist access

The median percentage of interventions performed was 38.8% (95% CI 33% to 44%) without checklist access and 85.7% (95% CI 80% to 88%) with checklist access ($p=7.5\times10^{-8}$). There was a marked difference in the distribution of interventions performed by teams with and without checklist access (figure 2 and online supplemental table 12). The number of interventions performed was unaffected by ED, team, senior physician experience, whether she/he was a specialist and senior nurse experience (online supplemental table 13). There was no evidence that any of these variables acted as effect modifiers to the relationship between checklist access and number of

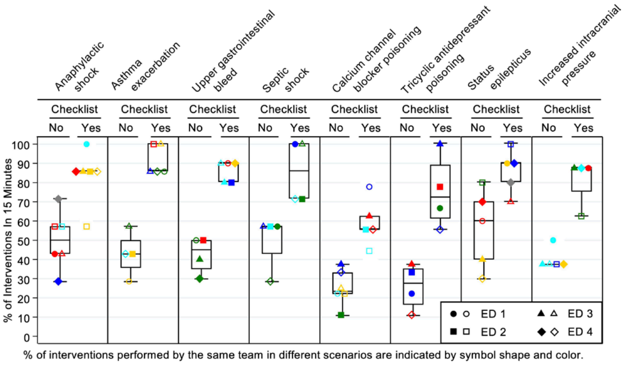

Figure 2 Percentages of performed indicated emergency interventions. ED, emergency department.

interventions performed (online supplemental table 14). Nor was there any evidence that scenario type (p=0.27) or use of cognitive aids (p=0.72) modified the impact of checklist access on number of interventions performed (online supplemental table 14).

Figure 3 shows the effect of checklists on median percentage of interventions performed as a function of time. Checklist access did not impede the performance of initial interventions. Table 2 provides examples of how checklist access impacted on the performance of specific interventions. Dangerous or inappropriate interventions occurred in 15 instances, of which 14 were during simulations performed without checklist access (online supplemental table 15).

Inter-rater agreement

Each simulation was independently reviewed by two investigators. The inter-rater agreement with respect to emergency interventions performed was high (kappa=0.92, 95% CI 0.89 to 0.95). Initial disagreement was easily resolved given that the interventions were hard endpoints. For the 16 simulations randomly selected for review by an outside physician, the inter-rater reliability with respect to interventions performed was also high (kappa=0.89, 95% CI 0.81 to 0.97).

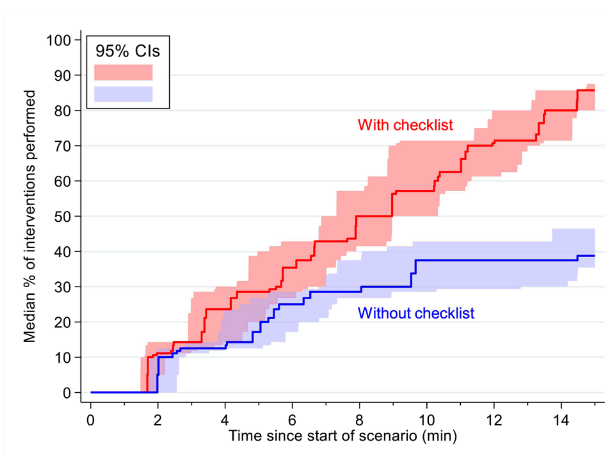

Figure 3 Median percentage of emergency interventions performed by teams with and without checklist access throughout the simulation.

Survey responses

On a Likert scale of 1–6, 94% of all participants agreed (ie, gave a score of 5 or 6) with the statement 'I would use the checklists if I got a similar case in reality'. Profession and scenario had no substantial effect on the responses to the survey (online supplemental tables 18–20).

DISCUSSION

This study found that checklist access was associated with an increase from 39% to 86% in the median percentage of indicated emergency interventions performed by teams managing simulated medical crises. There was no evidence that checklist use delayed the initial performance of emergency measures. Most participants indicated that they would use the checklist if they had a similar case in reality.

It may seem tautological to randomise teams to checklist access and evaluate performance based on completion of items featuring on the checklist. Yet, given that crises are by nature rare, unexpected, high-stakes events, it is logistically and ethically problematic to evaluate, in a clinical study, an intervention designed to facilitate the provision of currently recommended emergency interventions using as outcome measures morbidity and mortality. Simulation is specifically advantageous as research modality for studying rare events where experimentation may not be appropriate for ethical reasons, and for evaluating interventions that seek to improve care.[19] In this simulation-based study, the outcome measure was the performance of indicated emergency interventions based on current authoritative sources. The study results could have suggested that checklist access does not impact on emergency intervention performance, either because the checklists are unnecessary or because they do not adequately address the actual challenges of medical crisis management. Instead, the study results suggest that carefully designed, up-to-date, customised team checklists may promote the delivery of indicated emergency interventions during an actual medical crisis in the ED.

Two studies performed in simulated environments have reported a benefit of crisis checklists: one found that access to 10 surgical crisis checklists increased the rate of life-saving processes performed in the operating theatre from 77% to 94%,[9] while another reported that access to checklists for emergency procedures increased the median number of key items performed from 7 to 9.[10] The current study found a more dramatic effect of checklist access on performance, presumably due to the complexity of the second-line and third-line therapies for the selected crises.

In comparison to these previous studies, the current study evaluated checklists through simulations carried out by actual resuscitation teams, during their clinical shifts, in their own resuscitation rooms, with access to their usual cognitive aids and having to locate their

Table 2 Impact of checklist access on specific interventions

Scenario	Intervention	Performed number/total number Checklist access: No	Performed number/total number Checklist access: Yes
1. A patient taking a beta blocker presents in anaphylactic shock that fails to respond to epinephrine intramuscular; and then to epinephrine intravenous.	Epinephrine 50 µg intravenous	0/6	5/6
	Glucagon 1 mg intravenous	2/6	5/6
2. A patient presents with life-threatening asthma exacerbation and 'silent chest' that fails to respond to inhalation therapy; and then to intramuscular or subcutaneous adrenergic therapy.	Epinephrine 0.5 mg intravenous or subcutaneous or corresponding	2/4	5/5
	Magnesium 2 g intravenous	0/4	4/5
3. A patient with liver cirrhosis taking aspirin presents with haemorrhagic shock due to upper gastrointestinal bleeding.	Desmopressin 15 µg intravenous	0/4	5/5
	Terlipressin 2 mg intravenous	0/4	5/5
4. A patient presents with toxic shock syndrome due to an abscess.	Clindamycin 600 mg intravenous	0/4	3/4
	Ordering imaging or surgical consult	0/4	2/4
5. A patient presents with severe hypotension and bradycardia secondary to a calcium channel blocker overdose.	Calcium gluconate 10% 30 mL intravenous (or corresponding)	3/6	5/5
	High-dose insulin-glucose bolus	0/6	3/5
6. A patient presents with severe hypotension secondary to tricyclic antidepressant poisoning, and develops ventricular tachycardia.	Sodium bicarbonate 120 mEq intravenous	2/4	3/4
	Magnesium 2.5 g intravenous	2/4	4/4
7. A patient presents with status epilepticus due to acute hyponatraemia and fails to respond to benzodiazepine therapy.	3% Sodium chloride 150 mL intravenous	2/5	5/5
	Levetiracetam 60 mg/kg intravenous or corresponding	1/5	3/5
8. A patient presents with sudden onset of unresponsiveness and a unilateral dilated pupil unresponsive to light.	Raising the head of the bed by 30°	0/5	4/4
	3% Sodium chloride 270 mL intravenous or corresponding hyperosmolar therapy	0/5	3/4

own equipment and medications. Healthcare delivery is dependent on the attributes of healthcare personnel, the tools and technology at their disposal, the physical and organisational environment they work in and interactions between these factors.[20] The results of in situ studies may better approximate the effectiveness of a new tool than those obtained in simulated environments with volunteers deprived of their usual cognitive aids.

The study results may be less generalisable to EDs with different resuscitation team member characteristics, tools and support at their disposal. In the present study, the majority of physicians were residents, and resuscitation teams were not allowed to call other personnel for assistance. The benefit of checklist access may be diminished if the physicians were specialists, yet no association was found between physician experience and team performance in this study. Given that medical crises seldom occur, it is plausible that specialists would also benefit from cognitive aids. Furthermore, stress affects the performance of even seasoned professionals.[21–24] Some recommend that critical event checklists be geared to the level of the most junior physician expected to practise independently.[15]

This study focused on the management of crises where the diagnosis was clear from the outset. In practice, establishing the most likely cause of the patient's symptoms is not always clear-cut. Yet, even when diagnostic uncertainty is present, acute management is based on presumptive diagnosis. The relevant checklist was provided directly to the team at the outset of the simulation, in order to avoid displaying the main menu featuring all eight study crises, given the possibility that some team members would perform additional simulations on a later day. The study therefore did not evaluate personnel's ability to navigate among a collection of checklists.

It may be hypothesised that teams with checklist access benefited from knowing the diagnosis from the start, while teams without checklist access suffered from diagnostic uncertainty. Yet the diagnosis was readily apparent from the scenario introduction provided, video recordings provide proof of diagnostic awareness in all 38 simulations without checklist access and potential delay in diagnostic awareness cannot account for underperformance of teams without checklist access (online supplemental appendix 1 Section VIII).

When faced with a medical crisis in the ED, personnel need to know the indications for potential interventions, be able to locate relevant equipment or medications and deliver specific therapies and feel authorised to do so. Failure at any of these steps results in the intervention not being carried out. Medical crises unresponsive to first-line therapies are especially challenging given that their management may require the administration of unfamiliar medications under time pressure, each with specific generic and commercial names, dosages, routes and rates of administration. Checklists augment memory and attention[25] and presumably improved team performance during simulated complex medical crises by compensating for the unfamiliarity and stressful nature of the situation.[6–8]

The quality of teamwork in emergency medicine and during resuscitation has been linked to patient safety,[26 27] and the crisis resource management paradigm emphasises the centrality of customised team-based tools when managing complex high-risk situations.[28] The checklists evaluated in this study were displayed to all team members on large screens, contributing to a shared awareness of the severity of the situation, promoting a joint involvement in patient management and implicitly endorsing the delivery of indicated interventions. Displaying the checklist to the whole team may have encouraged crosschecking, a practice which has been shown to improve performance.[29 30] Assigning the task of systematically implementing the checklist to a nurse, as is the case for the Time Out section of the WHO Surgical Safety Checklist,[31] or to a medical secretary, may also have contributed to effective checklist use.[32]

It is unrealistic to expect healthcare personnel to keep up to date with non-first-line therapies for all potential medical crises that may present to an ED, where the medications are located, their generic and commercial names, their dosages and modes of administration. Cognitive aids such as pocketbooks and resources accessible through the internet may palliate for knowledge gaps, but they are not necessarily up to date and they may cause confusion when they recommend medications that are not available or are referred to by a different name. They often lack practical information such as where to find the medication, whether it needs to be diluted and its administration rate. Two-thirds of teams without checklist access used their usual cognitive aids, but this use did not significantly mitigate the benefit of checklist access. There is currently no standard framework for the development and design of medical checklists,[14 15] nor any requirements for their availability and use. Customised team checklists such as those used in this study may provide an updatable platform to translate best practices for patient care during acute events.[6]

This study suggests that carefully designed, customised checklists visible to the whole resuscitation team may significantly improve the management of complex medical crises. An interview-based study of emergency manual use during perioperative crises reported positive impacts on patient care delivery and teamwork, and no impediments.[33] Integrating checklist use in clinical practice is contingent on an implementation process that addresses why, how, when and by whom the checklist is intended to be used, and routines to update and improve the checklists.[15 31] Future research evaluating, during actual clinical practice, a large collection of checklists addressing the most common diagnostic and treatment processes encountered in the resuscitation room is warranted.

Figure 1 displays the checklist for asthma exacerbation. The backbone features seven interventions. Each intervention is associated with a popover icon (a white plus sign within a red dot); pushing on the popover icon brings forth a popover window. The illustration shows the content of the popover window for the intervention '5. Magnesium?'. The seventh intervention (Betapred) was not considered an emergency intervention within the context of the study (online supplemental appendix 1 Emergency Intervention Criteria).

These combined scatter and boxplots illustrate the percentages of indicated emergency interventions performed within 15 min for all 76 simulations, according to scenario and checklist access. Each team is represented by a unique colour and symbol combination. The symbol shape represents the ED where the simulation was performed. For example, round symbols denote teams from ED 1. The solid red circles in the anaphylactic shock scenario and the increased intracranial pressure scenario give results obtained by the same team performing without, and with, checklists, respectively. Thirty-five teams performed two simulations each, one with and one without checklist access; six teams performed only one simulation. The figure illustrates the profound effect of the checklist for each scenario. There is no obvious difference between the performance of the different EDs or different teams. Boxplots drawn behind the scatterplots give the 25th, 50th and 75th percentiles of the per cent of indicated interventions performed for each scenario, with and without checklists.

This figure illustrates the median percentage of indicated emergency interventions performed by teams that did, and did not, use the checklist as a function of time since the start of each scenario; 95% CIs for these percentages were derived from 2000 bootstrapped samples.[17] The sampling unit for these bootstrapped samples was the team. Since our study design required equal number of teams that used and did not use the checklists, these bootstrapped samples were stratified by checklist usage. Percentil-based confidence bands are displayed in this graph. Checklist access did not impede the initial performance of emergency interventions. After 7 min, checklist teams were performing significantly more interventions than non-checklist teams. As of 10 min into the simulation, virtually no additional interventions were performed in the no-checklist teams while additional interventions were performed throughout the final 5 min by teams with checklist access. This suggests that a longer simulation duration would, if anything, have resulted in an increased impact of checklist access on performance.

This table provides, for each of the eight scenarios, the number of times two emergency interventions were performed given access or not to crisis checklists, along with the total number of times the scenarios were performed.

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Contributors ED is a specialist and educator in emergency medicine. He contributed to the conception of the study, the acquisition, analysis and interpretation of data, drafting and revising the manuscript and approving the current version submitted for publication. JLF and CHS are specialists in emergency medicine and contributed to the acquisition of data, revising the manuscript and approving the current version submitted for publication. WDD is a Professor of Biostatistics and Preventive Medicine and contributed to the analysis and interpretation of data, revising the manuscript and approving the current version submitted for publication. AB is a Professor of Practical Medical Education and contributed to the conception of the study, the interpretation of data, revising the manuscript and approving the current version submitted for publication. UE is a Professor of Emergency Medicine and Associate Professor of Physiology. He contributed to the conception of the study, the analysis and interpretation of data, revising the manuscript and approving the current version submitted for publication.

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Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. All data relevant to the study are included in the article or uploaded as supplementary information. The data collected for this study and the programs that analysed these data are publicly available. The data for this study are posted at https://www.dropbox.com/sh/u1xfkz2s7fyjxsc/AAD3l3ZL1mHqoeRkNDkTCKr0a?dl=0 in an Excel spreadsheet named Checklists_ED_interventions.xlsx. It is freely available to anyone. To make a copy of this file, go to this URL, pull down the Open box next to Checklists_ED_interventions.xlsx and select 'Open in Excel'.

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Medical-Crisis Checklists in the Emergency Department: A Simulation-Based Multi-Institutional Randomized Controlled Trial Appendix 1

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I. Checklist Design & Content

A variety of sources, including literature pertaining to Emergency and Abnormal Checklists in the aviation industry, were used to guide the design and content of the checklists assessed in the current study.[1-7] The checklists were developed through an iterative process involving specialists and residents in Emergency Medicine and senior nurses working in the emergency department (ED).

Display

The checklists were designed to be displayed on a wide screen and be visible to all team members involved in the management of a critical patient in the resuscitation room.

Interface

The checklists were stored on a tablet computer connected to the wide screen.

Layout

The backbone of each checklist consisted of a numbered list of potentially indicated interventions. The text of the backbone was limited to medical names (e.g. "Atropine?") and actions (e.g. "Endotracheal intubation?") to enhance readability.

Symbology

When a question mark featured after the intervention, it indicated that the intervention had specific indications and contraindications. When no question mark was present, it indicated that the intervention was indicated for all patients with the given diagnosis.

Each intervention displayed on the checklist was followed by a popover icon (a white plus sign within a red dot). This icon symbolized the presence of additional information.

Popover Windows

Pushing on the popover icon on the tablet computer's screen lead to the appearance of a popover window that covered only part of the checklist backbone. The popover window included specific information regarding the intervention, namely:

- indication(s)
- contraindication(s) and/or risk(s)
- name(s) and concentration(s) of the medication
- location of the medication
- dose or volume
- preparation
- route and rate of administration

Typography

A sans sérif font (Arial) and minimal text size of 30 points were used to enhance legibility. The default colours were black on a white background. The colour green was used to highlight the word "Indications", the colour red to highlight the words "Contraindications", "Risks" and special aspects of intervention delivery prone to mistakes, and the colour blue was used to indicate the location of the medication.

Navigation

The backbone of the checklist for each medical crisis fitted on a single page. Popover windows were opened by pressing on the popover icon. The window was then closed by pressing on the screen outside the popover window. Within the context of the study, there

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was no need to navigate between different pages, with the exception of scenario 4 (severe sepsis) where pressing on the word Antibiotics brought forth a separate screen with antibiotic guidelines.

Content

Current authoritative sources were used to obtain a list of potentially indicated interventions for each of the eight medical crises selected for the study. UpToDate® was one of the primary sources. Other sources included guidelines from the European Resuscitation Council and recommendations from the Swedish Poisoning Control Center. Based on these sources, four specialists in Emergency Medicine who work clinically in three of the four study sites determined through consensus whether to include these interventions in the checklists, and in which order to list the interventions.

Local Adaptation

The medication names used in the checklists' backbones were those most commonly used in local clinical practice, regardless of whether the name was generic or brand. Additional names were provided in the popover window. All medications featuring in the eight checklists were reviewed with an experienced nurse and physician in each ED before carrying out the study there. The purpose of this review was to ensure that the medications were available locally, that the medication names featuring in the checklist backbone were those most commonly used, and to fill in the locations of the medications. The nurses and physicians involved in this review process did not participate in the simulations.

