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Clinical efficiency in a simulated emergency and relationship to team behaviours: a multisite cross-sectional study

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Objective To identify specific aspects of teamworking associated with greater clinical efficiency in simulated obstetric emergencies.

Design Cross-sectional secondary analysis of video recordings from the Simulation & Fire-drill Evaluation (SaFE) randomised controlled trial.

Setting Six secondary and tertiary maternity units.

Sample A total of 114 randomly selected healthcare professionals, in 19 teams of six members.

Methods Two independent assessors, a clinician and a language communication specialist identified specific teamwork behaviours using a grid derived from the safety literature.

Main outcome measures Relationship between teamwork behaviours and the time to administration of magnesium sulfate, a validated measure of clinical efficiency, was calculated.

Results More efficient teams were likely to (1) have stated (recognised and verbally declared) the emergency (eclampsia) earlier (Kendall's rank correlation coefficient $\tau_b = -0.53$, 95% CI from −0.74 to −0.32, $P = 0.004$); and (2) have managed the critical task using closed-loop communication (task clearly and loudly delegated, accepted, executed and completion acknowledged) ($\tau_b = 0.46$, 95% CI 0.17–0.74, $P = 0.022$). Teams that administered magnesium sulfate within the allocated time (10 minutes) had significantly fewer exits from the labour room compared with teams who did not: a median of three (IQR 2–5) versus six exits (IQR 5–6) ($P = 0.03$, Mann–Whitney *U*-test).

Conclusions Using administration of an essential drug as a valid surrogate of team efficiency and patient outcome after a simulated emergency, we found that more efficient teams were more likely to exhibit certain team behaviours relating to better handover and task allocation.

Keywords Closed loop, communication, eclampsia, education, emergencies, handoff, handover, leadership, magnesium sulfate, mnemonics, obstetric labour complications, patient care team, pre-eclampsia, SBAR, simulation, teaching, teamwork, training.

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Introduction

The effective management of critical clinical emergencies requires a rapid coordinated response by multiprofessional teams. It is known that some teams fail to manage clinical emergencies optimally because of poor teamworking, which can result in permanent harm and medical litigation.[1–3] The need to provide training for teams managing such emergencies has been identified as a priority for the reduction of preventable patient harm.[4–6] The specific aspects of teamworking that are associated with more effective care for medical emergencies have not yet been identified.[7,8]

Eclampsia is a potentially catastrophic obstetric emergency,[9,10] and its effective management requires maternity teams to perform several clinical tasks expeditiously. These include immediate life support and the administration of magnesium sulfate, for seizure control and secondary prevention.[11–13] The administration of magnesium sulfate in

this context is associated with a significant reduction in serious maternal and perinatal morbidity and mortality.[13] Using an analysis of simulated eclampsia as a model for the management of obstetric emergencies, it has been shown that some teams are significantly more efficient than others, and are therefore better able to perform key actions in a timely manner.[14] It has also been demonstrated that the difference in team efficiency is not explained by differences in the knowledge, skills and attitudes (KSA) of individual team members,[14] but is instead defined by their generic teamwork scores.[15]

Whereas generic teamwork scores (Appendix S1) are useful for research, they do not aid learning. If the specific behaviours of more effective teams could be identified through research, the information could be useful to evidence-based training programmes. The purpose of this study was to explore the relationships between team performance and team behaviours, including leadership, communication and task allocation.

Methods

This study was a cross-sectional secondary analysis of pre-intervention data from a randomised controlled trial of training for obstetric emergencies (Simulation & Fire-drill Evaluation, SaFE, study).[16] SaFE was a portfolio of studies commissioned by the Department of Health for England and Wales. The methodology has been described in detail elsewhere.[17]

Participants were recruited to the study in 2004–05, from six secondary and tertiary maternity units in South-West England.[17] Twenty-four participants were randomly selected from staff lists of each unit, and then allocated to one of four simulation teams. The individual teams were made up of staff from one unit, and each team comprised one senior doctor, one junior doctor, two senior midwives and two junior midwives. Members of staff were excluded if they had attended a nationally accredited obstetric emergency course within the last 12 months, had participated in a pilot study or were on leave. This study is limited to evaluations undertaken before the teams entered a training programme, so as to test the prevailing range of teamworking. The sample size had been pre-determined for the full factorial intervention trial, and not for this secondary analysis.

