Best Practice & Research Clinical Anaesthesiology 25 (2011) 239–249

Contents lists available at ScienceDirect

Best Practice & Research Clinical Anaesthesiology

journal homepage: www.elsevier.com/locate/bean

12

Simulation and CRM

Doris Østergaard, MD, DMSc *, Peter Dieckmann, Dipl.-Psych., PhD, Anne Lippert, MD, CHPE

Danish Institute for Medical Simulation, Herlev Hospital, Copenhagen University, Herlev, Denmark

Keywords:
simulation-based training
crisis resource management
non-technical skills
team training

Patients are harmed as a result of incidents. Both poor interdisciplinary communication and teamwork are contributing factors to such events. The principles of crisis resource management are meant to help prevent and manage difficulties and reflect both, the social-team-oriented and cognitive-individual-oriented aspects of human factors. This article explores the importance of human factors training for safe care of patients and the role of simulation. Based on the available literature, the need to integrate this type of training to increase awareness of the importance of human factors and to change attitudes appears obvious. A combination of different training methods appears to be useful. Simulation-based training appears to be favourable, although the number of studies demonstrating the impact of training is limited. It is important to develop training programmes for individual teams, based on the knowledge of challenges and deficiencies, and to monitor behavioural change. Several methods, including patient safety data, interviews, observational studies and simulations, can be used to specify learning objectives. The training should be established for the real team(s). Furthermore, leaders need to implement training in the organisation and establish databases to monitor the impact on patient outcome.

Anaesthesiology was one of the first specialities to demonstrate the impact of human factors in 1978.[1] An increased interest in learning from incidents was observed,[2] and resulted in considerable improvements in patient safety during anaesthesia over the past 30 years.[3] Although a recent review questions the results, due to methodological challenges,[4] it is widely believed that anaesthesia is safer

* Corresponding author. Tel.: +45 44883582.
E-mail address: dooe@heh.regionh.dk (D. Østergaard).

1521-6896/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.bpa.2011.02.003

today than it was earlier.[5,6] Patient safety has been improved by analysing and learning from events, and implementing necessary changes, such as introducing equipment for monitoring patients' vital parameters and evidence-based, standardised guidelines for procedures.[5] Furthermore, the first attempt, in the early 1990s, to systematically tackle such challenges was the introduction of the concept of anaesthesia crisis resource management (ACRM), which addressed human factors in the operating-room setting.[7,8] ACRM courses emphasised the importance of team skills and training for the actual team. Since then, several centres around the world have implemented simulation-based ACRM training. Those efforts emphasise the benefit of concerted analysis-and-intervention strategies. As the concept extended into different domains and specialities, it was called crisis resource management (CRM).

However, in the last two decades, several studies have emphasised that hospitalised patients are harmed as a result of errors and incidents occurring during their care.[3] Besides the suffering of those affected most – patients – their relatives and friends as well as health-care professionals suffer.[9] Several studies have shown that poor interdisciplinary communication and teamwork are important contributing factors to adverse events in general, in the operation room (OR) and in the area of perinatal deaths.[10–12] Poor communication was identified as the primary root cause in more than 70% of perinatal sentinel events recorded by the Joint Commission on Accreditation of Health Care Organisations.[13] This indicates that it is important to provide health professional teams with training in competencies; such as communication, teamwork, decision making and situation awareness, in addition to medical knowledge and practical skills.

The principles of CRM are intended to help prevent and manage difficulties during medical care, and they reflect both the social-team-oriented and cognitive-individual-oriented aspect of human factors.[14] Acquiring CRM abilities is, often, associated with a change of attitudes and behaviours as well as learning of new skills and de-learning of former habits. Change is necessary at the individual, team and organisational levels. As health professionals may constitute team members in different teams, it is important to develop a set of generic learning objectives (e.g., how to effectively communicate with unknown health-care professionals) as well as a set of specific objectives for a given team (e.g., solving a conflict in an existing team). The training of complete multi-disciplinary teams has been described to enable teams to function well, in both unexpected events and routine cases, to improve patient safety.[15,16] It is important to emphasise that simulation not only has a role in training people to handle catastrophes. CRM is equally important when handling common challenges and, in fact, can prevent a routine situation from deteriorating because early warning signs were missed. Simulation-based training has been recommended as a method to train teams in learning these skills for pedagogical and patient safety reasons, and the use of this tool is increasing across the world.

This article explores the importance of human factors training for high quality, safe care for patients and attempts to define the role that simulation can play with regard to these topics – both in terms of an analysis and as an interventional tool.

Aspects of patient safety and CRM in the medical domain

Like medicine, other high-risk domains such as the aviation industry, nuclear power plants, petroleum and maritime industries acknowledge the complexity of errors. Thus, error-management strategies need to be developed and implemented, focussing on reducing error as much as possible, while acknowledging that the zero-error rate will not be achievable. Reducing human error and minimising their negative impact might be tackled at different levels: at the system-design level, one might attempt to reduce error-triggering situations and, thus, make it easier to recognise errors and recover from them. Safety redundancies, multiple data sources, improved displays and alarm philosophies are examples of this level. The next level is to establish protective measures that shield patients and health-care professionals from errors that may occur (e.g., improved medication labels, double-checking of procedures). Education and training constitute another possible level to help health-care professionals avoid, recognise and recover from errors. This article focusses on this final level, emphasising, however, that integrated improvement strategies are required, and that they can be developed by applying CRM principles.