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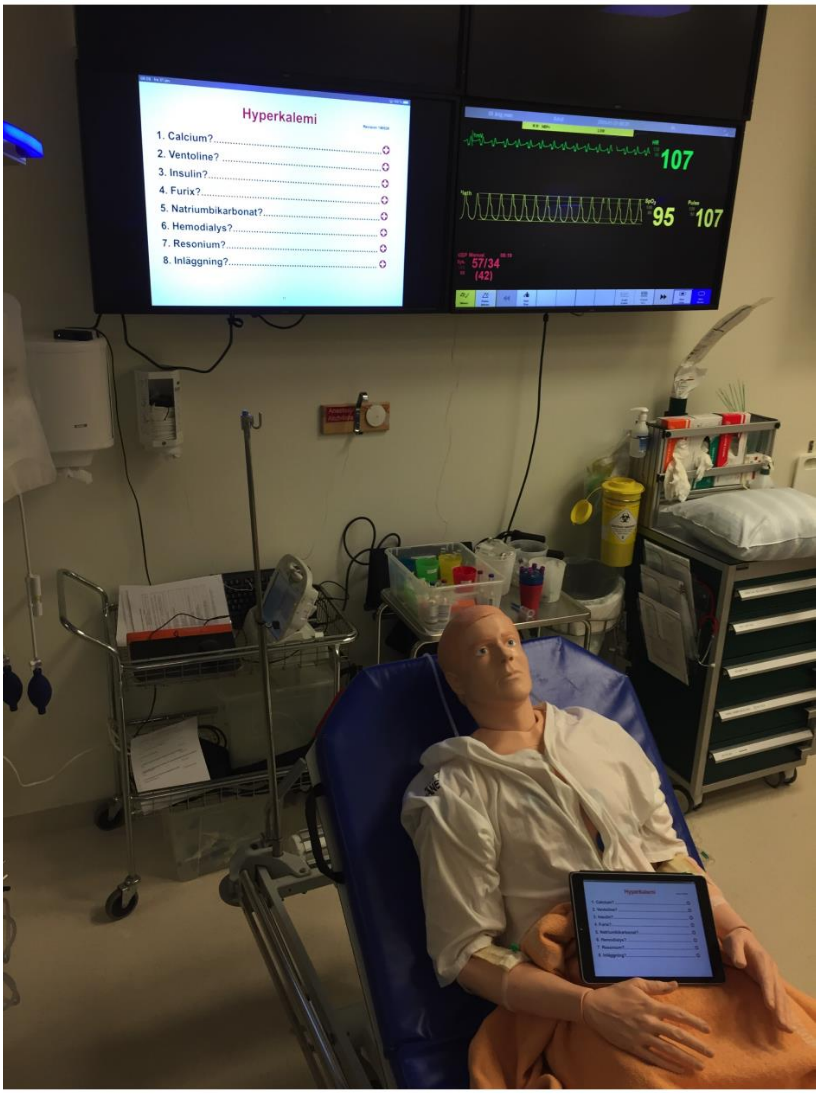
Appendix 1 Figure 1: Checklist Display



Appendix 1 Figure 1 legend: The checklists were stored on a tablet computer and displayed on large screen for all team members to see throughout the simulation. This picture was taken at one of the study sites. A demonstration checklist (hyperkalemia) is on display.

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II. Study Checklists

The following eight medical crises were selected for the study:

- Anaphylactic shock
- Life-threatening asthma exacerbation
- Hemorrhagic shock from upper gastrointestinal bleed
- Septic shock
- Poisoning from a calcium antagonist
- Poisoning from a tricyclic antidepressant
- Status epilepticus
- Increased intracranial pressure

The following sections provide:

- The backbones of each checklist; the medication names provided in the backbone are those commonly used in the ED where the study was conducted
- The content of the popover windows for each intervention
- The sources used to justify the content of the popover window; for some interventions, comments are provided

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1. Anaphylaxis

Appendix 1 Figure 2: Anaphylaxis Checklist

Anaphylaxis

Revision 190401

1. Adrenalin intramuscular..

2. Supine *or* lateral decubitus?.................................

3. Oxygen...

4. Ringer?...

5. Ventoline?...

6. Adrenalin intravenous?..

7. Glucagon intravenous?..

8. Tavegyl?...

9. Betapred...

2

1. Adrenalin intramuscular

Indication: all patients
Adrenalin 1 mg/ml (location) 0.5 ml
intramuscular anterolateral thigh
Can repeat every 5 min

Sources: [8,9]

2. Supine *or* lateral decubitus?

Indication: low blood pressure/feeling faint (prevents severe hypotension)
Contraindication: if the patient wants to remain upright due do shortness of breath
Supine
Lateral decubitus if nausea
Left lateral decubitus if advanced pregnancy

Sources: [8,9]

3. Oxygen

Indication: all patients
Oxygen ≥ 10 L/min via **mask with reservoir**

Sources: [8-10]

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4. Ringer?

Indication: low blood pressure
Ringer (location) 1000 ml **IV bolus**

Sources: [8 9]

5. Ventoline?

Indication: bronchospasm/ronchi
Risk: hypokalemia
Ventoline (Salbutamol, Airomir) (location)
2 mg/ml 2.5 ml (1 ampule) **nebulised**
(can be given with patient in lateral decubitus)

Sources: [8 9]

6. Adrenalin intravenous?

Indication: severe symptoms despite adrenalin IM
Risk: arrhythmia (EKG monitoring)
Take a 10 ml syringe
Draw up 1 ml of **Adrenalin 0.1 mg/ml** (location)
Dilute with 9 ml NaCl
Give 5 ml of the solution (50 microg) **IV over 1 min**
Repeat after 3 min as needed

Sources: [8 9]

7. Glucagon intravenous?

Indication: severe symptoms unresponsive to adrenalin (e.g. use of **beta-blocker**)
Risk: vomiting
Glucagon 1 mg/ml (location)
Inject the fluid into the vial and mixed with the powder
Draw up the solution using a **separate syringe**
Inject the solution (1 ml) **IV over 1 min**
Repeat as needed

Sources: [8 9 11 12]

8. Tavegyl?

Indication: itch/hives
Tavegyl (Klemastin) (location)
1 mg/ml 2 ml **IV**

Sources: [8 9]

9. Betapred

Indication: all patients
Betapred 4 mg/ml (location) 2 ml **IV**

Sources: [8 9]

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2. Asthma Exacerbation

Appendix 1 Figure 3: Asthma Exacerbation Checklist

Asthma exacerbation

Revision 190401

1. Oxygen?..
2. Ventoline + Atrovent?...
3. Adrenalin intramuscular?.......................................
4. Ketanest?...
5. Magnesium?..
6. Endotracheal intubation?..
7. Betapred?...

3

1. Oxygen?

Indication: SpO2 < 93%
Oxygen via nasal prongs *or* oxygen mask
or nebulizer mask with **target SpO2 94-98%**

Sources: [9 13]

2. Ventoline + Atrovent?

Indication: alla
Risk: hypokalemia
Ventoline (Salbutamol, Airomir) 2 mg/ml (location)
2,5 ml (1 ampull)
+ Atrovent (Ipratropium) 0,25 mg/ml (location)
2 ml (1 ampull) **nebulized**
Repeat immediately if no improvement

Sources: [9 13 14]

3. Adrenalin intramuscular?

Indication: severe exacerbation + can't inhale Ventoline
Adrenalin 1 mg/ml (location)
0.5 ml **intramuscular** anterolateral thigh

Sources: [9 13 14]

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Comment: recommending Adrenalin 0.5 mg IM as the default therapy for patients with acute severe asthma unable to use inhale bronchodilators can be justified according to the following arguments:
1-Asthma and anaphylaxis may be difficult to distinguish
2-Some patients with severe asthma may be dehydrated, and hence IM or IV is preferable as the default administration modality than SC
3-It is likely that the team can administer Adrenalin 1 mg/ml 0.5 mg IM more rapidly and confidently than Terbutaline 0.25 mg SC or Salbutamol 0.25 mg IV, since it is a well-established first-line treatment for anaphylaxis

4. Ketanest?

Indication: severe exacerbation + severe agitation which impairs treatment
Has PVK: **Ketanest (Esketamin) 5 mg/ml** (location) 10 ml **IV over 2 min**
No PVK: **Ketanest (Esketamin) 25 mg/ml** (location) 3 ml IM in each anterolateral thigh (total 6 ml)

Sources: [13-16]

5. Magnesium?

Indication: severe exacerbation unresponsive to above treatments
Risks: vomiting, hypotension
Magnesium (Addex) 1 mmol/ml (2.5 g/10 ml) (location)
8 ml in 100 ml NaCl **IV over 20 min**

Sources: [9 13 14]

6. Endotracheal intubation?

One or several of the following indicate life-threatening exacerbation:

- **SpO2 < 92%** *or* **PaO2 < 8**
- **pCO2 > 5.5 arterial** *or* **> 6.5 venous** *or* **rising**
- **Diminished breath sounds** on lung auscultation
- **Hypotension** *or* **arrhythmia**
- **Altered level of consciousness**

Call anesthesia *or* Call a Code

Sources: [9 13]

7. Betapred?

Indication: exacerbation that does not respond promptly to Ventoline
Betapred 4 mg/ml (location) 2 ml **IV**

Sources: [9 13 14]

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3. Upper Gastrointestinal Bleeding

Appendix 1 Figure 4: Upper Gastrointestinal Bleed Checklist

Upper gastrointestinal bleed

Revision 190401

1. Ringer?
2. Blood tests
3. Prevent hypothermia
4. Blood transfusion?
5. Confidex - Konakion - Praxbind?
6. Desmopressin?
7. Terlipressin?
8. Antibiotics?
9. Nexium
10. Cyklokapron?
11. Calcium?

4

1. Ringer?

Indication: blodtryck < 90 mm Hg
Ringer (location) 500 ml **IV bolus**

Sources: [17,18]

2. Blood tests

Indication: alla
BBT + Thrombocytes + INR + aPTT + Type and Cross-Match
If severe bleeding: + Fibrinogen

Sources: [17,19]

Comment: the following are included in BBT (bedside blood test): pH, pO2, pCO2, Na, K, Cl, Ca, glucose, Creatinine, Hb, lactate

3. Prevent hypothermia

Indication: all
Remove wet clothes
Cover with blanket

Source: [19]

4. Blood transfusion?

Indication: blood pressure < 90 mm Hg *or* Hb < 70

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or Hb < 90 + [ongoing blood loss *or* ischemic heart disease]
0 negative blood (location) 1-2 SAG via Fluido

Source: [17]

Comment: Fluido is a device to warms fluids prior to intravenous administration

5. Confidex - Konakion - Praxbind?

Indication: severe bleeding in a patient taking Warfarin *or* NOAC
If Warfarin, Eliquis, Xarelto, Lixiana:
Ocplex *or* **Confidex** (location) 2000 E IV
If Warfarin: **Konakion** (location) 10 mg IV
If Pradaxa: **Praxbind** (location) 5 g IV over 5 min

Sources: [17 20 21]

Comment: Konakion is vitamin K1

6. Desmopressin?

Indication: severe bleeding in a patient taking Aspirin
Desmopressin (Octostim) 15 mikrog/ml (location)
1 ml (50 kg) - 2 ml (100 kg) diluted in 10 ml NaCl
IV over 10 min

Sources: [21 22]

7. Terlipressin?

Indication: liver cirrhosis + blood pressure < 100 mm Hg
Terlipressin (Glypressin) (location) 2 mg **IV**

Sources: [17 23 24]

8. Antibiotics?

Indication: liver cirrhosis + blood pressure < 100 mm Hg
Risk: allergy to antibiotic
Cefotaxim (location) 1 g **IV over 3 min**

Sources: [17 23]

9. Nexium

Indication: all
Nexium (Esomeprazol) (location) 80 mg **IV**

Sources: [17]

10. Cyklokapron?

Indication: severe bleeding
Cyklokapron (Tranexamic acid, Statraxen)
100 mg/ml (location) 10 ml **IV over 10 min**

Sources: [19 21 25 26]

Comment: there is broad consensus in the medical literature that Tranexamic acid is indicated in the setting of serious bleeding in general. There appear to be few risks associated with the medication in the absence of urogenital hemorrhage. One of the sources above suggests that Tranexamic acid has a synergic effect on hemostasis when given along with Desmopressin in the setting of bleeding in a patient taking ASA. In the specific setting of upper gastrointestinal bleeding, a Cochrane meta-analysis suggests decreased mortality associated with tranexamic acid, but the authors considered the studies to be insufficiently powered and

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of poor quality. Several on-going trials are investigating the issue. Notwithstanding, in the setting of hemorrhagic chock, a fairly strong case can be made based on available sources to justify giving Tranexamic acid.

11. Calcium?

Ionised calcium < 1.0: **Calcium Gluconate 10%** (location)
10 ml **IV over 5 min**
Blood transfusion in liver disease: **Calcium Gluconate 10%**
10 ml **IV over 5 min for each SAG**

Sources: [19 27]

4. Sepsis

Appendix 1 Figure 5: Sepsis Checklist

Sepsis

Revision 190401

1. Oxygen?...

2. Ringer?...

3. Adrenalin intravenous?.......................................

4. Cultures...

5. Foley catheter?...

6. Antibiotics...

7. Solu-Cortef?...

8. Targeted investigations?..

5

1. Oxygen?

SpO_2 ≤ 90%: Oxygen 10 L/min via oxygen mask
SpO_2 91-95%: Oxygen 3 L/min via nasal prongs

Sources: [28,29]

2. Ringer?

Indication: all
Ringer 500 ml (location) IV bolus
Repeat directly if remains hypotensive

Sources: [28,29]

3. Adrenalin intravenous?

Indication: SBT < 60 mm Hg
Risk: arrhythmia (monitor EKG)
Take a 10 ml syringe
Draw up 1 ml **Adrenalin 0.1 mg/ml** (location)
Dilute with 9 ml NaCl and mix
Give 2 ml (20 mikrog) **IV bolus**
Repeat after 3 min as needed

Sources: [29-31]

4. Cultures

Indication: all

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Blood cultures (aerobic + anaerobic) x 2
Urine culture + urine dipstick
Consider cultures from **suspected infectious foci** (wound, nasopharynx); rapid strep-A test, urine antigen?

Sources: [28 29]

5. Foley Catheter?

Indication: low blood pressure *or* elevated lactate
Foley for urine output (+ obtain urine for culture)

Source: [29]

6. Antibiotics

Indication: give even if urine cannot be obtained for culture
Risk: allergy to antibiotic
See table (press on "**Antibiotics**")

Sources: [28 29]

7. Solu-Cortef?

Indication: known adrenal insufficiency *or* chronic corticosteroid treatment
Solu-Cortef (Hydrocortisone) (location) 100 mg **IV bolus**

Sources: [28 29]

8. Targeted investigations?

Indication: suspected infectious focus where procedure is required
Abscess, empyema, obstructive pyelonephritis, bowel perforation: X-ray *or* ultrasound
Necrotising fasciitis: surgery- *or* orthopedic consult

Sources: [28 29]

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Antibiotics

Appendix 1 Figure 6: Antibiotics Checklist

FOCUS	ANTIBIOTICS
Lung	• **Bensylpenicillin** 3g IV + **Levofloxacin** 750 mg IV *or* PO • If severe underlying lung disease: **Piperacillin/Tazobactam** 4g IV + **Levofloxacin** 750 mg IV *or* PO • If severe pc-allergy: **Clindamycin** 600 mg IV + **Levofloxacin** 750 mg IV *eller* PO
Abdomen	• **Piperacillin/Tazobactam** 4g IV • If septic shock: **Meropenem** 1g IV + **Tobramycin (Nebcina)** 5 mg/kg IV • If severe pc-allergy: **Meropenem** 1g IV
Urinary Tract	• **Cefotaxim** 2g IV • If septic shock: **Meropenem** 1g IV + **Tobramycin (Nebcina)** 5 mg/kg IV • If severe pc-allergy: **Meropenem** 1g IV
Joint & Bone	• **Cefotaxim** 2g IV • If septic shock: **Cefotaxim** 2g IV + **Tobramycin (Nebcina)** 5 mg/kg IV • If severe pc-allergy: **Meropenem** 1g IV
Fascia & Toxic Shock	• **Meropenem** 1g IV + **Clindamycin (Dalacin)** 600 mg IV • If septic shock: **Meropenem** 1g IV + **Clindamycin (Dalacin)** 600 mg IV + **Tobramycin (Nebcina)** 5 mg/kg IV
Unknown	• If sepsis: **Piperacillin/Tazobaktam** 4g IV • If septic shock: **Meropenem** 1g IV + **Tobramycin (Nebcina)** 5 mg/kg IV • If severe pc-allergy: **Meropenem** 1g IV
Neutro-penic	• **Meropenem** 1g IV • If septic shock: **Meropenem** 1 g IV + **Tobramycin (Nebcina)** 5 mg/kg IV

10

Source: Adapted from Strama Nationell.
https://strama.se/behandlingsrekommendationer/app-strama-nationell/ cited 2019 June 1st
Comment: in the setting of toxic shock syndrome, the antibiotic regimen should include Clindamycin [29 32 33]

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5. Calcium Channel Blocker Poisoning

Appendix 1 Figure 7: Calcium Channel Blocker Poisoning Checklist

Calcium channel blocker poisoning

1. Ringer?...
2. Atropine?...
3. Calcium?..
4. Adrenalin intravenous?...
5. Glucose?..
6. Insulin?..
7. Glucagon intravenous?...
8. Intralipid?...
9. ECMO?..

6

1. Ringer?

Indication: low blood pressure
Ringer (location) 1000 ml **IV bolus**

Sources: [34-36]

2. Atropine?

Indication: bradycardia
Atropine 0.5 mg/ml (location) 2 ml (1 mg) **IV bolus**
Can repeat up to a max of 3 mg

Sources: [34 36]

3. Calcium?

Indication: low blood pressure
Calcium Gluconate 10% (location) 30 ml **IV over 5 min**

Sources: [9 34-36]

4. Adrenalin intravenous?

Indication: critical patient (severe hypotension *or* bradycardia)
Risk: arrhythmia (monitor EKG)
Take a 10 ml syringe
Draw up 1 ml **Adrenalin 0.1 mg/ml** (location)
Dilute with 9 ml NaCl and mix
Give 2 ml (20 mikrog) **IV bolus**

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Repeat after 3 min as needed

Sources: [34-36]

5. Glucose?

Indication: critical patient (severe hypotension *or* bradycardia); given along with **6. Insulin**
Glucose 300 mg/ml (30%) (location) 50 ml **IV bolus**

Sources: [9 34-36]

6. Insulin?

Indication: critical patient (severe hypotension *or* bradycardia); given along with **5. Glucose**
Risk: hypokalemia
Humalog *or* Actrapid *or* Novorapid (location) 1 E/kg **IV bolus** (70 E for a 70 kg patient)

Sources: [9 34-36]

7. Glucagon intravenous?

Indication: critical patient (severe hypotension *or* bradycardia)
Risk: vomiting
Glucagon 1 mg/ml (location)
Inject the fluid into the vial and mixed with the powder
Draw up the solution using a **separate syringe**
Give 5 ml IV bolus (i.e. 5 packs)

Sources: [9 34-36]

8. Intralipid?

Indication: cardiac arrest *or* critically low blood pressure
Intralipid 200 mg/ml (location) 100 ml **IV over 1 min**
Repeat every 5th minute x 2

Sources: [34 35]

9. ECMO?

Indication: cardiac arrest *or* critically low blood pressure
Extracorporeal membrane oxygenation (ECMO) - contact thoracics #####

Sources: [9 34-36]

Dryver E, *et al. BMJ Qual Saf* 2021;0:1–9. doi: 10.1136/bmjqs-2020-012740

6. Tricyclic Antidepressant Poisoning

Appendix 1 Figure 8: Tricyclic Antidepressant Poisoning Checklist

Tricyclic antidepressant poisoning

1. Ringer?..
2. Sodium bicarbonate?...
3. Sodium bicarbonate dose 2?................................
4. Magnesium?..
5. Adrenalin intravenous?......................................
6. Sodium chloride 3%?...
7. Sodium chloride 3% dose 2?...............................
8. Intralipid?...
9. ECMO?...

7

1. Ringer?

Indication: low blood pressure
Ringer (location) 500 ml IV bolus

Sources: [37 38]

Comment: Isotonic saline contains 154 mmol/L of Na. Ringer's acetate contains 130 mmol/L of Na. It is dubious that there is a significant clinical effect for isotonic saline over Ringer's acetate. The point of this therapy is to expand intravascular volume, while the point of NaHCO3 therapy is to increase the Na gradient and improve myocyte function. Ringer's acetate is chosen here since it is the most commonly used crystalloid in our emergency departments.