Teams were recorded within their own unit managing a simulated obstetric emergency (eclampsia) with a standardised scenario that included a patient-actor. Audiovisual equipment was installed in a labour room in each unit for simulations to be recorded. Team members wore a coloured sash to indicate their profession and seniority. The team members were not told of the nature of the scenario before entering the room. A team leader was not appointed by the research co-coordinators. A designated named midwife from the team was briefed alone in the room about a woman with pre-eclampsia in labour just before the simulation started (representing a normal clinical handover). A patient-actor was instructed to have a seizure for about 1 minute, starting 60 seconds from the end of the first handover. To maintain anonymity and confidentiality, no personal identifying information was recorded other than the audiovisual records that were stored safely as electronic files in a locked and password-protected research computer.

Success in obtaining, preparing and administering magnesium sulfate was regarded as the most important observable intervention, as the simulations were conducted at a time when the results of the Magpie Trial were widely known,[18] and the use of magnesium sulfate for both severe pre-eclampsia and eclampsia was strongly advocated.[13] The time interval to the administration of magnesium sulfate was recorded, but was censored when the drill was stopped, after 600 seconds (10 minutes) from handover, or earlier if the team began to transfer the patient to the operating room (because there was no facility to continue to record the simulation outside of the delivery room). A clinical efficiency score (CES) for the administration of magnesium sulfate was formulated and validated (Appendix S2).[14]

A list of specific observable and measurable aspects of teamworking, for content analysis of the SaFE study video records, was created.

Step 1

A literature review of teamworking was conducted on 24 June 2009. We searched Medline, Embase, ISI Web, the Cochrane Database of Systematic Reviews, the Cochrane Control Register of Controlled Trials (CENTRAL), the Database of Abstracts of Reviews and Effects (DARE), the ACP Journal Club, National Guidelines Clearing House, Cochrane Methodology Register, EBM Reviews—Health Technology Assessment, EBM Reviews—NHS Economic Evaluation Database, Trip and Ovid databases, including in-process and other non-indexed citations, using medical subject headings (MeSHs) and free terms (teamwork, leadership, emergencies, team training, teamworking and team simulation). In the final list (Table 1), we only included factors that had been derived from evaluation studies, and excluded studies with self-assessment by participants alone. None of the studies found addressed clinical outcome.

Step 2

A multiprofessional steering group (two language and communication researchers, one clinical research psychologist, two obstetricians, one research midwife and one statistician) met to discuss and transform the initial list to

Table 1. Literature-derived teamwork behaviours, from studies with evaluation of training

Teamwork behaviours	References
Leadership	
Leadership qualities	
• Declare command	20,56,57
• Confident posture	
• Confident voice	
• Handover command when necessary	
• Respond positively to challenges	
• Praise completed actions	
Team and task delegation	
• Check role, responsibility and ability for every individual	20,58–63
• Allocate tasks	
• Use all available resources and data	
• Prioritise tasks	
Situational awareness	
• Gather information from handover: ask for briefing, including the status of patient; respond appropriately to changes in the patient's status via reallocation of team resources	20,58,62,64–66
• Identify mistakes and lapses in other team members actions and address constructively	
• Manipulate environment to ensure data visibility	
• Assess progress towards goal: percentage of actions that the leader cross-checked to see if completed	
• Helicopter factor: avoid distraction or performing menial tasks	
Decision making	
• Identify options	20,58,65–67
• Ask for relevant information from team members before decision	
• Balance risks and make appropriate provisional diagnosis and decision	
• Re-evaluate decision	
Team communication	
Using SBAR statement to handover	
• Situation	68,69
• Background	
• Assessment	
• Recommendation	
Call-outs (critical actions or information communicated loudly)	68,70,71
Quality of messages (closed-loop communication, check-back)	
• Clear	8,44
• Directed	
• Acknowledged	
• Acted upon	
Team member behaviors	
Challenge errors	68
Back up behaviour: task assistance/mutual support when needed	8

create a practical assessment tool for content analysis of the SaFE study video records. We initially grouped teamwork behaviours under three headings: leadership, team communication and team-member behaviour. The steering group members agreed that several factors derived from aviation were not relevant to clinical teams. Others related to elective teamworking were not applicable to the *ad hoc* management of critical emergencies. The list was revised accordingly to include relevant teamwork behaviours alone. These were simply listed as individual factors: it was agreed that the initial group headings were potentially restricting.

Step 3

To determine which factors were observable and measurable in the available material, three video records were transcribed by a language & communication specialist (KB). One clinician (DS) and three social scientists (HH, JA and KB) reviewed the three transcripts and the corresponding video records, as well as a further three post-training video

records. Based on the findings the teamwork list was refined at a meeting of the steering group.

Step 4

The list was converted into a practical assessment grid that contained the teamwork behaviours agreed as suitable in step 3. The grid contained instructions on when to record event-based items as observed or not, and how to score generic behaviours. There was also free space for additional comments and observations. Two researchers, a clinician (DS) and a language and communication specialist (KB), viewed the audio-visual records independently using the analytical grid. At the end of the independent analyses they approached the videos again together. Table 2 describes how each teamwork behaviour included in the grid was assigned a score, and presents the system for addressing any differences between the two assessors that had been agreed in advance by the steering group.

Step 5

As proof of construct validity, we tested for correlation between our specific teamwork scores contained in the grid and the generic teamwork scores of the teams using a validated tool.[19] For generic teamworking (skills, behaviour and overall), the teams were scored by two trained external assessors (a doctor and a midwife) working independently, using a Likert scale (from 1, worst, to 5, best; Appendix S1).[19] The assessors viewed the digital video recordings in different sequences randomly generated by computer, blinded to the site, timing and type of training. If the scores were discordant, a third independent assessor (a doctor) scored the team, and the average of the scores was calculated and rounded to the nearest integer.[17] There were statistically significant relationships between the scores for specific teamwork behaviours contained in our grid and the Weller generic teamwork scores (Table 3).[19]

Because of the ordinal nature of most of the variables, non-parametric statistical methods (Kendall's rank correlation coefficient τ_b, Mann–Whitney *U*-test and Kruskal–Wallis one-way analysis of variance by rank) were used throughout. For correlations involving 'time to state (recognise and verbally declare) the emergency', intervals that were censored at the end of drill-time ($n = 2$) were included but given the maximum statistical rank.

The statistical package STATA was used for analysis (STATA/IC v11.1 for WINDOWS; StataCorp LP, College Station, TX USA), but SAS v9.1 'proc FREQ' (SAS Inst. Inc., Cary, NC, USA) was used to calculate asymptotic 95% confidence intervals for Kendall's τ_b. The sample size was insufficient for multivariate analyses.

Ethical approval was granted from a Regional Research Ethics Committee (South-West Devon MREC 04/Q2103/68). Further approval to extend the analysis was granted from the Local Research Ethics Committee (Southmead REC 09/H0102/40).

Results

Although 24 teams had undertaken a pre-training evaluation, one simulation was not recorded because of a fault in the recording equipment, and four teams were incomplete because of non-attendance (five members instead of six). To ensure consistency and reliable assessment of efficiency, we report only on the 19 complete teams with a full audio-visual record. A flowchart and descriptive data have been published previously.[17]