2. Sodium bicarbonate?

Indication: wide QRS complex *or* low blood pressure *or* ventricular tachycardia
Sodium bicarbonate 50 mg/ml (location) 200 ml **IV bolus**

Sources: [37-39].

3. Sodium bicarbonate dose 2?

Indication: remaining wide QRS complex *or* low blood pressure *or* ventricular tachycardia
Sodium bicarbonate 50 mg/ml (location) 200 ml **IV bolus**

Source: [37 39].

4. Magnesium?

Indication: ventricular tachycardia despite Sodium bicarbonate bolus x 2

Magnesium (Addex) 1 mmol/ml (2.5 g/10 ml) (location) 10 ml **IV over 2 min**

Sources: [37 38]

5. Adrenalin intravenous?

Indication: remaining low blood pressure despite Sodium bicarbonate bolus x 2 **Risk**: arrhythmia (monitor EKG) Take a 10 ml syringe Draw up 1 ml **Adrenalin 0.1 mg/ml** (location) Dilute with 9 ml NaCl and mix Give 2 ml (20 mikrog) **IV bolus** Repeat after 3 min as needed

Sources: [30 31 37 38]

6. Sodium chloride 3%?

Indication: remaining low blood pressure despite above treatment Fetch **Sodium chloride 9 mg/ml (isotonic NaCl)** (location) 100 ml Add **Addex-Sodium chloride 4 mmol/ml** (location) 10 ml Give the whole solution (110 ml) as **IV bolus**

Source: [37 39]

7. Sodium chloride 3% dose 2?

Indication: remaining low blood pressure 10 min after Sodium chloride 3% bolus Fetch **Sodium chloride 9 mg/ml (isotonic NaCl)** (location) 100 ml Add **Addex-Sodium chloride 4 mmol/ml** (location) 10 ml Give the whole solution (110 ml) as **IV bolus**

Source: [37 39]

8. Intralipid?

Indication: cardiac arrest *or* critically low blood pressure **Intralipid 200 mg/ml** (location) 100 ml **IV over 1 min** Repeat every 5th minute x 2

Source: [37 38]

9. ECMO?

Indication: cardiac arrest *or* critically low blood pressure **Extracorporeal membrane oxygenation (ECMO)** - contact thoracics #####

Source: [38 40]

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7. Seizure

Appendix 1 Figure 9: Seizure Checklist

Seizure

Revision 190401

1. Nasopharyngeal airway?..
2. Oxygen...
3. Bag-valve-mask ventilation?..................................
4. Ringer?..
5. Benzodiazepine?..
6. Glucose - Sodium - Calcium?.................................
7. Specific therapies?..
8. Benzodiazepine dose 2?...
9. Keppra?..
10. Deep sedation + endotracheal intubation?........

8

1. Nasopharyngeal airway?

Indication: obstructive airway sounds
Risk: high-energy facial trauma (skull base fracture)
Nasal pharyngeal airway

Sources: [41 42].

2. Oxygen

Indication: all
≥ 10 L/min via oxygen mask

Sources: [41 43]

3. Bag-valve-mask ventilation?

Indication: low respiratory rate (< 10/min), reduced chest excursions
Bag-valve-mask connected to oxygen 12 breaths/min

Sources: [41 44]

4. Ringer?

Indication: blood pressure < 120 mm Hg
Ringer (location) 500 ml **IV bolus**

Sources: [41 44 45]

5. Benzodiazepine?

Indication: ≥ 5 minutes of continuous *or* intermittent seizure

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Stesolid (Diazepam) (location) 10 mg **IV bolus**
or **Midazolam** (location) 10 mg **IM**

Sources: [41 46 47]

6. Glucose - Sodium - Calcium?

Hypoglycemia:
Glucose 300 mg/ml (30%) (location) 30 ml **IV bolus**

Hyponatremia:
Fetch **Sodium chloride 9 mg/ml (isotonic)** (location) 250 ml
Add **Addex-Sodium chloride 4 mmol/ml** 20 ml
Give the whole solution (270 ml) as **IV bolus**

Hypocalcemia:
Calcium gluconate 10% (location) 10 ml **IV over 5 min**

Source for hyponatremia: [48 49]

7. Specific therapies?

Meningoencephalitis:
Betapred (location) 10 mg + **Cefotaxim** (location) 3 g
+ **Doktacillin** (location) 3 g + **Acyclovir** (location) 10 mg/kg **IV**

Eclampsia:
Magnesium (Addex) 1 mmol/ml (2.5 g/10 ml) (location)
20 ml **IV over 5 min**

Intoxication *and* wide QRS-complex:
Sodium bicarbonate 50 mg/ml (location) 200 ml **IV bolus**

Comment: these situations and specific therapies were included for the sake of completeness but not relevant to the simulation used in the study.

8. Benzodiazepine dose 2?

Indication: continuous *or* intermittent seizure
despite Stesolid (Diazepam) *or* Lorazepam IV
Stesolid (Diazepam) (location) 10 mg **IV bolus**

Sources: [41 46 47].

9. Keppra?

Indication: ≥ 5 minutes of continuous *or* intermittent seizure
regardless of response to treatment with Stesolid (Diazepam) *or* Midazolam
Keppra (Levetiracetam, Matever) 100 mg/ml (location)
60 mg/kg (max 6000 mg) **IV over 10 min**

Sources: [41 46 47].

Comment: guidelines available throughout the study period recommended Levetiracetam, Fosphenytoin or Valproic acid as second line therapy for status epilepticus, and stated that there was no convincing evidence that one medication was superior to the others. Fosphenytoin has a number of cardiovascular side-effects which Levetiracetam lacks. All emergency departments involved in the study had access to Levetiracetam. To improve readability, the checklist featured only Levetiracetam as second line therapy.

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10. Deep sedation + endotracheal intubation?

Indication: continuous *or* intermittent seizures persist despite above therapy
Summon anaesthesia for deep sedation and endotracheal intubation

Source: [41]

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8. Increased Intracranial Pressure

Appendix 1 Figure 10: Increased Intracranial Pressure Checklist

Increased intracranial pressure

1. Oxygen?...
2. Elevate head...
3. Ventilation..
4. Sodium chloride 0.9%?...
5. Benzo + antiepileptic?..
6. Paracetamol?...
7. Sodium chloride 3%?..
8. Betapred?...
9. Endotracheal intubation?.....................................
10. Head CT..

9

1. Oxygen?

Indication: SpO2 < 95%
Oxygen 10 L/min via oxygen mask

Source: [50]

2. Elevate head

Indication: all
Elevate the head of the bed by 30° *or* **tip the gurney (reverse Trendelenburg)** in order to increase venous return from the brain

Sources: [50 51]

3. Ventilation

Indication: all
Follow endtidal pCO2 (EtCO2)
Ventilate with **bag-valve-mask** *or* **via endotracheal tube** as needed
Aim for **EtCO2 5 kPa**
If unconscious + fixed dilated pupil (imminent coning): aim for **EtCO2 3.5 kPa**

Sources: [50 52 53]

4. Sodium chloride 0.9%?

Indication: blood pressure < 110 mm Hg
Sodium chloride 9 mg/ml (isotonic) (location) 500 ml IV bolus

Sources: [50 53 54]

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5. Benzo + antiepileptic?

Indication: suspected seizure
Treat seizures aggressively since they increase brain metabolism
See checklist Seizure

Source: [50]

6. Paracetamol?

Indication: temperature > 37.7°C
Contraindication: allergy to paracetamol
Paracetamol 10 mg/ml (location) 100 ml IV *and/or* **physical measures**
Target normal body temperature

Sources: [50 52]

7. Sodium chloride 3%?

Indication: unconscious + fixed dilated pupil (**imminent coning**)
Fetch **Sodium chloride 9 mg/ml (isotonic)** (location) 250 ml
Add **Addex-Sodium chloride 4 mmol/ml** (location) 20 ml
Give the whole solution (270 ml) as **IV bolus**

Sources: [50 52 54-56]

8. Betapred?

Indication: known brain tumor *or* CNS-infection
Contraindication: traumatic brain injury, stroke
Betapred 4 mg/ml (location) 4 ml **IV**

Sources: [50 52 54]

9. Endotracheal intubation?

Indication: unconscious *or* severely reduced level of consciousness
Risk: drop in blood pressure impairs brain perfusion
Summon anaesthesia

Sources: [56]

10. Head CT

Indication: all
Head CT without contrast

Source: [54]

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III. Scenarios & Emergency Interventions
Eight scenarios, one for each of the medical crises, were written based on real patients that had presented to the Emergency Department of _____. Introductory material was provided to the teams according to the SBAR format (Situation Background Assessment Recommendation) [57]. Real EKGs and blood gas results were provided to the teams during the simulations. During the study, blood gas values were provided in kPa, creatinine values in μmol/L, glucose in mmol/L and lactate in mmol/L. Values in other units are provided below using the following conversions:

- pO2 in mm Hg = pO2 in kPa x 7.5
- pCO2 in mm Hg = pCO2 kPa x 7.5
- Creatinine in mg/dl = Creatinine in μmol/L : 88.89
- Glucose in mg/dl = Glucose in mmol/L x 18
- Lactate in mg/dl = Lactate in mmol/L x 9

Emergency Intervention Criteria
For each scenario, seven to ten emergency interventions were identified a priori based on time-to-effect of the intervention and risk for patient deterioration if the intervention is not performed during the 30-minute time-frame of the management in the resuscitation room of a critically ill patient not responding to initial therapy. Determining which interventions were emergency ones was based on the authoritative sources used to generate the checklists and consensus from the specialists in emergency medicine working in the Emergency Departments where the study took place.

While calling for help is to be encouraged in the setting of a medical crisis, the act of calling for help was not considered an emergency intervention in the context of this study, since calling for help per se does not benefit the patient–rather, it is the administration of a medication or the performance of a procedure that is clinically beneficial.

Not all interventions featuring in the checklists were emergency interventions. For example, the administration of corticosteroids for anaphylaxis and for asthma exacerbation were not considered emergency interventions, since the effect of corticosteroids takes several hours to develop. The checklists were designed to be generic for the condition, and not all interventions featuring in the checklist were indicated in the context of the scenario. For example, the checklist for upper gastrointestinal hemorrhage featured interventions to reverse anticoagulants, but in the scenario, the patient did not take anticoagulants.

The administration of alternative treatments to those featuring in the checklist was acceptable as long as the treatment was considered equivalent and the dose adequate. For example, the checklist for seizure features administering Levetiracetam. The administration of Valproic acid in a reasonable dose was considered equivalent. The checklist recommended adding 10 ml of NaCl 4 mmol/ml to 100 ml of 0.9% NaCl or 20 ml of NaCl 4 mmol/ml to 250 ml of 0.9% NaCl to yield a solution of roughly 3% NaCl. Adding 40 ml of NaCl 4 mmol/ml to 500 ml of 0.9% NaCl was considered equivalent.

Based on the references used to derive the checklists, the study investigators decided a priori that given a medication dose lower than the one recommended by the checklist was not considered sufficient for the measure to be considered to have been performed, unless repeated doses were administered and the summative dose reached or exceeded the dose recommended by the checklist. For example, the checklist for seizure recommended giving 10 mg of Diazepam IV as first line antiepileptic treatment. Administering 5 mg of Diazepam

IV was not considered sufficient, but administering a second dose of 5 mg of Diazepam IV subsequently was considered equivalent to administering 10 mg of Diazepam.

The study investigators decided a priori that administering up to twice the medication dose recommended by the checklist was considered acceptable, but that exceeding this amount was not. For example, the checklist recommended giving 50 micrograms of adrenalin intravenously over 1 minute to a patient with anaphylactic chock who has not responded to intramuscular adrenalin and a bolus of crystalloid fluid. Giving 100 micrograms of adrenalin intravenously was considered equivalent, but giving 300 micrograms directly was considered dangerous and not equivalent.

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1. Anaphylaxis

Manikin	**Running the Scenario**
• Reclining at a 45° angle • No oxygen mask • No PVC • Blanket covering the manikin	• If asked how he feels, the patient responds that he is "dizzy and nauseous." • The patient prefers to lie flat or sideways despite having trouble breathing. • Vital signs do not improve despite treatment

Introduction

S	A 50-year-old man has just presented to the emergency department after being stung by a wasp 5 minutes ago.
B	The patient has previously had a heart attack and is taking Aspirin and Metoprolol. He is also severely allergic to wasps.
A	The patient's arm was stung by a wasp 5 minutes ago outside the emergency department and the patient came here immediately.
R	"All yours" (remove the blanket)

Airway / C-spine

Head & Neck	No signs of trauma
Airway Sounds	**Wheezing on expiration**
Oral Cavity	**Swollen tongue**

Breathing

SpO2%	**90% on room air**
Respiratory Rate	**40 breaths/min**
Lung Auscultation	**Bilateral wheezing on expiration**

Circulation

Blood Pressure	**60/30 mm Hg**
Heart Rate	**140 beats/min**
Monitor EKG	Narrow QRS-complexes, regular rhythm

Disability

Consciousness	**Barely responds to voice, drowsy**
Eyes	Pupils 4 mm
Extremities	Moves all 4 extremities spontaneously

Exposure

Front	**Pale, clammy**
Back	**Pale, clammy**
Temperature	37.2°C

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Adjuncts

Blood Tests	Provided if requested
EKG	"EKG shows a sinus tachycardia"
Ultrasound	"No intrapleural or intraabdominal free fluid. Empty IVC"

Bedside Blood Tests

Blood Gas Values				
pH	7.28			
pCO_2	6.0	kPa	45	mm Hg
pO_2	4.03	kPa	30	mm Hg
Electrolyte Values				
Na^+	143	mmol/L		
K^+	4.8	mmol/L		
Creatinine	108	µmol/L	1.21	mg/dl
Ca^{2+}	1.23	mmol/L		
Cl^-	107	mmol/L		
Metabolite Values				
Glucose	8.8	mmol/L	158	mg/dl
Lactate	4.7	mmol/L	42.3	mg/dl
Oximetry Values				
Hb	137	g/L		
sO_2	70.6	%		
Other				
Base(Ecf)c	-5.1	mmol/L		
$HCO3^-$(P,st)c	20.3	mmol/L		

Emergency Interventions

1-Adrenalin 0.3 - 0.5 mg IM 2-Supine 3-Oxygen ≥ 10 L/min via reservoir mask 4-Crystalloid 1000 ml IV bolus	5-Salbutamol 5 mg nebulised 6-Adrenalin 50 microg IV 7-Glucagon 1 mg IV

Comments

- Antihistamine administration was not considered an emergency intervention, since it does not impact on hypoxia/hypotension.
- Corticosteroid administration was not considered an emergency intervention, since several hours are require before corticosteroids have an effect.

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2. Asthma Exacerbation

Manikin	Running the Scenario
• Reclining at a 45° angle • Nebuliser mask • Two PVCs • Blanket covering the manikin	• Saturation drops steadily during the scenario, from 93% initially to 85% at a rate of 1% drop/min. • Patient gets severely agitated 6 min into the scenario, takes off oxygen mask

Introduction

S	A 52-year-old man with shortness of breath will be arriving by ambulance in 1 minute.
B	The patient suffers from asthma and anxiety. He takes Oxis (Formoterol), Bricanyl (Terbutaline), Betapred as needed and Oxascand as needed.
A	He became short of breath 2 hours ago. He reports that it feels like the asthma attacks he has previously had, though worse this time. Ambulance personnel have been treating him for the last 15 minutes with 5 mg of Ventolin nebulized and have placed two PVCs.
R	"All yours" (remove the blanket)

Airway / C-spine

Head & Neck	No signs of trauma
Airway Sounds	**Wheezing on expiration**
Oral Cavity	Unremarkable

Breathing

SpO2%	**93% initially, drops 1%/min despite supplementary oxygen**
Respiratory Rate	**35 breaths/min**
Lung Auscultation	**Bilateral wheezing on expiration, rather silent breath sounds**

Circulation

Blood Pressure	**190/110 mm Hg**
Heart Rate	**130 beats/min**
Monitor EKG	Narrow QRS-complexes, regular rhythm

Disability

Consciousness	Awake and alert, looks anxious, having trouble talking **Becomes severely agitated at +6 min and removes mask** **Becomes docile if receives Ketamin / Ketanest**
Eyes	Pupils 4 mm
Extremities	Moves all 4 extremities spontaneously

Exposure

Front	**Pale, clammy**
Back	**Pale, clammy**
Temperature	37.1°C

Dryver E, *et al. BMJ Qual Saf* 2021;0:1–9. doi: 10.1136/bmjqs-2020-012740

Adjuncts

Blood Tests	Provided if requested
EKG	"EKG shows a sinus tachycardia"
Ultrasound	"Bilateral lung-sliding, no pleural fluid, no B-lines, normal right ventricle, normal IVC"

Bedside Blood Tests

Blood Gas Values				
pH	7.17			
pCO_2	9.34	kPa	70	mm Hg
pO_2	13.9	kPa	104	mm Hg
Electrolyte Values				
Na^+	141	mmol/L		
K^+	4.6	mmol/L		
Creatinine	82	µmol/L	0.92	mg/dl
Ca^{2+}	1.25	mmol/L		
Cl^-	106	mmol/L		
Metabolite Values				
Glucose	12.0	mmol/L	216	mg/dl
Lactate	2.5	mmol/L	22.5	mg/dl
Oximetry Values				
Hb	170	g/L		
sO_2	95.6	%		
Other				
Base(Ecf)c	-2.7	mmol/L		
$HCO3^-$(P,st)c	19.6	mmol/L		

Emergency Interventions

1-Oxygen 2-Ventoline 5 mg (dose #2) 3-Atrovent 0.5 mg (dose #1) 4-Adrenalin 0.5 mg IM	5-Ketanest 5 mg/ml 10 ml IV over 2 min 6-Magnesium 8 mmol IV over 20 min 7-Summon anesthesia for endotracheal intubation

Comments

- Intervention 4: alternatives to Adrenalin 0.5 mg IM considered to be equivalent:
  - Terbutaline (Bricanyl) 0.25 mg SC
  - Terbutaline (Bricanyl) 0.25 mg IV
  - Salbutamol 0.25 mg IV
- Intervention 5: alternative to Ketanest 5 mg/ml 10 ml IV considered to be equivalent:
  - Ketamine 10 mg/ml 10 ml IV
  - Ketanest 25 m/ml 6 ml IM
  - Ketamine 50 mg/ml 6 ml IM
- Corticosteroid administration was not considered an emergency intervention, since several hours are require before corticosteroids have an effect.