Twelve teams administered magnesium sulfate within the allocated time for the drill (10 minutes), and seven did not. The median handover-to-administration time was 415 seconds (IQR from 337 to >524 seconds). The quickest time to administration was 247 seconds, but the least efficient team had not even discussed the need for magnesium sulfate by the end of 10 minutes time limit. In all but one of the drills the senior doctor was seen to be the main leader, but qualitative observation of the video records showed a lack of explicit declaration of leadership in all of the drills. There was also no clear transfer of command at any points. One team did not call the senior doctor to help them, even though they were all available on request outside the simulation room. The junior doctor remained leader of the team until the end of the drill period. That team did not prepare magnesium sulfate for administration within the allocated drill time (10 minutes). Another observation was that it was not possible to assess confidence or stress of individuals reliably without interviewing the subjects (not allowed by the terms of the ethical approval), as there were no unambiguous external cues. There were very few observable instances of supportive behaviour or language. There were no observable teamwork behaviours in the videos other than those listed in Table 2. Detailed descriptive data are shown in Table 4.

Two teams did not state the nature of the emergency during the drill. Teams that were more efficient in administering magnesium sulfate were more likely to have stated the emergency using specific unambiguous terminology (eclampsia, fit, convulsion or seizure) earlier ($\tau_b = -0.53$, 95% CI from −0.74 to −0.32, $P = 0.004$), and to have managed the critical task using closed-loop communication ($\tau_b = 0.46$, 95% CI 0.17–0.74, $P = 0.022$).

Visual inspection of the data (Figure 1) suggested possible relationships between the CES and: (1) the use of an SBAR style of communication (situation, background, assessment and recommendation) during the handover to the senior doctor; (2) the number of exits from the labour room (while the emergency was taking place); and (3) having a leader with a higher global situational awareness

Table 2. List of observable and measurable teamwork behaviours

Specific teamwork behaviours	Notes	Scoring system and assumptions	Method of reaching final score
Leadership style	1. Directive: takes over and gives instructions, all further decisions made by him/her 2. Guiding : evaluates first then only supports previous/junior leader, and confirms their decisions 3. Mixed: gives some direct instructions but also evaluates and confirms others 3. Observational: no direction or guidance to previous leader (junior doctor, senior midwife or other)	Leader assigned one style (coded 1–4)	Video reviewed again by both assessors; mixed style assigned to leaders with elements of more than one style
Team coordination	• Proxy: number of instances where a team member exited the room • Also captured with global situational awareness and task allocation scores below	Number of instances (the higher the number, the worse the score)	Video reviewed; agreement between the two assessors
Situational awareness	a. Distraction score	Number of manual tasks performed by senior doctor (the higher the number, the worse the score)	Video reviewed; agreement between the two assessors
	b. Global situational awareness	3, asks questions to understand the situation, ensures that all team members have a clear picture of the objective, ensures that all team members have a clear role 2, asks a few questions, allocates/confirms roles and tasks for some team members only 1, unclear objective, does not ask questions, does not ensure everyone has a role	The two scores were added and one point was subtracted for a minimum of 1 and a maximum of 5. There were no cases with scores of 1 given by one assessor and 3 by the other.
Decision making	Overlapped with handover and task allocation; it was decided to drop it from the list of factors	–	–
Using SBAR statement to handover 1. Situation 2. Background 3. Assessment 4. Recommendation	There were at least two handover opportunities within each drill: one within the team before the senior doctor arrived (usually by the junior midwife to the rest of the team) and one from the team to the senior doctor	Each handover was assigned 5 points for each category (of the four) covered, plus one extra point for each item of information within each category	Video reviewed; agreement between the two assessors
Stating the emergency		The time was recorded that elapsed after the first handover until the emergency was stated as 'fit/seizure/convulsion'	Video reviewed; agreement between the two assessors
Task allocation with closed-loop communication 1. Task Delegated/questioned ('call-out')	Critical task: as obtaining, preparing and administering the magnesium sulfate was the single most important clinical action, the score was calculated for this task	Each team was assigned a score of 1–4 depending on the number of elements covered. 'Good' scores were 3 or 4.	Video reviewed; agreement between the two assessors

Table 2. (*Continued*)