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3. Upper Gastrointestinal Bleeding

Manikin	Running the Scenario
• Supine • Oxygen mask • Two PVCs • Blanket covering the manikin	• The patient reports feeling faint • Blood pressure increases from 70/40 to 90/60 if the patient receives intravenous fluids (crystalloids or blood)

Introduction

S	A 67-year-old man is brought to the emergency room because of hematemesis.
B	The patient lives alone. He takes Aspirin because of a heart attack 10 years ago. He suffers from chronic alcohol abuse and has liver cirrhosis.
A	Throughout the night, he has vomited a mixture of fresh blood and coffee grounds. He was found by home care and the ambulance personnel have placed 2 PVCs.
R	"All yours" (remove the blanket, leave it at the foot of the bed)

Airway / C-spine

Head & Neck	No signs of trauma
Airway Sounds	Normal airway sounds
Oral Cavity	**Dried black coating on the tongue**

Breathing

SpO2%	97% while receiving 5 L/min oxygen via mask
Respiratory Rate	35 breaths/min
Lung Auscultation	Normal breath sounds

Circulation

Blood Pressure	**70/40 mm Hg**
Heart Rate	**130 beats/min**
Monitor EKG	Narrow QRS-complexes, regular rhythm

Disability

Consciousness	Alert
Eyes	Pupils 3 mm, **scleral icterus**
Extremities	Moves all 4 extremities spontaneously

Exposure

Front	**Pale, slightly yellow**, clammy, **swollen abdomen (suspected ascites),** no findings suggestive of peritonitis
Back	**Black foul-smelling faeces**
Temperature	36.0°C

Adjuncts

Blood Tests	Provided if requested
12-lead EKG	"EKG looks unchanged compared with previous EKG"
Ultrasound	No free fluid, empty IVC

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Bedside Blood Tests

Blood Gas Values				
pH	7.41			
pCO_2	4.79	kPa	36	mm Hg
pO_2	2.03	kPa	21	mm Hg
Electrolyte Values				
Na^+	143	mmol/L		
K^+	4.8	mmol/L		
Creatinine	118	µmol/L	1.33	mg/dl
Ca^{2+}	1.16	mmol/L		
Cl^-	109	mmol/L		
Metabolite Values				
Glucose	8.8	mmol/L	158	mg/dl
Lactate	7.7	mmol/L	69.3	mg/dl
Oximetry Values				
Hb	37	g/L		
sO_2	10.6	%		
Other				
Base(Ecf)c	-1.8	mmol/L		
$HCO3^-$(P,st)c	22.3	mmol/L		

Emergency Interventions

1-Ringer 500 ml IV bolus	6-Terlipressin 2 mg IV
2-Blood tests including Fibrinogen	7-Cefotaxim 1 g IV
3-Blanket	8-Nexium 80 mg IV
4-O negative blood x 2 units	9-Cyklokapron 1 g IV over 10 min
5-Octostim 15 mikrog/ml 1 ml over 10 min	10-Calcium gluconate 10% 10-20 ml IV

Comments

- Intervention 2: blood tests are included as an emergency intervention since blood typing should be carried out prior to blood transfusion with O negative blood

Dryver E, *et al. BMJ Qual Saf* 2021;0:1–9. doi: 10.1136/bmjqs-2020-012740

4. Sepsis

Manikin	**Running the Scenario**
• Supine • No mask or nasal prongs • Two PVCs • Blanket covering the manikin	• Vital signs remain unchanged despite treatment

Introduction

S	A 42-year-old woman with a fever will be arriving in the emergency room in 1 minute via ambulance.
B	The patient underwent a sectoral resection of the right breast six weeks ago because an unclear tumor was detected; the pathology showed no malignancy. She is otherwise healthy.
A	For the past three days, the patient has had high fever and dry cough. During the last day, she has developed increasing pain in the right axilla and abdomen. Today, she became confused, and her husband called for an ambulance.
R	"All yours" (remove the blanket)

Airway / C-spine

Head & Neck	No signs of trauma
Airway Sounds	Normal airway sounds
Oval Cavity	Unremarkable

Breathing

SpO2%	**92% on room air**
Respiratory Rate	**32 breaths/min**
Lung Auscultation	Normal breath sounds

Circulation

Blood Pressure	**55/30 mm Hg**
Heart Rate	**145 beats/min**
Monitor EKG	Narrow QRS-complexes, regular rhythm

Disability

Consciousness	Drowsy
Eyes	Pupils 3 mm, react to light
Extremities	Moves all 4 extremities spontaneously

Exposure

Front	**Salmon-colored / sunburn-like rash over the chest** **No petechiae. Right axilla: significantly warm, red, somewhat swollen**
Back	Normal skin
Temperature	40°C

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Adjuncts

Blood Tests	Provided if requested
EKG	"EKG shows a sinus tachycardia"
Ultrasound	"Hyperkinetic heart, no pericardial fluid, empty IVC. No intraabdominal free fluid, **suspected fluid collection in the chest wall of the right axilla.** No free fluid in the pleural space, no lung consolidation."

Bedside Blood Tests

Blood Gas Values				
pH	7.18			
pCO_2	5.44	kPa	41	mm Hg
pO_2	2.91	kPa	22	mm Hg
Electrolyte Values				
Na^+	135	mmol/L		
K^+	4.0	mmol/L		
Creatinine	564	µmol/L	6.34	mg/dl
Ca^{2+}	1.06	mmol/L		
Cl^-	101	mmol/L		
Metabolite Values				
Glucose	6.6	mmol/L	119	mg/dl
Lactate	11.4	mmol/L	102.6	mg/dl
Oximetry Values				
Hb	141	g/L		
sO_2	26.0	%		
Other				
Base(Ecf)c	-12.2	mmol/L		
$HCO3^-$(P,st)c	13.3	mmol/L		

Emergency Interventions

1-Oxygen 3 L/min via nasal prongs/mask	5-Bladder catheter
2-Ringer 500 ml IV bolus, repeat as needed	6-Antibiotics, including Clindamycin
3-Adrenalin 20 microg IV bolus	7-X-ray/ultrasound ("abscess in the axilla?")
4-Blood cultures x 2 and urine culture	or surgical consult

Comments

- Intervention 4: both the words "blood culture" AND "urine culture" need to be mentioned
- Intervention 6: Clindamycin OCH another antibiotic which is either broad-spectrum or directed against Staphylococcus need to be administered

Dryver E, *et al. BMJ Qual Saf* 2021;0:1–9. doi: 10.1136/bmjqs-2020-012740

5. Calcium Channel Blocker Poisoning

Manikin	Running the Scenario
• Supine • Nasopharyngeal airway + oxygen mask with reservoir • Two PVCs, 1 liter Ringer's acetate connected to one PVC without surrounding blood pressure cuff • Blanket covering the manikin	• The vital signs remain unchanged throughout the scenario despite therapy

Introduction

S	A 45-year-old woman has been found with decreased level of consciousness in her apartment
B	The patient has high blood pressure and is on Cardizem Retard. She also suffers from depression.
A	The patient was found by her daughter. The patient had written a suicide note. 30 tablets of 180 mg Cardizem Retard are missing. It is unclear when the patient took the tablets. The ambulance personnel have placed two PVCs, nasopharyngeal airway, and the patient is receiving 10 L/min of oxygen via mask. The personnel state that they have not been able to palpate the radial pulse. They connected 1 L of Ringer just before arrival in the ED.
R	"All yours" (remove the blanket)

Airway / C-spine

Head & Neck	No signs of trauma
Airway Sounds	Normal airway sounds, nasopharyngeal airway in place
Oral Cavity	Unremarkable

Breathing

SpO2%	96% while the patient is receiving 10 L/min O2 via mask
Respiratory Rate	20 breaths/min
Lung Auscultation	Normal breath sounds

Circulation

Blood Pressure	**70/50 mm Hg**
Heart Rate	**31 beats/min**
Monitor EKG	**Wide QRS-complexes**, regular rhythm

Disability

Consciousness	**Drowsy**
Eyes	Pupils 3 mm
Extremities	Moves all 4 extremities spontaneously

Exposure

Front	Normal skin
Back	Normal skin
Temperature	36.8°C

Dryver E, *et al. BMJ Qual Saf* 2021;0:1–9. doi: 10.1136/bmjqs-2020-012740

Adjuncts

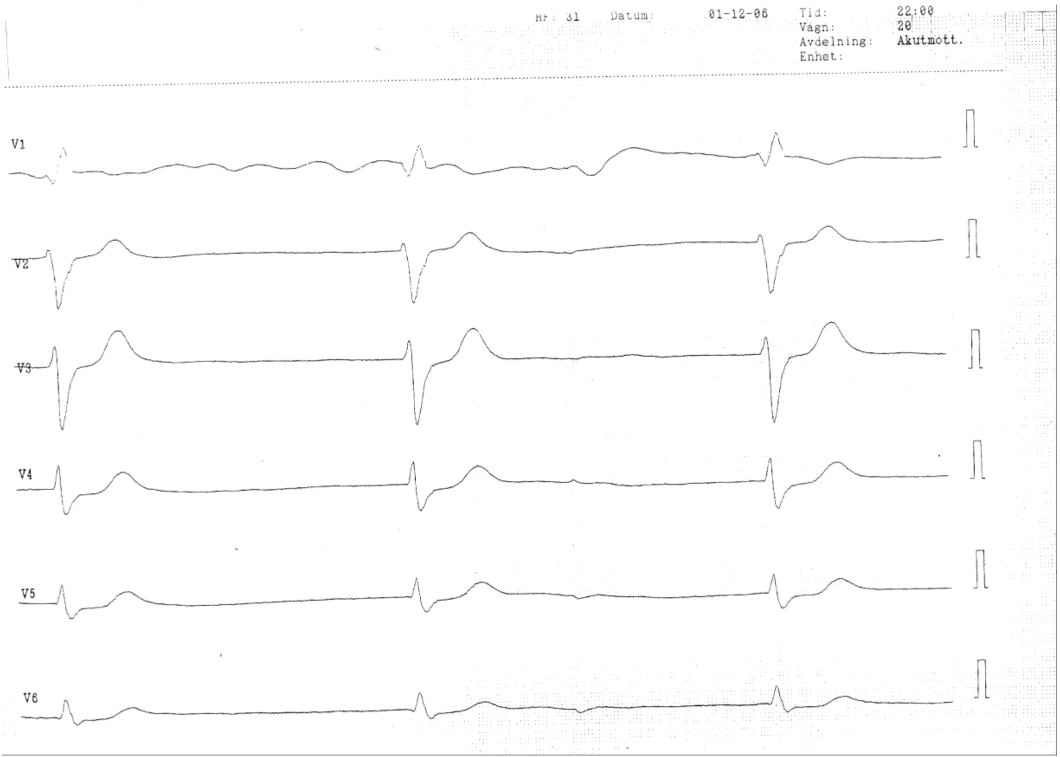
Blood Tests	Provided if requested
EKGs	EKG #1a and EKG #1b are provided simultaneously if EKG is requested
Ultrasound	"No pericardial fluid. Poor contractility. Large IVC. No free fluid."

Bedside Blood Tests

Blood Gas Values				
pH	7.2			
pCO_2	6.79	kPa	51	mm Hg
pO_2	4.03	kPa	30	mm Hg
Electrolyte Values				
Na^+	141	mmol/L		
K^+	4.8	mmol/L		
Creatinine	104	µmol/L	1.17	mg/dl
Ca^{2+}	1.26	mmol/L		
Cl^-	107	mmol/L		
Metabolite Values				
Glucose	8.8	mmol/L	158	mg/dl
Lactate	6.2	mmol/L	55.8	mg/dl
Oximetry Values				
Hb	119	g/L		
sO_2	69.6	%		
Other				
Base(Ecf)c	-7.2	mmol/L		
$HCO3^-$(P,st)c	17.6	mmol/L		

Dryver E, *et al. BMJ Qual Saf* 2021;0:1–9. doi: 10.1136/bmjqs-2020-012740

Appendix 1 Figure 11: Calcium Channel Blocker Poisoning EKG #1a



Appendix 1 Figure 12: Calcium Channel Blocker Poisoning EKG #1b

Emergency Interventions

1-Ringer's acetate bolus 2-Atropine ≥ 1 mg IV bolus 3-Calcium gluconate 10% 30 ml IV 4-Adrenalin 20 microg IV bolus 5-Glucose 300 mg/ml 50 ml IV bolus	6-Humalog *or* Actrapid *or* Novorapid 70 E IV bolus 7-Glucagon ≥ 1 mg IV bolus 8-Intralipid 100 ml IV 9-ECMO

Comments

- Intervention 8: since intralipid is not available at one of the four sites, the maximum number of potential emergency interventions with eight when the scenario was simulated there.
- Intervention 9: ECMO stands for extracorporeal membrane oxygenation

Dryver E, *et al. BMJ Qual Saf* 2021;0:1–9. doi: 10.1136/bmjqs-2020-012740

6. Tricyclic Antidepressant Poisoning

Manikin	Running the Scenario
• Supine • Nasopharyngeal airway + oxygen mask with reservoir • Two PVCs • Blanket covering the manikin	• Three minutes into the scenario, the patient develops ventricular tachycardia, which persists until the patient receives sodium bicarbonate dose #2 and magnesium IV

Introduction

S	A 54-year-old man has been found unconscious at his home by his relatives. The patient will be arriving by ambulance in 1 minute.
B	The patient suffers from depression and takes Saroten (Amitriptyline), a tricyclic antidepressant.
A	The patient was found unconscious. His relatives suspect that the patient took an overdose of Amitriptyline. The time of ingestion is unclear. The ambulance personnel have placed a nasal pharyngeal airway and two PVCs.
R	"All yours" (remove the blanket)

Airway / C-spine

Head & Neck	No signs of trauma
Airway Sounds	Normal airway sounds, nasopharyngeal airway in place
Oral Cavity	Unremarkable

Breathing

SpO2%	95% with oxygen via mask
Respiratory Rate	12 breaths/min
Lung Auscultation	Normal breath sounds

Circulation

Blood Pressure	**60/35 mm Hg**
Heart Rate	**110 beats/min. With ventricular tachycardia: 210 beats/min**
Monitor EKG	**Wide QRS-complexes**, regular rhythm

Disability

Consciousness	**Unresponsive to voice and painful stimulus**
Eyes	**Pupils 6 mm, poor reaction to light**
Extremities	**No reaction to painful stimuli**

Exposure

Front	**Skin is red, warm and dry. No rash.**
Back	**Skin is red, warm and dry. No rash.**
Temperature	**37.8ºC**

Dryver E, *et al. BMJ Qual Saf* 2021;0:1–9. doi: 10.1136/bmjqs-2020-012740

Adjuncts

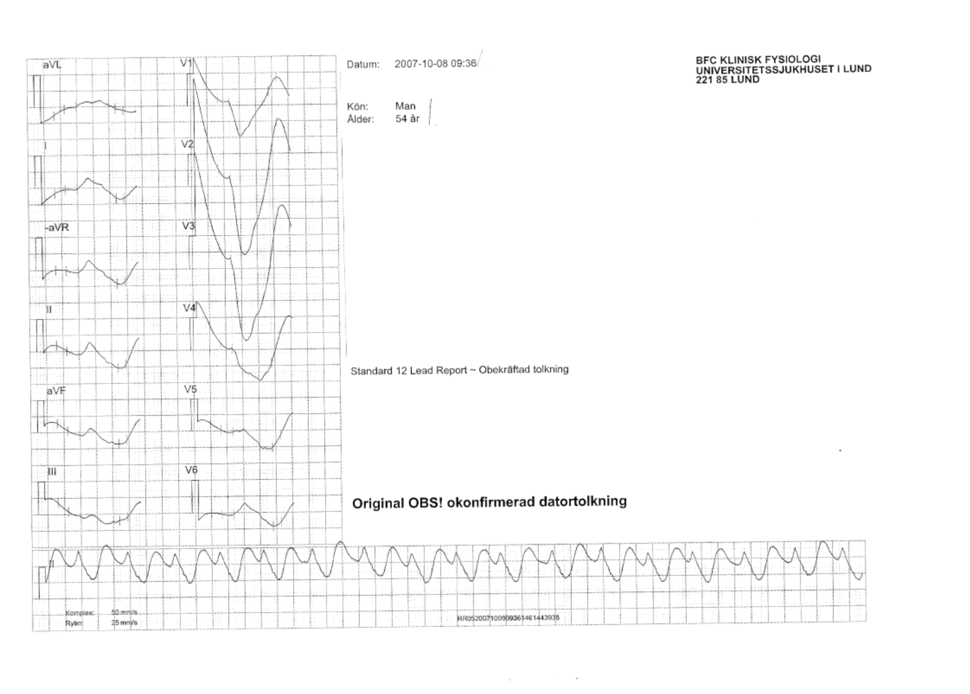
Blood Tests	Provided if requested
EKG	EKG #1 is provided if requested. EKG #2 is provided if requested when the patient has developed ventricular tachycardia
Ultrasound	"No pericardial fluid, poor contractility. Large IVC. No free fluid."

Bedside Blood Tests

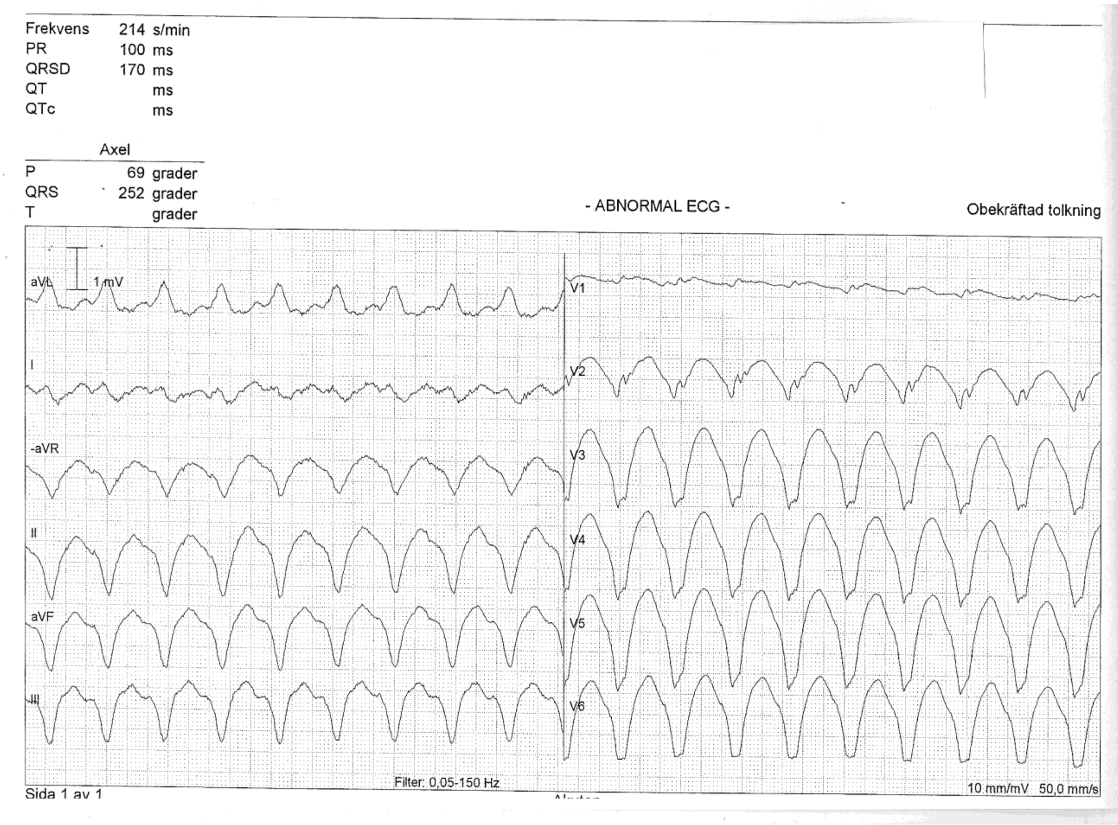
Blood Gas Values				
pH	7.28			
pCO_2	5.3	kPa	40	mm Hg
pO_2	14.9	kPa	151	mm Hg
Electrolyte Values				
Na^+	135	mmol/L		
K^+	4.7	mmol/L		
Ca^{2+}	1.2	mmol/L		
Cl^-	98	mmol/L		
Metabolite Values				
Glucose	7.6	mmol/L	137	mg/dl
Lactate	6.9	mmol/L	62.1	mg/dl
Oximetry Values				
Hb	148	g/L		
sO_2	99	%		
Other				
Base(Ecf)c	-7.6	mmol/L		
$HCO3^-$(P,st)c	18	mmol/L		

Dryver E, *et al. BMJ Qual Saf* 2021;0:1–9. doi: 10.1136/bmjqs-2020-012740

Appendix 1 Figure 13: Tricyclic Antidepressant Poisoning EKG #1



Appendix 1 Figure 14: Tricyclic Antidepressant Poisoning EKG #2



Dryver E, *et al. BMJ Qual Saf* 2021;0:1–9. doi: 10.1136/bmjqs-2020-012740

Emergency Interventions

1-Ringer's acetate 500 ml IV bolus 2-Sodium bicarbonate #1 200 ml IV bolus 3-Sodium bicarbonate #2 200 ml IV bolus 4-Magnesium 10 mmol IV over 2 min	5-Adrenalin 20 microg IV 6-Sodium chloride 3% #1 110 ml 7-Sodium chloride 3% #2 110 ml 8-Intralipid 100 ml IV 9-ECMO

Comments

- Intervention 8: since intralipid is not available at one of the four sites, the maximum number of potential emergency interventions with eight when the scenario was simulated there.
- Intervention 9: ECMO stands for extracorporeal membrane oxygenation

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7. Seizure

Manikin	Running the Scenario
• Supine • No oxygen mask • Two PVCs • Blanket covering the manikin	Within 1 minute of simulation onset, the patient has a tonic-clonic seizure. The patient continues to seize intermittently throughout the simulation.