Specific teamwork behaviours	Notes	Scoring system and assumptions	Method of reaching final score
2. Task accepted/confirmed (clearly and loudly for all of team) 3. Task executed 4. Task acknowledged as completed (clearly and loudly for all of team; 'check-back')			
Supportive language/behaviour		Number of instances where supportive behaviour (e.g. tap on the shoulder) or language ('perfect', 'brilliant', 'excellent' etc.) were observed	Video reviewed; agreement between the two assessors
Challenge errors and back-up behaviour	Would require specific event-based scenarios to elicit and reliably measure the response of the teams[20,72]	–	–

Table 3. Construct validity of the teamwork measurement tool: correlation with validated generic teamwork scores (GTS)[19]

Teamwork behaviour	Construct validity
Stating the emergency early	Highly significant correlation with 'skills' GTS (τ_b = −0.56, 95% CI from −0.76 to −0.36, P = 0.003)
Using SBAR structure for handover	Significant correlation with 'skills' GTS (τ_b = 0.43, 95% CI 0.10–0.76, P = 0.033; n = 18)
Task allocation with closed-loop communication	Significant correlation with 'overall' GTS (τ_b = 0.41, 95% CI 0.07–0.75, P = 0.047)
Fewer room exits	General correlation with 'skills' GTS (τ_b = −0.36, 95% CI from −0.65 to −0.07, P = 0.065)
Global situational awareness	General correlation with 'overall' GTS (τ_b = 0.38, 95% CI from −0.01 to 0.78, P = 0.066)
Instances of supportive language	Significant correlation with 'behaviour' GTS (τ_b = 0.44, 95% CI 0.12–0.76, P = 0.026)

score. The relationships were similar for the CES and SBAR-style handover, whether this occurred within the teams or by the teams to the senior doctors on arrival (data not shown). However, these relationships were not statistically significant using Kendall's rank correlation (all $P > 0.05$). Teams that administered magnesium sulfate within the allocated time (10 minutes, i.e. CES score 4 or 5) had significantly fewer exits compared with teams who did not: a median of three exits (IQR 2–5) versus six (IQR 5–6; $P = 0.03$, Mann–Whitney U-test). There were no clinically significant relationships between the CES and: (1) leadership style (Kruskal–Wallis (one-way analysis of variance by rank) test, $P = 0.54$); (2) the number of instances where supportive language was used ($\tau_b = 0.01$, $P > 0.99$); or (3) the number of manual tasks that were performed by the senior doctor ($\tau_b = -0.05$, $P = 0.82$).

Discussion

Teams that administered magnesium sulfate more efficiently demonstrated better handover (stating the emergency earlier and using an SBAR-like structure) and task allocation. Given that administration of magnesium sulfate for eclampsia is associated with a reduction in maternal and perinatal morbidity and mortality,[13] these findings suggest that by improving handover and task allocation skills, the clinical outcome of obstetric emergencies could be enhanced. There was no association between clinical efficiency and other aspects of teamworking that were measurable in this study. Some leadership and team behaviours could not be tested as they did not occur or were used infrequently.

One issue was that the sample size was predetermined by the original SaFE trial, and was not based on a power

Table 4. Descriptive data

Clinical efficiency Score	Specific teamwork behaviours									Total number of teams
	Managed to administer the essential drug (Mg)	Time from handover to stating the emergency (median, range)	SBAR handover score to senior doctor (median, range)	Teams with good task allocation score (*n*)	Number of exits from the room (median, range)	Number of tasks performed by senior doctor (median, range)	Global situational awareness score (median, range)	Leadership style	Instances of supportive behaviour or language (median, range)	
1. Did not obtain Mg	No	>557 seconds *	23	0	6	1	1	One mixed	0	1
2. Obtained but did not prepare Mg		59 seconds (39–524 seconds or more*)	25 (24–29; *n* = 3)	0	5.5 (4–6)	1 (0–2)	3 (2–4)	One directive, one guiding, two mixed	1.5 (0–4)	4
3. Prepared but did not administer Mg		46.5 seconds (33–60 seconds)	23.5 (20–27)	1	8.5 (5–12)	1.5 (1–2)	3 (2–4)	One directive, one mixed	1.5 (0–3)	2
4. Administered Mg but took 6 minutess or longer from start of drill	Yes	35.5 seconds (24–80 seconds)	25 (11–33)	4	3 (1–11)	0.5 (0–3)	3.5 (2–4)	One directive, one guiding, four mixed	1.5 (0–2)	6
5. Administered Mg in less than 6 minutess from start of drill		32.5 seconds (20–37 seconds)	28.5 (21–32)	5	3.5 (2–10)	0.5 (0–3)	3.5 (2–5)	Two directive, three mixed, one observational	0.5 (0–5)	6
Total		37 seconds (20–557 seconds or more; IQR** 31–60 seconds)	26 (11–33; IQR 24–29)	10 (53%)	1 (1–12; IQR 3–6)	1 (0–3; IQR 1–5)	3 (2–5; IQR 2–4)	Five directive two guiding 11 mixed one observational	1 (0–5; IQR 0–3)	19