Introduction

S	It's evening. An 84-year-old woman who presented to the emergency department has just had a seizure and she has been transferred to the resuscitation room.
B	The patient has been essentially healthy except a progressive anemia.
A	She underwent a colonoscopy this morning to investigate her progressive anemia. During the afternoon she became increasingly confused and vomited. Her husband called the ambulance. The patient received two PVCs during transport to the ED. She has been a Priority 2 until now when she developed a generalized seizure that lasted 1 minute. She has just been transferred to the resuscitation room.
R	"All yours" (remove the blanket)

Airway / C-spine

Head & Neck	No signs of trauma
Airway Sounds	**Snoring breath sounds (disappear when receives nasopharyngeal airway, oropharyngeal airway or jaw thrust)**
Oral Cavity	Unremarkable

Breathing

SpO2%	**89% on room air**
Respiratory Rate	**6 breaths/min**
Lung Auscultation	Normal breath sounds

Circulation

Blood Pressure	**108/70 mm Hg**
Heart Rate	75 beats/min
Monitor EKG	Narrow QRS-complexes, regular rhythm

Disability

Consciousness	**Unreactive to voice or pain**
Eyes	Pupils 3 mm
Extremities	**Intermittent shaking of all 4 extremities; withdraws to pain**

Exposure

Front	Normal skin
Back	Normal skin
Temperature	36.8°C

Adjuncts

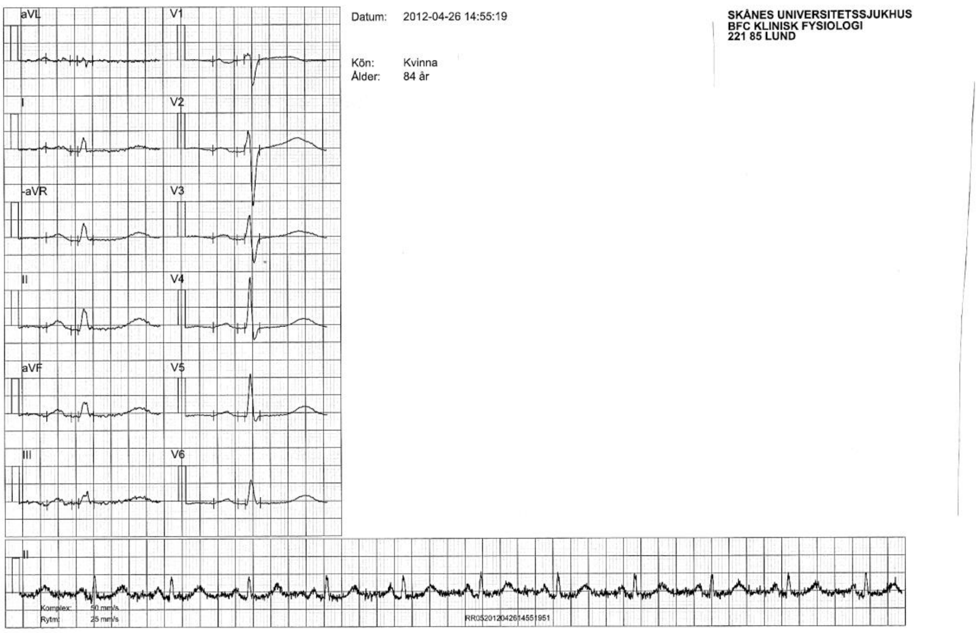
Blood Tests	Provided if requested
EKG	Provided if requested
Ultrasound	Reveals no abnormalities

Dryver E, *et al. BMJ Qual Saf* 2021;0:1–9. doi: 10.1136/bmjqs-2020-012740

Bedside Blood Tests

Blood Gas Values				
pH	7.1			
pCO_2	7.2	kPa	54	mm Hg
pO_2	6.9	kPa	52	mm Hg
Electrolyte Values				
Na^+	115	mmol/L		
K^+	4.8	mmol/L		
Creatinine	58	µmol/L	0.65	mg/dl
Ca^{2+}	1.1	mmol/L		
Cl^-	79	mmol/L		
Metabolite Values				
Glucose	11.2	mmol/L	202	mg/dl
Lactate	8.2	mmol/L	73.8	mg/dl
Oximetry Values				
Hb	115	g/L		
sO_2	89.0	%		
Other				
Base(Ecf)c	-8.2	mmol/L		
$HCO3^-$(P,st)c	16	mmol/L		

Appendix 1 Figure 15: Seizure EKG



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Emergency Interventions

1-Nasopharyngeal airway	6-Sodium chloride 3%: correct preparation
2-Supplemental oxygen	7-Sodium chloride 3%: 275 ml
3-Ventilation with bag-valve-mask	8-Benzodiazepine dose #2
4-Crystalloid 500 ml bolus	9-Keppra 60 mg/kg IV over 10 min
5-Benzodiazepine dose #1	10-Endotracheal intubation

Comment

- Intervention 9: alternatives to Keppra considered to be equivalent:
  - Fosfenytoin 15-20 mg/kg IV
  - Valproic acid 30-40 mg/kg IV

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8. Increased Intracranial Pressure

Manikin	Running the Scenario
• Supine • Nasopharyngeal airway • Two PVCs • Blanket covering the manikin	• EtCO2 is 5.5 kPa initially

Introduction

S	A 54-year-old man has been found unconscious in his apartment.
B	The patient has no known prior illnesses and does not take any medications.
A	The patient suddenly started talking incoherently on the phone 1 hour ago. His son went to the patient's apartment and found the patient unconscious. The patient had vomited profusely in bed. During transport to the emergency room, the patient has received a nasopharyngeal airway and 2 PVCs.
R	"All yours" (remove the blanket)

Airway / C-spine

Head & Neck	No signs of trauma
Airway Sounds	Normal airway sounds, nasopharyngeal airway in place
Oral Cavity	Unremarkable

Breathing

SpO2%	**91% on room air**
Respiratory Rate	**10 breaths/min**
Lung Auscultation	Normal breath sounds

Circulation

Blood Pressure	**100/60 mm Hg**
Heart Rate	**135 beats/min**
Monitor EKG	Narrow QRS-complexes, regular rhythm

Disability

Consciousness	**No verbal response to voice or pain**
Eyes	Right pupil 3 mm, reacts to light **Left pupil 6 mm, unresponsive to light**
Extremities	Withdraws left arm + left leg to pain **Right arm and right leg do not react to pain**

Exposure

Front	Normal skin appearance
Back	Normal skin appearance
Temperature	**38.0°C**

Adjuncts

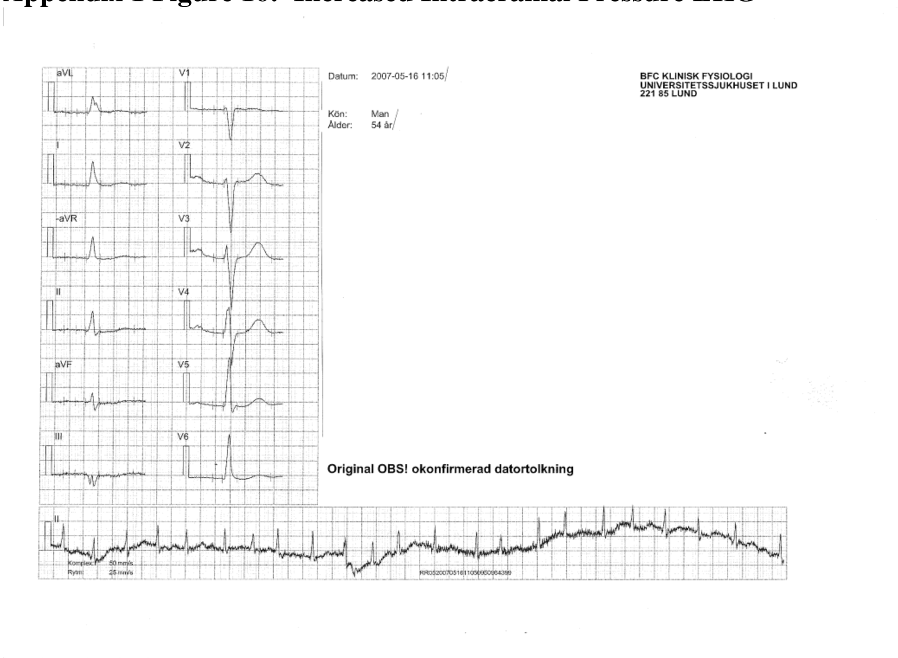
Blood Tests	Provided if requested
EKG	Provided if requested
Ultrasound	"Reveals no abnormalities"

Dryver E, *et al. BMJ Qual Saf* 2021;0:1–9. doi: 10.1136/bmjqs-2020-012740

Bedside Blood Tests

Blood Gas Values				
pH	7.35			
pCO_2	6.2	kPa	46	mm Hg
pO_2	5.2	kPa	39	mm Hg
Electrolyte Values				
Na^+	141	mmol/L		
K^+	4.6	mmol/L		
Creatinine	70	µmol/L	0.79	mg/dl
Ca^{2+}	1.19	mmol/L		
Cl^-	105	mmol/L		
Metabolite Values				
Glucose	9.2	mmol/L	166	mg/dl
Lactate	1.5	mmol/L	13.5	mg/dl
Oximetry Values				
Hb	136	g/L		
sO_2	67.0	%		
Other				
Base(Ecf)c	+0.8	mmol/L		
$HCO3^-$(P,st)c	24	mmol/L		

Appendix 1 Figure 16: Increased Intracranial Pressure EKG



Emergency Interventions

1-Oxygen ≥ 10 L/min via oxygen mask	5-Paracetamol 1 g IV
2-Elevate the head of the bed	6-Sodium chloride 3% 275 ml IV bolus
3-Bag-valve-mask ventilation to EtCO3 3.5	7-Endotracheal intubation
4-Sodium chloride 500 ml IV bolus	8-Head CT

IV. Simulations–Methods
Manikin
Given that the simulations were carried out in-situ in actual resuscitation rooms, a manikin that could quickly be wheeled in and out of the resuscitation room was required. Vital signs were generated by a computer and displayed on a screen, hence a simple manikin without spontaneous respiratory activity, palpable pulse or electrical rhythm generation was deemed suitable (Laerdal Extri Kelly®). The same manikin was used in all emergency departments.

Vital Signs
Computer-generated vital signs were displayed on the screen used during actual clinical practice or on a screen of similar size placed in a similar location.

Duration
Based on results from a pilot study,[58] the optimal simulation duration was determined to be 15 minutes. During the simulations, infusions were considered to have been completely given once initiated in order to minimize the amount of time that personnel on clinical duty were involved in the trial.

Incomplete Simulations
Simulations that could not be completed due to actual emergencies were excluded from the study, and the data discarded.

Sample Size Calculation
When ethics approval was sought (Dnr 2013/858), no data was available to estimate sample size, and we sought ethical approval to carry out the study in all five EDs in Southern Sweden.

Appendix 1 Table 1: Results from a Pilot Study of Crisis Checklists

% Emergency Interventions	**Without Checklist**	**With Checklist**
Mean	48	76
Median	44	83
Standard Deviation	23	20

Appendix Table 1 displays the results obtained from a pilot study of crisis checklists in the ED performed during the spring of 2016[58]

The minimum sample size for each group was calculated using the following formula for comparison of two means: $(u + v)^2 (\sigma_1^2 + \sigma_0^2) / (\mu_1 - \mu_0)^2$
where:
$\mu_1 - \mu_0$: difference between the means
σ_1, σ_0: standard deviations

Based on this equation, performing each scenario twice (with and without checklist access) in three EDs (3 x 8 scenarios with and 3 x 8 scenarios without checklist access) would be sufficient to detect a clinically meaningful difference of 20% in performed emergency interventions with a power of 0.80 and a Type I error probability of 0.05. However, given the uncertainty as to whether the study could be performed in-situ despite on-going clinical duties, we planned to carry out the study in four EDs.

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Randomization of Teams to Scenarios and Checklists

Teams consisted of local personnel assigned to manage priority 1 patients in the resuscitation room on the study day. Should a priority 1 patient present during the course of a simulation, the simulation would need to be interrupted unless another team could be mobilized to manage the patient. In order to increase the likelihood that each team could perform two simulations, an extra resuscitation team was scheduled to work in the ED during the mornings of the study period in two of the four EDs. Yet there was no guaranty that a given team would have the opportunity to perform one or two simulations without interruption. In addition, the exact composition of each team was at the discretion of the local staff in charge of resource allocation in the ED on the given day. Team composition could therefore not be ascertained in advance.

Team allocation to scenario and checklist access was designed to satisfy the following criteria:

- randomized sequence according to which the scenarios (with and without checklist access) were run in each ED
- each scenario would be simulated at least twice (once with and once without checklist access) in each ED
- teams performing two simulations would run one with checklist access and one without
- no team member would perform the same scenario more than once
- an allocation system that would allow for teams to perform only one simulation and palliate for situations in which the simulation had to be interrupted due to clinical duties

Team allocation to scenario and checklist access was determined in the following manner:

- The sequence according to which the eight scenarios were carried out at each ED was determined through a permuted block randomization process using the Excel RAND function.
- Whether the first simulation was run with checklist access (+) or without (-) in each ED was alternated, ensuring that the first simulation was run with checklist access in two EDs and that the first simulation was run without checklist access in the other two EDs.
- Checklist access was alternated thereafter. For example, if the scenario sequence was 5-3-2-8-4-6-1-7 and the first scenario was run with checklist access (+), the following sequence was generated: 5+; 5-; 3+; 3-; 2+; 2-; 8+; 8-; 4+; 4-; 6+; 6-; 1+; 1-; 7+; 7-. This sequence can be thought of as a stack of 16 cards, with the top card representing scenario 5 with checklist access and bottom card scenario 7 without checklist access.
- For a given team, the allocated scenario was the highest card in the stack representing a scenario that none of the team members had performed previously.
- Once a team had successfully carried out a whole simulation, the corresponding card was discarded. If the team had to interrupt the scenario prior to its completion, the card was left in the stack at its original position, until a team consisting of different personnel could perform the scenario.
- When a given team could perform a second simulation, the allocated scenario was the highest card in the stack representing a scenario that none of the team members had performed previously and with a different checklist access than during the first simulation.

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Appendix 1 Table 2: Scenario Sequences for Each ED

ED1	**ED2**	**ED3**	**ED4**
8+	3-	5+	7-
8-	3+	5-	7+
1+	6-	6+	1-
1-	6+	6-	1+
4+	5-	8+	3-
4-	5+	8-	3+
6+	4-	3+	8-
6-	4+	3-	8+
7+	2-	1+	6-
7-	2+	1-	6+
3+	1-	7+	5-
3-	1+	7-	5+
5+	8-	2+	4-
5-	8+	2-	4+
2+	7-	4+	2-
2-	7+	4-	2+

This table provides the sequences according to which the eight scenarios were run in each of the four EDs. The + symbolizes that the scenario was run with checklist access, the – that the scenario was run without checklist access. For one ED, simulations were performed over the course of three weeks until all 16 simulations had been performed. For the other three EDs, all simulations were performed over the course of five consecutive weekdays, with the goal of performing four simulations per day and an extra day scheduled to perform remaining or additional simulations.

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Appendix 1 Table 3: Scenario Sequence for Additional Simulations in Three EDs

ED2	ED3	ED4
1-	3+	2-
1+	3-	2+
5-	5+	7-
5+	5-	7+
3-	8+	1-
3+	8-	1+
6-	2+	5-
6+	2-	5+
8-	6+	4-
8+	6-	4+
2-	4+	6-
2+	4-	6+
7-	7+	8-
7+	7-	8+
4-	1+	3-
4+	1-	3+

For three EDs, all simulations were performed over the course of five consecutive weekdays, with the goal of performing four simulations per day and an extra day scheduled to perform remaining or additional simulations. Sequences were randomly generated in the event that additional simulations could be performed. This table provides these additional sequences. The + symbolizes that the scenario was run with checklist access, the – that the scenario was run without checklist access.

Investigator Protocol

The investigator who led the simulations was not blinded to whether the team had access to checklists or not. In order to minimize the risk of influencing team performance, the investigator had to follow a strict protocol. Adherence to protocol was evaluated during the video review by two investigators.

Prior to Reading the Introduction to the Study

When the lead nurse and physician in the ED deemed that the timing was most suitable, a resuscitation team was gathered in the resuscitation room without being informed about the nature of the scenario. Team members were enrolled at this point in the study and signed an informed consent form. The scenario to be used was determined based on the generated scenario sequence and the composition of the team (see Scenario Sequence).

Introduction to the Study

The investigor who led the simulations then read out introductory information to all team members that emphasized:

- that the diagnosis would be readily apparent from the introductory information, and that the simulation would focus on treatment
- that team members were meant to treat the manikin as a real patient, e.g. by placing an oxygen-mask on the patient, injecting medications through the peripheral venous catheter
- that team members were to locate actual equipment and medications, and would then receive training equipment/placebo

The following is a translation into English of the text that the investigator running the simulations read out to all team members:

"1-The focus during the scenario will be on treatment. The patient's diagnosis will be quite obvious from the report you receive.
2-You do not have the time to carry out a Sign-In, but instead start direcly with assessing and treating the patient.
3-Treat the patient as if he or she were a real patient. Insert a PVC if the patient does not already have one. Give fluids and drugs via the PVC; the fluid you give is collected under the bed. If you want to give IM treatment, use this cushion.
4-I can answer questions regarding respiratory rate, sounds on chest auscultation, level of consciousness, skin findings, temperature. Vital parameters appear on the screen. I will provide a 12-lead ECG and bedside blood tests upon on request.

In regard to medications:

- If the medication is located in the emergency room, you must find the medication, show it to me, then you will receive a placebo to be given to the patient.
- If the medication is not in the emergency room, you just need to tell me where it is, then you will receive a placebo
- If the medication needs to be injected over 10-20 minutes, it is enough that you start the injection or infusion and then state the duration of the injection or infusion
- You can then ask if the medication had any effect

In regard to equipment, I can provide practice equipment."

If the team was randomized to no-checklist access, the following was read out to the team members: "You may use all resources that you normally use."

If the team was randomized to checklist access, the following was read out to the team members: "During this simulation, you will have access to a checklist that will appear on the screen after the simulation has started. You are meant to use the checklist when managing the case. You can trust the checklist content, it is based on the latest literature and reviewed by four specialists in emergency medicine."

At this point, a demonstration checklist (management of hyperkalemia) is shown on the screen and the following text is read out: "The checklist is controlled with this iPad."

The team is asked to select a team member (a nurse or a medical secretary) whose task it is to go through the checklist. This team member is then asked to open a couple of popover windows by pressing on the corresponding popover icon. The following text is read out to this team member: "One of your tasks during the simulation will be to go through all the items on the checklist and see if the patient meets the criteria for receiving certain treatments. This means opening all the popover windows in the checklist one by one. Of course, you can also contribute to giving medicines and doing other tasks."

Introduction to the Scenario

The introduction to the scenario was then read to the team members. If the team was randomized to checklist access, the relevant checklist was brought forth on the computer tablet upon starting the simulation.

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Investigor Leading the Simulations: Required

- The investigor leading the simulations was required to provide clinical information (e.g. how the patient answers questions, skin colour, findings on examination of the mouth etc.), EKG, blood tests immediately upon request.
- The investigor leading the simulations was required to state that treatments could be considered fully administered once administration has begun, and to provide information about their clinical effects.

Investigor Leading the Simulations: Allowed

- The investigor leading the simulations was allowed to repeat the instruction to treat the manikin as a real patient, i.e. administer medications via the PVC, placing an oxygen mask on the patient.
- The investigor leading the simulations was allowed to ask the team to clarify/specify which treatments that had been given and which blood tests that had been taken.

Investigor Leading the Simulations: Forbidden

- The investigor leading the simulations was not allowed to enjoin the team to use the checklist once the simulation had begun.
- The team was meant to decide whether to give or not give an intervention without assistance from other personnel. The investigator leading the simulations was not allowed to convey approval from external personnel regarding the administration of specific interventions.

Protocol Violations

All simulations were independently reviewed by two investigators for protocol violations. There were two protocol violations that occurred within the 15-minute simulation-windows:

- When the nurse could not find the Sodium Bicarbonate, the investigor leading the simulation said: "look at the checklist" where it stated where the Sodium Bicarbonate was located. Sodium Bicarbonate was successfully located and administered but no point was given for this measure given the protocol violation.
- A nurse and a physician were confused about how fast insulin should be given, and were about to fetch an infusion-pump. The investigor leading the simulation said: "look at the checklist". No point was given for insulin administration.

V. Simulations–Results

Simulation Dates

The simulations were performed

- Emergency Department 1: between the 19th of July and 28th of August 2019
- Emergency Department 2: between the 18th and 22nd of November 2019
- Emergency Department 3: between the 25th and 29th of November 2019
- Emergency Department 4: between the 29th of January and 4th of February 2020

Appendix 1 Table 4: Scenarios Performed by Each Team

Team	ED	First Scenario	Second Scenario
1	1	8+	1-
2	1	4+	6-
3	1	4-	6+
4	1	8-	1+
5	1	7+	
6	1	7-	3+
7	1	5+	
8	1	3-	2+
9	1	5-	
10	1	2-	
11	2	3-	6+
12	2	3+	6-
13	2	5-	4+
14	2	5+	4-
15	2	2-	1+
16	2	2+	1-
17	2	8-	7+
18	2	8+	7-
19	2	1-	5+
20	2	1+	5-
21	3	5+	6-
22	3	5-	6+
23	3	8+	3-
24	3	8-	3+
25	3	1+	7-
26	3	1-	7+
27	3	2+	4-
28	3	2-	4+
29	3	3+	8-
30	3	5-	2+
31	4	7-	1+
32	4	7+	1-
33	4	3-	
34	4	8+	
35	4	3+	8-
36	4	6-	5+
37	4	6+	5-
38	4	4-	2+
39	4	4+	2-

40	4	7-	1+
41	4	7+	1-

This table provides the scenario or scenarios performed by each team. Thirty-five of the 41 teams performed two simulations, one with (+) and one without (-) checklist access. Six of the 41 teams were only able to perform one simulation due to the need to take care of actual patients in the resuscitation room. No team member performed the same scenario twice.

Appendix 1 Table 5: Team Composition

Team Composition				**Number**			
Physician	**Nurse**	**Nursing Assistant**	**Medical Secretary**	**ED1**	**ED2**	**ED3**	**ED4**
1	1	1	1	0	8	10	0
1	2	0	1	0	2	0	0
1	2	1	0	6	0	0	7
2	2	1	0	0	0	0	3
1	2	2	0	3	0	0	0
1	3	1	0	0	0	0	1
1	3	0	0	1	0	0	0
Total				10	10	10	11

Each of the 41 teams were composed of 4 or 5 healthcare personnel. In two EDs, the standard team consisted in one physician, one nurse, one nursing assistant and one medical secretary (18 teams), but in two teams a nurse replaced the nursing assistant. In the other two EDs, the standard team consisted in one physician, two nurses and one nursing assistant (13 teams), but three teams featured an additional physician, three teams an additional nursing assistant, one team an additional nurse, and in one team a nurse replaced the nursing assistant.

Appendix 1 Table 6: Number of Simulations Performed by Each Participant

Number of simulations performed by a participant	**Numbers of participants**
1	13
2	101
3	2
4	17
5	1
6	4

This table displays the number of simulations performed by the participants in the study. The physicians, nurses, nursing assistants and secretaries that participated in the study were those staffing the resuscitation teams on the day the study was carried out. Some personnel were part of the resuscitation team during more than one study day and hence performed more than two simulations.

Appendix 1 Table 7: Characteristics of the Teams Performing Only One Scenario

Team	Size	Physician Age (years)	Physician Experience (1-5)	Senior Nurse Age (years)	Senior Nurse Experience (1-5)
5+	5	35	2	48	5
7+	4	33	2	37	4

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9-	4	28	2	49	5
10-	4	42	4	52	5
33-	5	39	3	44	4
34+	4	39	3	44	4

The three teams that only performed one scenario with checklist access (+) did not differ significantly from the three teams that only performed one scenario without checklist access (-) in regard to team size, physician age, physician experience, senior nurse age or senior nurse experience. Experience was graded on a 1-5 scale where 1 indicates < 1 year of experience, 2 1-4 years of experience, 3 5-9 years of experience, 4 10-14 years of experience, and 5 ≥ 15 years of experience.

Simulation Termination and Duration

Simulations were terminated when all emergency interventions had been performed, when the team expressed that they could not think of any other intervention to perform, or when 15 minutes has elapsed, whichever came first. The following table provides a break-down of the reasons for simulation termination.

Appendix 1 Table 8: Grounds for Simulation Termination

	Checklist Access (n=38)	No Checklist Access (n=38)
All interventions performed	14 (37%)	0 (0%)
No further ideas	4 (10%)	12 (32%)
15 minutes elapsed	20 (53%)	26 (68%)

The following table provides a break-down of simulation duration according to checklist access.

Appendix 1 Table 9: Simulation Duration (seconds)

	Checklist Access (n=38)	No Checklist Access (n=38)
Median	900	900
Mean	827	863
Standard deviation	120	78
Minimum	358	597
Maximum	900	900

There was no statistically significant difference between the simulation durations with or without checklist access (P=0.12).

Appendix 1 Table 10: Simulation Duration (seconds) when Teams Could Not Think of Additional Interventions

	Checklist Access (n=4)	No Checklist Access (n=12)
Median	797	807
Mean	796	785
Standard deviation	54	102
Minimum	729	597
Maximum	861	896

There was statistically significant difference between the simulation durations with or without checklist access (P=0.77).

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Usual Cognitive Aids

Usual cognitive aids were exclusively used to guide the performance of first-line and non-first-line interventions, not for diagnostic purposes. Teams that were randomized to no checklist access were explicitly allowed to use whatever usual cognitive aids they had at their disposal for whatever purpose they saw fit. Teams that were randomized to checklist access were explicitly encouraged to use the checklist. The following table provides a breakdown of the type of usual cognitive aids used, depending on whether the teams had checklist access or not.

Appendix 1 Table 11: Use of Usual Cognitive Aids

Type of Aid Used	Checklist Access (n=38)	No Checklist Access (n=38)
Internet	2	12
Pocket-Book	2	6
Printed Card	2	0
Internet + Pocket-book	0	7
Internet + Printed Card	0	1
One or more aids	6	26

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VI. Analysis According to Mixed Effects Proportional Odds Regression

The following table displays the observed proportions of teams, with and without checklist access, who performed from 1 to 10 emergency interventions. The table also displays the corresponding expected values, along with associated 95% confidence intervals, that were derived from the observed data under a proportional odds regression model. The observed and expected percentages are analogous to those provided in simple linear regression. In a regression of one continuous response variable y against an independent variable x, the observed results are the scatter plot of the actual observations (x, y). The expected response is the estimated regression line, which is the optimal straight-line fit of the relationship between y and x under the model assumption that the true expected relationship is linear. In this paper we are using a mixed effects proportional odds regression model. The close agreement between the observed and expected percentages in this table indicates that this model is appropriate for our data. There was a profound difference in the number of indicated interventions performed by teams that did, and did not, use the checklist (P = 7.5×10-8). The 95% confidence intervals for these probabilities did not overlap for all but the five- and 10-interventions outcomes.

Appendix 1 Table 12: Effect of checklists on the number of indicated emergency interventions performed within 15 minutes

Number of interven-tions performed	**Teams Without Checklist Access (n=38)**			**Teams With Checklist Access (n=38)**		
	No. (%)		95% confidence intervals	No. (%)		95% confidence intervals
	Observed	Expected		Observed	Expected	
1	2 (5.3%)	5.1%	(1.2% - 20%)	0 (0.0%)	0.1%	(0.0% - 0.8%)
2	7 (18.4%)	18.1%	(5.6% - 31%)	0 (0.0%)	0.4%	(0.0% - 1.1%)
3	14 (36.8%)	36.4%	(19% - 53%)	0 (0.0%)	1.8%	(0.0% - 4.3%)
4	9 (23.7%)	25.4%	(12% - 39%)	2 (5.3%)	6.0%	(0.1% - 12%)
5	3 (7.9%)	10.3%	(1.8% - 19%)	7 (18.4%)	16.1%	(5.9% - 26%)
6	1 (2.6%)	2.7%	(0.0% - 6.0%)	8 (21.1%)	19.3%	(7.0% - 32%)
7	1 (2.6%)	1.4%	(0.0% - 3.4%)	11 (28.9%)	28.4%	(13% - 43%)
8	1 (2.6%)	0.3%	(0.0% - 0.9%)	4 (10.5%)	12.6%	(2.2% - 23%)
9	0 (0.0%)	0.2%	(0.0% - 0.7%)	5 (13.2%)	12.8%	(1.4% - 24%)
10	0 (0.0%)	0.0%	(0.0% - 0.6%)	1 (2.6%)	2.6%	(0.3% - 17%)
1-10	38 (100%)	100%		38 (100%)	100%	

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VII. Analysis of Factors Potentially Influencing Performance

Appendix 1 Table 13: Effect of Factors on Performance

Potential Factors	Significance
Emergency Department	P = 0.90
Senior Physician Experience	P = 0.77
Senior Physician is a Specialist	P = 0.87
Senior Nurse Experience	P = 0.38
Checklist Access	P ≤ 0.0005
Scenario	P = 0.006

Appendix 1 Table 14: Interactions between Factors and Checklist Access on Performance

Potential Interactions	Significance
Checklist Access x Scenario Type	P = 0.27
Checklist Access x Emergency Department	P = 0.48
Checklist Access x Senior Physician Experience	P = 0.50
Checklist Access x Senior Physician is a Specialist	P = 0.12
Checklist Access x Senior Nurse Experience	P = 0.09
Checklist Access x Cognitive Aid Use	P = 0.72

The P-value reported under the column “Significance” is for the interaction term(s).

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VII. Dangerous or Inappropriate Interventions
Definitions

- "Dangerous" interventions were defined as administered interventions that are potentially harmful, such as administering an intravenous bolus of adrenalin exceeding 100 ug.
- "Inappropriate" interventions were defined as interventions ordered by the physician that are not suitable to the situation, such as ordering an antidote for a poisoning other than the one that the patient was suffering from.

The following table lists dangerous or inappropriate interventions according to scenario and checklist access. All but one of these interventions occurred during simulations where the team did not have access to the checklists.

Appendix 1 Table 15: Dangerous or Inappropriate Interventions

Situation	Intervention	Checklist Access	
		No	**Yes**
Anaphylactic chock	Adrenalin 0.3 - 0.5 mg IV push	1	1
Life-threatening asthma exacerbation with agitation	Diazepam IV push	3	0
	Morphine IV push	2	0
	Theophylline nebulized	1	0
Calcium Channel Blocker Poisoning with shock and bradycardia	Physostigmin	1	0
	Adrenalin 0.2 mg IV push	1	0
	Sodium bicarbonate infusion	1	0
Tricyclic Antidepressant Poisoning	Tribonate infusion	2	0
	Calcium gluconate infusion	1	0
Seizure from hyponatremic encephalopathy	NaCl 23% 20 ml IV push	1	0
Total		**14**	**1**

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VIII. Diagnostic Awareness

It may be hypothesized that teams randomized to checklist access benefitted from knowing the diagnosis from the start, while the performance of teams without checklist access was hampered by diagnostic uncertainty. We argue that any potential delay in diagnostic awareness among teams randomized to no checklist access is unlikely, for the following three reasons.

First, all teams were informed prior to the simulations that the diagnosis would be readily apparent from the information provided at the outset (Section V). The diagnosis was readily apparent from the scenario introduction and sentinel clinical findings provided during the primary survey (Section III). For example, teams were informed that the patient was severely allergic to wasps and had just been stung by a wasp prior to the anaphylaxis scenario; that the patient had vomited a mixture of fresh blood and coffee grounds throughout the night prior to the upper gastrointestinal hemorrhage scenario; that the patient suffered from depression, had written a suicide note, and that 30 tablets of Cardizem Retard were missing prior to the calcium antagonist poisoning scenario. Prior to the seizure scenario, teams were informed that the patient had just suffered from a seizure, and teams were informed that seizures were recurring throughout the simulation.

Second, the video recordings provide objective proof that the team physician was aware of the diagnosis in one of two ways:

- the physician states the diagnosis (e.g. "so this patient has anaphylaxis")
- the physician orders first-line diagnosis-specific interventions; for example, ordering a blood transfusion is proof that the physician's working diagnosis is hemorrhage; ordering blood cultures is proof that the physician suspects an infection

The following table lists the terms used by the physicians in the context of stating the patient's diagnosis and the first-line diagnosis-specific interventions ordered by the physicians that were considered proof of diagnostic awareness.

Appendix 1 Table 16: Proof of Diagnostic Awareness

Scenario	Terms	Interventions
Anaphylaxis	"Anaphylaxis" or "Anaphylactic shock"	• Adrenalin i.m.
Asthma	"Asthma"	• Bronchodilator nebulized
Upper Gastrointestinal Bleed	"Gastrointestinal" or "GI" + "bleeding"	• Blood transfusion • Esomeprazole i.v. push
Sepsis	"Sepsis" or "Septic shock"	• Blood cultures
Calcium Channel Blocker Poisoning	"Calcium antagonist" or "Calcium blocker"	• Calcium infusion
Tricyclic Antidepressant Poisoning	"Tricyclic"	• Sodium bicarbonate infusion
Seizure from Hyponatremic Encephalopathy	"Seizure" or "Status"	• Benzodiazepine i.v. push • 3% Sodium chloride infusion
Increased Intracranial Pressure	"Brain" + "bleeding"	• Acute head CT

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Third, in 12 of the 38 simulations performed without checklist access, the simulation was terminated when the teams clearly expressed that they had no further ideas for indicated emergency interventions (Appendix 1 Table 6). It can therefore not be argued that these teams lacked time to perform interventions after having become aware of the diagnosis. In 13 of the 26 simulations without checklist access lasting 15 minutes, no interventions were performed during the final 5 minutes. Such inactivity on the part of the team is hard to explain other than by positing that the team could not think of an intervention to perform or could not perform it (e.g. by not knowing how to find, prepare or dose the medication). Finally, in the remaining 13 simulations, diagnostic awareness could be confirmed within 90 seconds in 6 simulations and between 2 and 5 minutes into the scenario in 6 simulations. These numbers suggest that any potential delay in treatment due to diagnostic uncertainty was minor.

It should be emphasized that actual diagnostic awareness preceded the time at which it could be confirmed using the video recordings. For example, we randomly ascertained, by reviewing the video recordings, the time of proof of diagnostic awareness in a team with checklist access randomized to the upper gastrointestinal bleeding scenario. Time at which blood transfusion was ordered was 127 seconds into the scenario, yet the team was arguably aware of the diagnosis from simulation start. In 6 of the 7 simulations where proof of diagnostic awareness occurred beyond 2 minutes from scenario start, teams performed at least one emergency interventions prior to the time of proof of diagnostic awareness.

Appendix 1 Table 17: Characteristics of Simulations Without Checklist Access Lasting 15 Minutes During Which Interventions Were Performed During the Final 5 Minutes

Scenario	Time of PDA[1] (sec)	Number of indicated interventions performed	
		Prior to PDA[1]	After PDA[1]
Seizure	8	0	6
Upper gastrointestinal bleed	25	0	4
Anaphylaxis	63	0	4
Anaphylaxis	66	0	4
Seizure	79	2	6
Anaphylaxis	87	0	4
Asthma	166	1	2
Seizure	176	2	3
Calcium channel blocker overdose	187	1	3
Tricyclic antidepressant overdose	195	0	3
Seizure	228	1	6
Calcium channel blocker overdose	267	1	1
Calcium channel blocker overdose	706	1	2

1-PDA: Proof of Diagnostic Awareness (see Appendix 1 Table 16)

The impact of checklist access on the percentage of indicated emergency interventions was reanalyzed after replacing the percentages of indicated emergency interventions performed during these 13 simulations by 100%. Teams with checklist access still outperformed teams without checklist access: median percentage of interventions performed 50.0% (95% CI 37.5% - 78.6%) without checklist access and 85.7% (95% CI 77.8% - 87.5%) with checklist access (P=0.01).