*One observation censored at drill end.
**IQR, interquartile range.

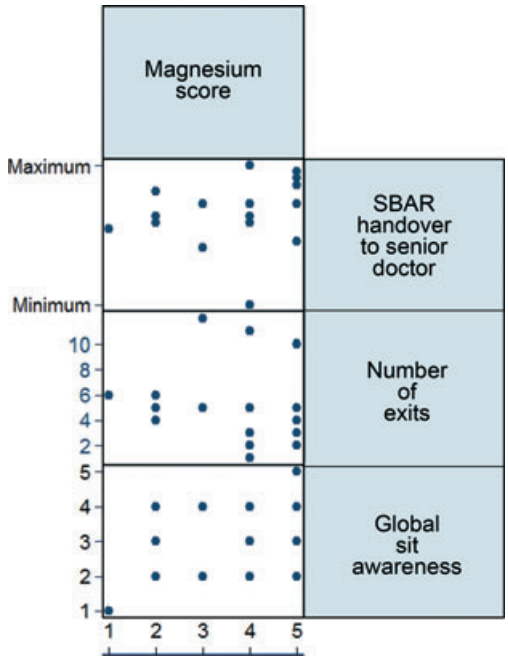

Figure 1. Scatter plot matrix of clinical efficiency scores for the teams (relating to the administration of magnesium sulfate) and selected teamwork behaviours, indicating a possible association.

calculation specific to this sub-analysis. Although the key findings are unequivocal, further study is needed to elucidate the role of behaviours of borderline statistical significance, and to determine interactions between variables. Another consideration was teams having been restricted to obstetricians and midwives. The immediate management of most obstetric emergencies usually involves obstetricians and midwives alone, however, with other professionals such as anaesthetists being summoned later.[17] In the eclampsia scenario written for this study, the patient-actor was instructed to stop fitting spontaneously by 2 minutes into the drill so that anaesthetic input was not part of optimal care. In addition to these issues, we were only able to test factors that were observable and measurable in the SaFE study simulation recordings. Additional factors may be relevant to the performance of *ad hoc* teams; these could be explored in the future with scenarios that include specific events aiming to elicit specific teamwork behaviours.[20,21] A final point is that we used records of simulated emergencies rather than records from real life. However, this would only be a limitation if one considers simulation as a low-fidelity approximation of real life. It has been shown that simulation, role play and rehearsals can all be viewed as a variety of naturally occurring data, as long as they elicit interactions between participants. They can be more valuable for research and training than would be expected of mere mimicry.[22]

The main strength of this study is the use of tools that were validated with a rigorous process, involving both quantitative and qualitative methodology, with experts from both disciplines. In addition, there was no reliance on self-assessment by the participants, which lacks objectivity, particularly for behaviours such as communication.[23–27] Outcome measures were event-based clinical actions (e.g. unambiguously stating the emergency; Table S1), together with a few externally scored measures of generic team behaviours (e.g. global situational awareness; Table S1). Event-based measures can identify teachable skills and behaviours,[24] and inform the development of education programmes. To ensure generalisable results, it was important that the participants had been selected randomly from several units across a large health region. It was also critical that they worked in teams with colleagues from their base hospitals, and so were familiar with team members and the clinical environment; future studies could test the degree to which such familiarity influences team performance. The study also benefited from matched teams working to a standardised eclampsia scenario. Overall, the simulation had a high level of realism in terms of environment, team composition and scenario content. Finally, the choice of magnesium sulfate administration as a surrogate marker of efficiency is supported by the safety literature, as a clinical action directly linked to improved patient outcome.[13,28]