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When it comes to the status epilepticus scenario, all teams were informed that the patient had just suffered from a seizure, and all teams were informed that seizures were recurring throughout the simulation. It is hard to conceive that teams were not aware that the patient was suffering from seizures, even if the teams were not provided with a checklist labeled "Seizure." Four of the above 13 simulations were seizure scenarios. If we replace the percentages of indicated emergency interventions performed for the remaining 9 simulations by 100%, we obtain median percentage of interventions performed 50.0% (95% CI 37.5% - 58.6%) without checklist access and 85.7% (95% CI 77.8% – 87.5%) with checklist access (P=0.000).

These facts argue against the hypothesis that the performance of teams randomized to no checklist access was hampered by diagnostic uncertainty.

IX. Survey

Appendix 1 Table 18: Participants' Perceptions of the Checklists Used in the Study

Survey Statement	Response Score
The checklist helped me to manage the case	6 +/- 0.80
The checklist was useful	6 +/- 0.58
I would use the checklist if I got a similar case in reality	6 +/- 0.69
If I were the patient affected by the condition in the scenario, I would like the team to use the checklist	6 +/- 0.69
The checklist did not interfere with the management of the case	6 +/- 0.89

A total of 158 surveys (40 from physicians, 60 from nurses, 38 from nursing assistants and 20 from medical secretaries) were filled out by members of teams who had carried out a simulation with checklist access. Response scores, expressed as median +/- standard deviation, were on a Likert scale that ranged from 1 (disagree strongly) to 6 (agree strongly).

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Appendix 1 Table 19: Survey Responses According to Profession

Survey Statement	Response Score			
	Physician (n=40)	**Nurse (n=60)**	**Nursing assistant (n=38)**	**Medical secretary (n=20)**
The checklist helped me to manage the case	5 +/-0.8	6 +/-0.6	5 +/-1.0	6 +/-0.5
The checklist was useful	6 +/-0.7	6 +/-0.5	6 +/-0.6	6 +/-0.5
I would use the checklists if I got a similar case in reality	6 +/-0.8	6 +/-0.5	6 +/-0.8	6 +/-0.4
If I were the patient affected by the condition in the scenario, I would like the team to use the checklist	6 +/-0.9	6 +/-0.5	6 +/-0.7	6 +/-0.6
The checklist did not interfere with the management of the case	5 +/-1.0	6 +/-0.8	6 +/-0.7	5.5 +/-1.0

A total of 158 surveys were filled out by members of teams who had carried out a simulation with checklist access. Personnel were asked to indicate to what degree they agreed with five statements, on a Likert scale of 1 (disagree strongly) to 6 (agree strongly). Response scores are expressed as means +/- standard deviation.

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Appendix 1 Table 20: Survey Responses According among Physicians

Survey Statement	Response Score		
	Specialists in EM (n = 4)	**Residents in EM (n = 27)**	**Other Residents (n = 4)**
The checklist helped me to manage the case	5 +/- 1.1	6 +/- 0.7	6 +/- 0.5
The checklist was useful	5 +/- 0.6	6 +/- 0.7	5 +/- 0.5
I would use the checklists if I got a similar case in reality	5 +/- 0.6	6 +/- 0.9	6 +/- 0.5
If I were the patient affected by the condition in the scenario, I would like the team to use the checklist	5 +/- 0.6	6 +/- 1.1	6 +/- 0.5
The checklist did not interfere with the management of the case	4.5 +/- 0.8	5 +/- 1.1	6 +/- 1.3

A total of 35 surveys were filled out by either specialists in Emergency Medicine (EM), residents in EM or residents in another speciality. Personnel were asked to indicate to what degree they agreed with five statements, on a Likert scale of 1 (disagree strongly) to 6 (agree strongly). Response scores are expressed as means +/- standard deviation.

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Medical-Crisis Checklists in the Emergency Department: A Simulation-Based Multi-Institutional Randomized Controlled Trial
Appendix 2: Reproducible Data

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Data

The data collected for this study and the programs that analyzed these data are publicly available. The data for this study are posted at
https://www.dropbox.com/sh/u1xfkz2s7fyjxsc/AAD3l3ZL1mHqoeRkNDkTCKr0a?dl=0
in an Excel spreadsheet named *Checklists_ED_interventions.xlsx.* It is freely available to anyone. To make a copy of this file, go to this URL, pull down the *Open* box next to *Checklists_ED_interventions.xlsx*, and select "Open in Excel".

Figure 2

Figure 2 was generated by the Stata program *Figure1.do*. It creates graphs called *fifteen*, *boxplot* and *legend*. PowerPoint was used to overlay *fifteen* on top of *boxplot* and to annotate the figure. *Figure1.do* is given in the following monospaced font.

```
log using Figure1.log, replace
* Figure1.log
version 16

import excel  Checklists_ED_interventions.xlsx , sheet("Results") firstrow

* n15_interventions = number of interventions by a team in a particular
* scenario in the first 15 minutes.

gen n15_interventions = 0
foreach intervention of varlist m?_done_15 m10_done_15 {
    replace n15_interventions = n15_interventions + `intervention' ///
        if  `intervention' != .
}

* The variable m_max indicates the total number of
* possible interventions for each scenario at each ED.

list checklist n15_interventions m?_done_15 m10_done_15 m_max in 1/10, table
list checklist n15_interventions m?_done_15 m10_done_15 m_max ///
    if m_max < n15_interventions, table

* Draw preliminary scatter plot of number of interventions by checklist use

scatter n15_interventions checklist
more
codebook scenario

* Summarize interventions by scenarios

forvalues i = 1/8 {
    dis ""
    dis "scenario `i'"
    preserve
    keep if scenario == `i'
    sum m?_done_15 m10_done_15
    restore
}

* percent_int15 = the percentage of interventions performed by each team
* with each scenario in 15 minutes

gen percent_int15 = 100*n15_interventions/m_max

* Draw preliminary scatter plot of % of interventions performed by checklist use

scatter percent_int15 checklist

* Generate x-axis  for scatter plots by scenarios.
* The following local macros will be used to tune the graph.

local check_width = 1
local scenario_width = 1.5
local jiggle = 0.25
gen x = .
forvalues i = 1/8 {
    replace x = (scenario-1)*(`check_width' + `scenario_width') ///
        + checklist*`check_width' if scenario == `i'

* generate veritcal separation lines
```

```
    local line`i' = `scenario_width'/2 + (`i'-1)*(`check_width' + `scenario_width') ///
        + `check_width'
    di " line`i' = " `line`i''
}

* Jiggle % interventions in 15 minutes to avoid collisions in scatter plot

sort scenario checklist percent_int15
by scenario checklist percent_int15, sort : egen float ties15 = count(percent_int15)
by scenario checklist percent_int15: gen j15 = _n
gen jiggle_x15 = x
replace jiggle_x15 = x + (-int(ties15/2) + j15-1)*`jiggle'
replace jiggle_x15 = jiggle_x15 + `jiggle'/2 if mod(ties15,2) == 0


if team <= 10 &              ed != 1 {
    display "team ED conflict, team = " team " ED = " ed
}
if team > 10 &  team <= 20 & ed != 2 {
    display "team ED conflict, team = " team " ED = " ed
}
if team > 20 &  team <= 30 & ed != 3 {
    display "team ED conflict, team = " team " ED = " ed
}
if team > 30 &  team <= 41 & ed != 4 {
    display "team ED conflict, team = " team " ED = " ed
}
scatter percent_int15 x, name(ed1, replace) ylabel(0(10)100, angle(zero))
more
*local maxx = `scenario_width'/2 + (7)*(`check_width' + `scenario_width') + `check_width' + .5
local maxx = `line8' - 0.25
 di "maxx = `maxx'"
 di "line1 = " `line1'
twoway                                                                                       ///
    (scatter percent_int15 jiggle_x15 if team ==1,  mcolor(red)   msymbol(circle))           ///
    (scatter percent_int15 jiggle_x15 if team ==2,  mcolor(blue)  msymbol(circle))           ///
    (scatter percent_int15 jiggle_x15 if team ==3,  mcolor(green) msymbol(circle))           ///
    (scatter percent_int15 jiggle_x15 if team ==4,  mcolor(cyan)  msymbol(circle))           ///
    (scatter percent_int15 jiggle_x15 if team ==5,  mcolor(gold)  msymbol(circle))           ///
    (scatter percent_int15 jiggle_x15 if team ==6,  mcolor(red)   msymbol(circle_hollow))    ///
    (scatter percent_int15 jiggle_x15 if team ==7,  mcolor(blue)  msymbol(circle_hollow))    ///
    (scatter percent_int15 jiggle_x15 if team ==8,  mcolor(green) msymbol(circle_hollow))    ///
    (scatter percent_int15 jiggle_x15 if team ==9,  mcolor(cyan)  msymbol(circle_hollow))    ///
    (scatter percent_int15 jiggle_x15 if team ==10, mcolor(gold)  msymbol(circle_hollow))    ///
                                                                                             ///
    (scatter percent_int15 jiggle_x15 if team ==11,  mcolor(red)   msymbol(square))          ///
    (scatter percent_int15 jiggle_x15 if team ==12,  mcolor(blue)  msymbol(square))          ///
    (scatter percent_int15 jiggle_x15 if team ==13,  mcolor(green) msymbol(square))          ///
    (scatter percent_int15 jiggle_x15 if team ==14,  mcolor(cyan)  msymbol(square))          ///
    (scatter percent_int15 jiggle_x15 if team ==15,  mcolor(gold)  msymbol(square))          ///
    (scatter percent_int15 jiggle_x15 if team ==16,  mcolor(red)   msymbol(square_hollow))   ///
    (scatter percent_int15 jiggle_x15 if team ==17,  mcolor(blue)  msymbol(square_hollow))   ///
    (scatter percent_int15 jiggle_x15 if team ==18,  mcolor(green) msymbol(square_hollow))   ///
    (scatter percent_int15 jiggle_x15 if team ==19,  mcolor(cyan)  msymbol(square_hollow))   ///
    (scatter percent_int15 jiggle_x15 if team ==20,  mcolor(gold)  msymbol(square_hollow))   ///
                                                                                             ///
    (scatter percent_int15 jiggle_x15 if team ==21,  mcolor(red)   msymbol(triangle))        ///
    (scatter percent_int15 jiggle_x15 if team ==22,  mcolor(blue)  msymbol(triangle))        ///
    (scatter percent_int15 jiggle_x15 if team ==23,  mcolor(green) msymbol(triangle))        ///
    (scatter percent_int15 jiggle_x15 if team ==24,  mcolor(cyan)  msymbol(triangle))        ///
    (scatter percent_int15 jiggle_x15 if team ==25,  mcolor(gold)  msymbol(triangle))        ///
    (scatter percent_int15 jiggle_x15 if team ==26,  mcolor(red)   msymbol(triangle_hollow)) ///
    (scatter percent_int15 jiggle_x15 if team ==27,  mcolor(blue)  msymbol(triangle_hollow)) ///
    (scatter percent_int15 jiggle_x15 if team ==28,  mcolor(green) msymbol(triangle_hollow)) ///
    (scatter percent_int15 jiggle_x15 if team ==29,  mcolor(cyan)  msymbol(triangle_hollow)) ///
    (scatter percent_int15 jiggle_x15 if team ==30,  mcolor(gold)  msymbol(triangle_hollow)) ///
                                                                                             ///
    (scatter percent_int15 jiggle_x15 if team ==31,  mcolor(red)   msymbol(diamond))         ///
    (scatter percent_int15 jiggle_x15 if team ==32,  mcolor(blue)  msymbol(diamond))         ///
    (scatter percent_int15 jiggle_x15 if team ==33,  mcolor(green) msymbol(diamond))         ///
    (scatter percent_int15 jiggle_x15 if team ==34,  mcolor(cyan)  msymbol(diamond))         ///
    (scatter percent_int15 jiggle_x15 if team ==35,  mcolor(gold)  msymbol(diamond))         ///
    (scatter percent_int15 jiggle_x15 if team ==36,  mcolor(red)   msymbol(diamond_hollow))  ///
    (scatter percent_int15 jiggle_x15 if team ==37,  mcolor(blue)  msymbol(diamond_hollow))  ///
    (scatter percent_int15 jiggle_x15 if team ==38,  mcolor(green) msymbol(diamond_hollow))  ///
    (scatter percent_int15 jiggle_x15 if team ==39,  mcolor(cyan)  msymbol(diamond_hollow))  ///
    (scatter percent_int15 jiggle_x15 if team ==40,  mcolor(gold)  msymbol(diamond_hollow))  ///
```

```
    (scatter percent_int15 jiggle_x15 if team ==41,  mcolor(gray)  msymbol(diamond))         ///
    ,  ytitle(% of Interventions In 15 Minutes) ylabel(0(10)100, angle(zero))                ///
       name(fifteen)  xtitle("") legend(off) xlabel(none) xsize(7.5in) aspectratio(0.356)    ///
       xline(`line1' `line2' `line3' `line4' `line5' `line6' `line7' `line8', lcolor(black)) ///
       graphregion(fcolor(white) lcolor(white)) xscale(range(0 `maxx'))
save Checklists_ED_interventions.dta, replace

* Generate legend symbols to be copied and edited in PowerPoint
gen percent_int15_check = percent_int15
replace percent_int15_check = . if checklist == 0
gen percent_int15_nocheck = percent_int15
replace percent_int15_nocheck = . if checklist == 1
graph box percent_int15_nocheck percent_int15_check,                                    ///
    over(scenario) box(1, color(black) fcolor(none)) box(2, color(black) fcolor(none))  ///
    ytitle(% of Interventions In 15 Minutes) ylabel(0(10)100, angle(zero))              ///
    name(boxplot) legend(off) xsize(7.5in) aspectratio(0.356)                           ///
    graphregion(fcolor(white) lcolor(white))

clear
set obs 8
gen x = 1
replace x = 1.25 if _n > 4
gen ED = _n
replace ED = _n -4 if _n > 4
twoway (scatter ED x if ED==4 & x ==1, mcolor(black) msymbol(circle))             ///
       (scatter ED x if ED==4 & x ==1.25, mcolor(black) msymbol(circle_hollow))   ///
       (scatter ED x if ED==3 & x ==1, mcolor(black) msymbol(square))             ///
       (scatter ED x if ED==3 & x ==1.25, mcolor(black) msymbol(square_hollow))   ///
       (scatter ED x if ED==2 & x ==1, mcolor(black) msymbol(triangle))           ///
       (scatter ED x if ED==2 & x ==1.25, mcolor(black) msymbol(triangle_hollow)) ///
       (scatter ED x if ED==1 & x ==1, mcolor(black) msymbol(diamond))            ///
       (scatter ED x if ED==1 & x ==1.25, mcolor(black) msymbol(diamond_hollow))  ///
     , xscale(range(0 7.5))  yscale(range(0 5)) name(legend)

clear
log close
```

Figure 3

This figure was created by the program *Figure2.do*. It uses the data file *Checklists_ED_interventions.dta*, which is created by *Figure1.do*. Your must run *Figure1.do* before running *Figure2.do*. *Figure2.do* is given in the following monospaced font.

```
program define medianInterventionsPerformed, rclass
    args times n_teams

* Calculate the median % of interventions performed in teams that
* did, or did not, use the checklist.

* This program was written to enable the calculation of bootstrapped confidence intervals

* Determine a list of all of the unique times at which interventions occured in the first 15
minutes.
* Set the first and last time to be 0 and 15 minutes, respectively.  These times
* will be used in all bootstrapped samples

* This program requires that the data be in wide format.
* A temporary file with the macro name `times' must
* already exist that contains the unique times that interventions were performed in the real
data
* prior to 15 minutes. Note that in the bootstrapped samples there will be times in this file
when no
* intervention was made.

version 16
preserve
* tabulate checklist
forvalues i = 1/`n_teams' {
    local check`i' = checklist[`i']
    local scen`i'  = scenario[`i']
}
* Reformat the data so that there is one record for each intervention
* The team id must be unique. For boostrapped samples we will redefine
* this id to ensure that this is true.
quietly gen id_boot = _n
quietly reshape long m_sec, i(id_boot) j(intervention)
sort id_boot m_sec
quietly drop if m_sec == .

* convert time to minutes
quietly gen m_min = m_sec / 60
label variable m_min "Time since start of scenario (min)"

* Drop data beyond 15 minutes
quietly drop if m_min > 15

* count is the number of interventions performed by each team by time m_ses
by id_boot: gen count = _n

* Expand time so that everyone starts with 0 interventions and ends with
* their maximum number of interventions by 15 minutes

local littleN = _N
local bigN = _N + `n_teams'*2
quietly set obs `bigN'
forvalues i = 1/`n_teams' {
    quietly replace id_boot = `i'           if _n == `littleN' + `i'
    quietly replace m_min = 0               if _n == `littleN' + `i'
    quietly replace count = 0               if _n == `littleN' + `i'
    quietly replace checklist = `check`i''  if _n == `littleN' + `i'
    quietly replace scenario = `scen`i''    if _n == `littleN' + `i'
    quietly sum count if id_boot == `i'
    local maxcount`i' = r(max)
}
forvalues i = 1/`n_teams' {
    quietly replace id_boot = `i'       if _n == `littleN' + `n_teams' + `i'
    quietly replace m_min = 15    if _n == `littleN' + `n_teams' + `i'
    quietly replace count = `maxcount`i''   if _n == `littleN' + `n_teams' + `i'
    quietly replace checklist = `check`i''  if _n == `littleN' + `n_teams' + `i'
    quietly replace scenario = `scen`i''    if _n == `littleN' + `n_teams' + `i'
}
sort id_boot m_min
* m_max is the maximum number of possible interventions for the current id.
```


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```
* It is a function of the scenario and the ED.
* There is an intervention used in some scenarios that was not available in one ED.

quietly replace m_max = m_max[_n+1] if m_min == 0
quietly replace m_max = m_max[_n-1] if m_min == 15
* percent is the percent of interventions prformed by each team by time m_min
* on the assigned senario

quietly gen percent = 100*count/m_max
label variable percent "% of interventions performed"
tempfile long
quietly save "`long'", replace
clear
use "`times'"
quietly sum m_min, detail
quietly expand `n_teams'
sort m_min
quietly gen  id_boot = .
quietly replace id_boot = 1 if m_min != m_min[_n-1]
quietly replace id_boot = id_boot[_n-1] +1 if id_boot == .
quietly merge 1:m m_min id_boot using "`long'"
sort  id_boot checklist
quietly replace checklist = checklist[_n-1] if checklist == .
sort checklist id_boot m_min percent
quietly drop if m_min == m_min[_n+1]

quietly replace percent = percent[_n-1] if percent ==.
collapse (median) percent , by(checklist m_min)
sort checklist m_min percent
forvalues i =1/$num_times {
        return scalar timeNoCheck`i' = percent[`i']
        local j = $num_times + `i'
        return scalar timeWithCheck`i' = percent[`j']
}
end //----------------------------------------------

*################# Start of program #######################################################

log using Figure2.log, replace
* Figure2.log

* Graph the average % of interventions performed for each scenario by teams that
* are, and are not, using checklists as a function of time.
* Stop graph at 15 minutes

* n_teams is the number of ED teams participating in this trial

* This program uses percentile-based confidence intervals.

 local n_teams = 76

set seed 6616157
use Checklists_ED_interventions.dta
*N.B. Checklists_ED_interventions.dta was created by Figure1.do, which must be run before
*     running Figure2.do.