Eclampsia is a largely unpredictable obstetric emergency of rapid onset that is associated with high maternal and perinatal mortality rates. Optimal care involves a small number of crucial tasks, including the administration of magnesium sulfate. The time to administration of magnesium sulfate varies significantly between teams in simulations,[17] and represents a measure of the efficiency of the coordinated response.[14] Given that the use of magnesium for eclampsia is associated with a reduction in maternal and perinatal morbidity and mortality,[13] the time to administration of magnesium is also a valid surrogate for patient outcome.

These new findings show that teams that are more efficient differ from those that are less efficient by a small number of relatively simple behaviours. It is often said that there is more to a team than the sum of its parts. Teamwork is used to describe the component of clinical performance that is more than the clinical knowledge and skills of the individual members. It has been shown that this can result in poor patient outcomes when group members do not coordinate their actions efficiently.[5,10] Despite an awareness of the importance of teamwork,[2,29] reliable methods to assess and develop team clinical behaviours have been lacking. 'Generic' teamwork taxonomies (Appendix S1) are useful for validation or assessment,[19] but they cannot identify specific teachable behaviours.[27] It may be for these reasons that team training based on principles adopted directly from aviation failed to make an impact on obstetric outcomes in a large cluster randomised controlled

trial.[30] Several systematic reviews of team training in obstetrics,[7,31] and other disciplines,[8,32,33] have concluded that aviation-based teamwork training alone has little impact on real outcomes, as opposed to practical team training and clinical drills.[31,34–36] It follows that assessment and training methods specific to each service may be needed.[37] It is reassuring that the same observable and measurable behaviours that made it to our final research tool correspond closely to the skills that were selected as suitable for training by more than 70% of respondents in the final round of a panel of teamwork experts.[38] This study confirmed that specific teamwork behaviours were linked to crucial clinical actions, potentially making them more amenable to improvement. Intuitively, it is likely to be more effective to teach clinicians 'to ask clearly for magnesium sulfate to be prepared and given' in the event of a woman with probable eclampsia, rather than tell them that they have to 'synthesise data and formulate a management plan'.[20]

We found that with more efficient teams the nature of the emergency had been unambiguously and clearly declared early on in the drill: the team arrived quickly to the correct diagnosis (eclampsia), and someone stated it clearly and loudly for all to hear (Table S1). In one simulation, the nature of the emergency was never declared, and that team did not even mention magnesium sulfate throughout the drill. A benefit of stating the emergency early has been hypothesised before, but not proven. There had been indirect evidence from malpractice incidents in emergency departments that the lack of identification of the emergency in hand, and thus the appropriate protocol to follow, was one of the main contributors to clinical error.[39] Our study shows a direct link between stating the emergency quickly and better team performance.

These data also show a probable benefit of the use of structured handover for emergencies. SBAR (Table S1) is one of the communication tools that have been suggested for improving rapid transmission ('handover') of important clinical information between team members or teams. A systematic review revealed a paucity of high-quality studies linking the use of handover mnemonics to clinical behaviour or outcome.[40] Although SBAR was not widely known at the time of the SaFE study (2004), some teams followed a similar structure, and those teams were also more efficient. Teaching of emergency care could usefully include SBAR tools specific to the context, similar to the perinatal tools available from the Institute for Health Improvement (IHI).[41]

Similarly, closed-loop communication has been widely advocated (task clearly and loudly delegated, accepted, executed and completion acknowledged; Table S1),[42,43] but its impact on the outcome of emergencies has not previously been shown. A pilot study from our group analysed four different recorded drills (postpartum haemorrhage), and found that tasks are more likely to be completed when directed to specific team members by using their name, touching them or directly looking at their face.[44] This new study now shows that closed-loop communication for the critical task of the scenario (in this study, the preparation and administration of magnesium sulfate) is associated with better team efficiency. It is interesting that the more efficient teams tended to have fewer exits from the room during the simulated emergency, but the nature of this association is not entirely clear. It may be an indicator of poor coordination, but it may also be a sign of displacement behaviour related to stress. Further research should aim to clarify this association and explore further issues (Table S2).

Teamwork was also not influenced by the style of the leader in this study. A possible explanation, which agrees with previous studies, is that the impact of the style of leader may vary with the experience of the team.[45] In our study all the teams contained two experienced midwives, and their presence has been previously shown to significantly enhance team performance in managing obstetric emergencies.[46] Perhaps the most important way to improve team effectiveness in managing emergencies, from a leadership viewpoint, is simply to ensure the presence of a senior doctor. There is evidence that the availability of senior doctors, particularly out of hours, is important, but is often lacking,[47–49] and this may result in poor outcomes.[47,50–52] This study focussed on the effect of team behaviours on measures directly linked to physical outcome. As patient experience is an important quality measure,[53] future research should also clarify the range of behaviours relating to team–patient interaction, and their effect on patient satisfaction and psychological outcome, with both simulation and patient surveys, with validated tools.[54,55]

For some time, teamwork training for healthcare staff has been advocated largely on the basis of opinion, and not on scientific evidence. This study shows it is possible to analyse team behaviours using a structured process and validated tools. The results show a clear relationship between clinical performance and defined teamwork behaviours in a simulated healthcare emergency. Future studies should determine whether the findings are relevant to real obstetric emergencies and generalisable to other specialties. There is an urgent need to understand how best to inculcate beneficial teamwork behaviours into practice, so as to improve clinical outcomes.

Disclosure of interests

All authors have completed a Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare that: (1) JFC received funding from the Department of Health,

and DS, KB, JA and HH were funded from the North Bristol Small Grant Scheme for the submitted work; (2) none of the other authors owns stock, or hold stock options, in any obstetric emergency training company; (3) none of the authors' spouses, partners or children has any financial relationships that may be relevant to the submitted work; and (4) TJD, CW and JFC are members of the steering committee of PROMPT, a UK-based charity running training courses. They have no financial interest from this association.

Contributions to authorship

All the authors participated in several multiprofessional meetings to design the study and develop the research tools. Everyone listed met the ICMJE criteria for authorship. More specifically: DS conceived the idea, designed and developed the assessment tool, conducted the video analysis, wrote and edited the article, and was the grant holder (NBT); KB designed and developed the assessment tool, conducted the video analysis, and edited the article; TD was the guarantor of the data, conceived the idea, coordinated the analysis and edited the manuscript; HH, supervised the analysis and edited the article; JA supervised the analysis and edited the manuscript; JC coordinated the SaFE study, helped with the conceptual analysis and approved the article; CW coordinated the SaFE study, helped with the conceptual analysis and edited the article; LH provided methodological considerations, conducted the statistical analysis, wrote parts of the article related to methods and edited the manuscript; RF contributed to the methodology, coordinated the analysis, and wrote and edited the article.

Details of ethics approval

This study was conducted in accordance with the Research Governance Framework for Health and Social Care, and Good Clinical Practice. Data storage and protection was in accordance with the research governance framework and the Data Protection Act. The study hypothesis arose before inspection of the data. The study protocol was approved by the ethics committee, the funder and the sponsor. Trial registration: ISRCT no. 67906788.

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Supporting information

The following supplementary materials are available for this article:

Table S1. Significant teachable behaviours.

Table S2. Teamwork behaviours that require further exploration.

Appendix S1. Generic teamwork scores.

Appendix S2. Clinical efficiency scores.

Additional Supporting Information may be found in the online version of this article.

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