* Check if intervention time is given whenever the intervention is coded as being performed
* or if intervention time is given when the intervention is not performed

forvalues i = 1/10 {

* List if intervention is not done by time of intervention is given
    list id ed scenario checklist m`i'_done m`i'_sec if m`i'_done == 0 & m`i'_sec != .
* List if intervention is done by time of intervention is not given
    list id ed scenario checklist m`i'_done m`i'_sec if m`i'_done == 1 & m`i'_sec == .
}
sort id

* Calculate time to intervention from Canon and Sony times in minutes
* Note that Stata times are in miliseconds

forvalues i = 1/10 {
    gen m`i'_sec_canon = ( m`i'_time_canon- start_time_canon)/1000
    gen m`i'_sec_sony = (m`i'_time_sony- start_time_sony)/1000
* List if times are given for both timers
    list id  m`i'_sec_canon  m`i'_sec_sony if m`i'_sec_canon !=. &  m`i'_sec_sony != .
* List if no time is recorded but intervention was performed
```

```
    list id  m`i'_sec_canon  m`i'_sec_sony if m`i'_sec_canon ==. &  m`i'_sec_sony == . &
m`i'_done == 1
* Select intervention time to be the minimum recorded time.  Note that sometimes
* the timers disagree by a second.
    gen m_sec`i' =  min(m`i'_sec_canon, m`i'_sec_sony)
}

* Check that we have an intervention time whenever the intervention was done
forvalues i = 1/10 {
    list id m_sec`i' if m_sec`i' == . & m`i'_done == 1
}

tempfile widerealdata
save "`widerealdata'", replace

* Determine a list of all of the unique times at which interventions occured in
* the first 15 minutes.  Set the first and last time to be 0 and 15 minutes,
* respectively.  These times will be used in all bootstrapped samples

* Reformat the data so that there is one record for each intervention
reshape long m_sec, i(id) j(intervention)
sort id m_sec
drop if m_sec == .

* convert time to minutes
gen m_min = m_sec / 60
label variable m_min "Time since start of scenario (min)"

* Drop data beyond 15 minutes
drop if m_min > 15
keep m_min
local obsplus2 = _N + 2
set obs `obsplus2'
replace m_min = 0 if _n == _N -1
replace m_min = 15 if _n == _N
sort m_min
drop if m_min == m_min[_n-1]

* We will use the rarea command to graph confidence intervals.  This command
* does not permit the stairstep connect option. To induce this connection we
* enter a time that is 0.01 minutes before each value of m_min if the gap between
* between consecutive values is greater than 0.01.

gen too_wide = 1 +(((m_min - m_min[_n-1] ) > 0.01 ) & (m_min[_n-1] != .))
expand too_wide
sort m_min
replace m_min = m_min[_n+1] -0.01 if m_min == m_min[_n+1]
global num_times = _N
di " times = $num_times"
tempfile times
save "`times'"

clear
use "`widerealdata'", clear
medianInterventionsPerformed `times' `n_teams'
di "program completed"
use "`times'", clear
gen n_times = _n
gen checkpercent = .
gen nocheckpercent = .
forvalues i = 1/$num_times {
    local timeWith r(timeWithCheck`i')
    local timeNo r(timeNoCheck`i')
    quietly replace checkpercent = ``timeWith'' if _n == `i'
    quietly replace nocheckpercent = ``timeNo'' if _n == `i'
}
list n_times m_min checkpercent nocheckpercent if m_min == 0 |      ///
    (m_min > 5.04 & m_min < 5.06) | (m_min > 10.1 & m_min < 10.21) | m_min == 15


twoway (line checkpercent m_min , connect(stairstep) lcolor(red) lwidth(medthick))   ///
       (line nocheckpercent m_min , connect(stairstep)lcolor(blue) lwidth(medthick)) ///
     , name(interventionByTime2) graphregion(fcolor(white) lcolor(white))            ///
       ylabel(0(10)100, angle(0))  xlabel(0(2)14) xmtick(0(1)15)                     ///
       ytitle(% of interventions performed)                                          ///
       legend(order(1 "With checklist" 2 "Without checklist")                        ///
           ring(0) position(11) col(1))
```

```
tempfile longrealdata
save "`longrealdata'", replace

use "`widerealdata'", clear
medianInterventionsPerformed `times' `n_teams'
clear
set obs 1
forvalues i = 1/$num_times {
    local timeWith r(timeWithCheck`i')
    local timeNo r(timeNoCheck`i')
    quietly gen timeWithCheck`i' = ``timeWith''
    quietly gen timeNoCheck`i' = ``timeNo''
}
gen n=0
preserve
drop timeNo*
reshape long timeWithCheck , i(n) j(time_pt)
gen checklist = 1
tempfile longrealwithforboot
save "`longrealwithforboot'"
restore
drop timeWith*
reshape long timeNoCheck , i(n) j(time_pt)
gen checklist = 0
tempfile longrealnoforboot
save "`longrealnoforboot'"

use "`widerealdata'", clear

* Bootstrap confidence intervals for the percent of interventions
* performed at each time, with or without the checklist.
* Note that the unit of selection in this bootstrap is the team id
* and not the team's performance at any time. That is, in each bootstrapped
* sample we either select (with replacement) either all or none of the
* observations for any specific id.

* Bootstrapping will be statified by checklist status.  That is, each bootstrapped sample will
* contain 38 teams that used checklists and 38 teams that do not.

local boot_arg = " "
forvalues i = 1/$num_times {
    local boot_arg = "`boot_arg' timeWithCheck`i' = r(timeWithCheck`i') timeNoCheck`i' =
r(timeNoCheck`i')"
}
di "`boot_arg'"
bootstrap `boot_arg', rep(2000)  saving(bootstrap.dta, replace) strata(checklist):   ///
    medianInterventionsPerformed `times' `n_teams'

use bootstrap.dta, replace
gen n =_n

preserve
drop timeNo*
reshape long timeWithCheck , i(n) j(time_pt)
gen checklist = 1
tempfile longwithboot
save   "`longwithboot'"
restore
drop timeWith*
reshape long timeNoCheck , i(n) j(time_pt)
gen checklist = 0
tempfile longnoboot
save   "`longnoboot'"

append using "`longwithboot'" "`longrealwithforboot'" "`longrealnoforboot'"
sort n checklist time_pt
tempfile longboot
save "`longboot'"
use "`times'", clear
sort m_min
gen time_pt = _n

save "`times'", replace
merge 1:m time_pt using "`longboot'"
sort n checklist m_min

* Replot the real data to see if I have messed up.
```

```
twoway (line timeWithCheck m_min if n ==0 & checklist==1, connect(stairstep) color(red) ///
    lwidth(medthick)) (line timeNoCheck m_min if n==0 & checklist == 0, color(blue)     ///
    lwidth(medthick) connect(stairstep))                                                 ///
  , name(interventionbytimereal) graphregion(fcolor(white) lcolor(white))        ///
    ylabel(0(10)100, angle(0))  xlabel(0 (2) 14) xmtick(0(1)15) ytitle(% of interventions
performed)

* Plot each of the bootstrapped intervention percentages for checklist users as a function
* of time since start of intervention. Overlay the real intervention percentages on this
* plot.
preserve
keep if checklist == 1
twoway (line timeWithCheck m_min if n !=0 , connect(L) color(red) lwidth(vthin))      ///
     (line timeWithCheck m_min if n==0 & checklist == 1, color(blue) lwidth(medthick) ///
         connect(stairstep))                                             ///
   , name(bootwithcheck) graphregion(fcolor(white) lcolor(white))                    ///
     ylabel(0(10)100, angle(0))  xlabel(0 (2) 14) xmtick(0(1)15)                      ///
     ytitle(% of interventions performed) legend(subtitle("With checklist")           ///
         order(1 "Bootstrapped samples" 2 "Real data") ring(0) position(10) cols(1))

restore

* Plot each of the bootstrapped intervention percentages for non-checklist users as a function
* of time since start of intervention. Overlay the real intervention percentages on this
* plot.

preserve
keep if checklist == 0
twoway (line timeNoCheck m_min if n !=0 , connect(L) color(red) lwidth(vthin))        ///
     (line timeNoCheck m_min if n==0 & checklist == 0, color(blue) lwidth(medthick)   ///
         connect(stairstep))                                                          ///
   , name(bootnocheck) graphregion(fcolor(white) lcolor(white))                    ///
     ylabel(0(10)100, angle(0))  xlabel(0 (2) 14) xmtick(0(1)15)                      ///
     ytitle(% of interventions performed) legend(subtitle("Without checklist")        ///
         order(1 "Bootstrapped samples" 2 "Real data") ring(0) position(10) cols(1))
restore

* Plot the true compliance  curve together with the bootstrapped
* 95% confidence interval bands based on bootstrapped percentiles.

keep if n==0
* e(ci_percentile) is a matrix returned by the bootstrap program that gives the percentile-
based
* 95% confidence intervals for each of the median number of interventions calculated by
* medianInterventionsPerformed
matrix CI_percentile = e(ci_percentile)
matrix list CI_percentile
di "$num_times"
sort checklist m_min
gen index = .
replace index =_n*2    if checklist == 0 & _n <= $num_times
replace index =(_n - $num_times)*2 -1 if checklist == 1 & _n > $num_times

gen lb_pct=CI_percentile[1,index]       if checklist == 0
gen ub_pct=CI_percentile[2,index]       if checklist == 0
replace lb_pct=CI_percentile[1,index]      if checklist == 1
replace ub_pct=CI_percentile[2,index]      if checklist == 1

twoway (rarea lb_pct ub_pct m_min if checklist ==1, color(red*.4) lwidth(none))       ///
       (rarea lb_pct ub_pct m_min if checklist ==0, color(blue*.4%50) lwidth(none))   ///
       (line timeWithCheck m_min ,connect(stairstep) color(red) lwidth(medthick))        ///
       (line timeNoCheck m_min ,connect(stairstep) color(blue) lwidth(medthick))      ///
     , name(InterventionsByTimeCIptile) graphregion(fcolor(white) lcolor(white))       ///
       ylabel(0(10)100, angle(0))  xlabel(0(2)14) xmtick(0(1)15 )                     ///
       ytitle(% of interventions performed)                                           ///
       legend(subtitle("95% CIs") order(1 "" 2 "")  ring(0) position(11) col(1))
log close
```

Appendix 1 Table 12

Appendix 1 Table 12 was created by the program *Table2.do*. It runs a number of mixed-effects ordinal logistic regression models (also known as proportional odds regression models) that assess the effects of checklists and other team attributes on the number of interventions performed in 15 minutes. Random intercepts for the EDs and treatment teams are included in these models, with the effect for teams nested within the effect for EDs. The program also performs a maximum likelihood ratio test to compare each mixed-effects model with the analogous fixed effects model. Your must run *Figure1.do* before running *Table2.do*. *Table2.do* is given in the following monospaced font.

```
log using Table2.log, replace
* Table2.log

* Explore mixed effects proportional odds models on 15 minute data

use Checklists_ED_interventions.dta, clear

* Calculate the observed % of interventions performed by teams that did,
* and did not, use checklists
tabulate n15_interventions checklist, col

* Regress interventions in 15 minutes against checklist usage using a
* proportion odds model with EDs and teams treated as random effects.
* Teams are nested within EDs in this model
meologit n15_interventions checklist || ed: || team:
display "z = " _b[checklist]/_se[checklist]

* Display the P value associated with the null hypothesis that checklists
* have no effect on the number of interventions performed.
display "P = "2*normal(-abs(_b[checklist]/_se[checklist]))

* Display probability that a team using the checklist performed each of the possible
* number of interventions.
lincom -_b[/cut1] + _b[checklist]
* Probability of 1 intervention with checklist
di 1- invlogit(r(estimate))
di 1- invlogit(r(lb))
di 1- invlogit(r(ub))

nlcom 1- invlogit(-_b[/cut1] + _b[checklist])
* Probability of 2 interventions with checklist
nlcom    invlogit(-_b[/cut1] + _b[checklist])- invlogit(-_b[/cut2] + _b[checklist])
* Probability of 3 interventions with checklist
nlcom    invlogit(-_b[/cut2] + _b[checklist])- invlogit(-_b[/cut3] + _b[checklist])
* Probability of 4 interventions with checklist
nlcom    invlogit(-_b[/cut3] + _b[checklist])- invlogit(-_b[/cut4] + _b[checklist])
* Probability of 5 interventions with checklist
nlcom    invlogit(-_b[/cut4] + _b[checklist])- invlogit(-_b[/cut5] + _b[checklist])
* Probability of 6 interventions with checklist
nlcom    invlogit(-_b[/cut5] + _b[checklist])- invlogit(-_b[/cut6] + _b[checklist])
* Probability of 7 interventions with checklist
nlcom    invlogit(-_b[/cut6] + _b[checklist])- invlogit(-_b[/cut7] + _b[checklist])
* Probability of 8 interventions with checklist
nlcom    invlogit(-_b[/cut7] + _b[checklist])- invlogit(-_b[/cut8] + _b[checklist])
* Probability of 9 interventions with checklist
nlcom    invlogit(-_b[/cut8] + _b[checklist])- invlogit(-_b[/cut9] + _b[checklist])
nlcom    invlogit(-_b[/cut9] + _b[checklist])
lincom    -_b[/cut9] + _b[checklist]
* Probability of 10 interventions with checklist
di invlogit(r(estimate))
di invlogit(r(lb))
di invlogit(r(ub))

* Display probability that a team not using the checklist performed each of the possible
* number of interventions.
lincom -_b[/cut1]
* Probability of 1 interventions without checklist
di 1- invlogit(r(estimate))
di 1- invlogit(r(lb))
di 1- invlogit(r(ub))

nlcom 1- invlogit(-_b[/cut1] )
* Probability of 2 interventions without checklist
nlcom    invlogit(-_b[/cut1] )- invlogit(-_b[/cut2] )
* Probability of 3 interventions without checklist
```

```
nlcom    invlogit(-_b[/cut2] )- invlogit(-_b[/cut3] )
* Probability of 4 interventions without checklist
nlcom    invlogit(-_b[/cut3] )- invlogit(-_b[/cut4] )
* Probability of 5 interventions without checklist
nlcom    invlogit(-_b[/cut4] )- invlogit(-_b[/cut5] )
* Probability of 6 interventions without checklist
nlcom    invlogit(-_b[/cut5] )- invlogit(-_b[/cut6] )
* Probability of 7 interventions without checklist
nlcom    invlogit(-_b[/cut6] )- invlogit(-_b[/cut7] )
* Probability of 8 interventions without checklist
nlcom    invlogit(-_b[/cut7] )- invlogit(-_b[/cut8] )
* Probability of 9 interventions without checklist
nlcom    invlogit(-_b[/cut8] )- invlogit(-_b[/cut9] )
nlcom    invlogit(-_b[/cut9] )
lincom    -_b[/cut9]
* Probability of 10 interventions without checklist
di invlogit(r(estimate))
di invlogit(r(lb))
di invlogit(r(ub))

* Investigate the importance of years of experience of the senior physician
tabulate p1_exp_years
meologit   n15_interventions i.p1_exp_years  || ed: || team:

* Investigate the importance of whether the senior physician is a specialist
tabulate p1_specialist
meologit   n15_interventions i.p1_specialist || ed: || team:

* Investigate the importance of whether the senior physician is a man
tabulate p1_male
meologit   n15_interventions i.p1_male || ed: || team:

* Investigate the importance of years of experience of the senior nurse
tabulate p2_exp_years
meologit   n15_interventions i.p2_exp_years || ed: || team:

* Investigate the importance of use of cognitive aids without checklist
gen cognitive_aid = uses_local_cognitive_aid
replace cognitive_aid = 2 if checklist == 1
tabulate cognitive_aid
meologit   n15_interventions i.cognitive_aid || ed: || team:
log close
```


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Appendix 1 Table 13 and Table 14

Appendix 1 Table 13 and Table 14 were created by the program *Tables13&14.do*. It generates the P values for Table 13 and Table 14. Table 13 displays the impact of ED, team, senior physician experience, whether the senior physician is a specialist, scenario nurse, checklist access and scenario type on the number of interventions performed. Table 14 analyses whether any of these factors, with the addition of use of local cognitive aids, modifies the impact of checklist access on the number of interventions performed. These analyses also use mixed effects ordinal logistic regression models that are similar to those used in *Table2.do*.

```
log using Appendix1Tables13&14.log, replace
* Appendix1Tables13&14.log

* Test for confounding and interaction using a mixed effects proportional odds models on 15
minute data

use "..\Checklists_ED_interventions_short_200525.v5.dta", clear
tabulate n15_interventions checklist, col
gen col_n_int = n15_interventions
recode col_n_int 1/4 = 0 7/10 = 11
tabulate col_n_int checklist, col

* Test the importance of potentially confounding variables

* investigate the importance of individual EDs
meologit   n15_interventions i.ed   || team:
tabulate ed
test (2.ed 3.ed 4.ed)

* Investigate the importance of years of experience of the senior physician
tabulate p1_exp_years
meologit   n15_interventions i.p1_exp_years  || ed: || team:
test (2.p1_exp_years 3.p1_exp_years 4.p1_exp_years 5.p1_exp_years)

* Investigate the importance of whether the senior physician is a specialist
tabulate p1_specialist
meologit   n15_interventions i.p1_specialist || ed: || team:

* Investigate the importance of years of experience of the senior nurse
tabulate p2_exp_years
meologit   n15_interventions i.p2_exp_years || ed: || team:
test (2.p2_exp_years 3.p2_exp_years 4.p2_exp_years 5.p2_exp_years)

* Investigate the importance of checklist access
tabulate checklist
meologit   n15_interventions checklist || ed: || team:

* Investigate the importance of the scenario
tabulate scenario
meologit   n15_interventions i.scenario || ed: || team:
test (2.scenario 3.scenario 4.scenario 5.scenario 6.scenario 7.scenario 8.scenario )

* Test for interactions between checklists and potentially confounding variables

* investigate interaction between checklists and individual EDs
meologit   n15_interventions ed##checklist   || team:
test (2.ed#1.checklist 3.ed#1.checklist 4.ed#1.checklist  )

* Investigate interaction between checklists and years of experience of the senior physician
tabulate p1_exp_years
meologit   n15_interventions p1_exp_years##checklist  || ed: || team:
test (2.p1_exp_years#1.checklist 3.p1_exp_years#1.checklist 4.p1_exp_years#1.checklist
5.p1_exp_years#1.checklist)

* Investigate interaction between checklists and whether the senior physician is a specialist
tabulate p1_specialist
meologit   n15_interventions p1_specialist##checklist || ed: || team:

* Investigate interaction between checklists and years of experience of the senior nurse
tabulate p2_exp_years
meologit   n15_interventions p2_exp_years##checklist || ed: || team:
test (2.p2_exp_years#1.checklist 3.p2_exp_years#1.checklist 4.p2_exp_years#1.checklist
5.p2_exp_years#1.checklist)

* Investigate interaction between checklists and use of cognitive aids
tabulate uses_local_cognitive_aid
```


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```
meologit   n15_interventions uses_local_cognitive_aid##checklist || ed: || team:

* Investigate interaction between checklists and the scenario
tabulate scenario
meologit   n15_interventions scenario##checklist || ed: || team:
test (2.scenario#1.checklist 3.scenario#1.checklist 4.scenario#1.checklist
5.scenario#1.checklist ///
    6.scenario#1.checklist 7.scenario#1.checklist 8.scenario#1.checklist )


log close
```


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