In most high-risk domains, training has shifted from focussing on knowledge, skills and attitudes related to the medical expertise of the operation, so-called technical skills (TSs), to focussing on non-technical skills (NTSs). By definition, NTSs are cognitive, social and personal resource skills that complement TSs, and contribute to safe and efficient task performance.[17] In traditional medical education, subject-matter expertise is rated very high. Less emphasis is, at times, placed on capabilities that help professionals to actually use their subject-matter expertise in challenging and ambiguous real-world situations. Being a good anaesthesiologist, however, also requires being able to work in multi-disciplinary teams and make decisions under conditions of uncertainty. Several frameworks have aimed at describing and defining NTSs comprising, among other elements, communication, co-operation, decision making, conflict resolution and workload management. These constituent elements are, often, tackled in CRM courses. NTSs and CRM are, thus, aimed to help the human aspect to prevent and manage errors that could not be arrested by system design or other protective barriers. The human ability to discover and recover from error should – or must – be improved individually and in a team.

The CRM concept was introduced more than 30 years ago in the aviation industry.[18] Since its inception, the concept has been further developed on the basis of safety data obtained from the organisation. In the medical domain, there is little analytical recognition of the role played by human error. In the past, errors in the care of individual patients were seldom investigated or discussed. While it is necessary to understand differences between aviation and medicine, some basic ideas will be applicable across contexts, the strongest of which might be the insight that isolated courses in NTSs will seldom show results, but must be supported by an organisations' safety behaviour across all levels. Further studies are needed to modify the experiences about how to improve safety using CRM programmes according to health-care's particular needs.[19]

Several challenges have to be overcome in the integration of NTSs into the medical curriculum.[16,19–21] The first challenge is to decide what is necessary to be taught.[21] It has been recommended to develop a stronger human factors theory base, make more use of the available theories and identify key skills in different situations and for different teams in medicine.[16] Another challenge is to develop and validate measurement tools, such as behavioural markers to measure skills in the necessary TSs and NTSs in receiving outcome-oriented education. A behavioural marker system has been developed for anaesthesiologists: the Anaesthestists' Non-Technical Skills System (ANTS).[22] Similar systems have been developed for surgeons, the Non-Technical Skills for Surgeons (NOTSS).[23] The Observational Teamwork Assessment for Surgery (OTAS) system has been developed for the evaluation of teams.[24] The links between the various systems and terms have been illustrated (see Table 1).[25] A further challenge within the medical domain is to link and embed NTSs with TSs such that it helps health professionals to understand the importance of both and to use them for the benefit of patients.

Overall, this review of the literature illustrates an increasing interest in CRM and NTSs and in introducing these in pre- and postgraduate educational programmes as well as continuous medical education for health professions. The challenge is to adapt to the users' needs and to fully implement this type of training in organisations. One method to get started is to increase awareness within the organisation.

Teams in the medical domain

Crisis or critical situations are challenging for several reasons including time constraints or nonspecific/unknown symptoms that make it difficult to arrive at a diagnosis. A critical situation often implies a complex problem that requires a well-functioning team comprising of experts from several disciplines working together. However, the team is, often, being formed as the situation develops, and team members may not have met each other before. Several intermediate teams might be formed until the complete multi-disciplinary team is established. Expert teams such as these can be described as 'ad hoc teams'.[10]

This 'ad hoc' team has several challenges. The members of the team are constantly exchanged and the team consists of specialists from different departments with diverse cultures. New team members have to be briefed and receive updated information efficiently to be able to participate quickly in the stabilisation of the patient. The role of the team leader is often emphasised, but it can be debated as to

Table 1
Illustrates the relationship between the elements in the Anaesthesia Non-Technical Skills (ANTS) system[22] and the Crisis Resource Management (CRM) system.[25]

ANTS	CRM
Cognitive and mental skills	
Planning and preparing	Anticipate and plan
	Know your environment
Prioritising	Exercise leadership
	Set priorities dynamically
Provide and maintain standards	Use cognitive aids
Identify and use resources	Distribute workload
	Mobilise all available resources
Gathering information	Use all available resources
Recognising and understanding	Allocate attention
Anticipating	Anticipate and plan
Identifying options	
Balancing risks and selecting options	Prevent and manage fixation errors
Re-evaluating	Re-evaluate repeatedly
Social and interpersonal skills	
Coordinating activities with team	Communicate effectively
	Teamwork
Exchanging information	Communicate effectively
Using authority and assertiveness	Exercise leadership and followership
Assessing capabilities	Exercise followership
Supporting others	

Table modified from Ref.[25]

who actually is the leader of a multi-disciplinary team. Transferral of leadership from one discipline to another can also be difficult when new team members come in, for example, from the obstetrician to the anaesthesiologist in the delivery room. Other challenges include the allocation of tasks to different team members and the ability to communicate effectively within the team, if the team members do not already know one another and each others' competencies. In the past, various health-care professionals have been educated to be self-reliant individuals in accordance with the curriculum of their chosen speciality, and, usually, the training has been focussed on medical expertise skills rather than teamwork. Therefore, a group of individuals, who are experts in their own fields, do not necessarily coalesce to form an ad hoc expert team.[26]

In addition to education, several other challenges exist in health care. Routine operations in hospitals are, often, performed in 'silos' or vertical structures such as wards, where the staff members work in teams consisting of health professionals who work within the same speciality and share a common culture. However, horizontal systems, used when patients have co-morbidities or are critically ill, are less well developed.[27] Therefore, team members in local teams are able to familiarise themselves more easily with routine tasks and their fellow team members over some time, but might be less familiar with handling complex or critically ill patients and working within a multi-disciplinary 'ad hoc' team. A critical situation is, by nature of some urgency, one which might contribute to the difficulties in the functioning of the 'ad hoc' team. In addition, differences in educational and patient safety cultures exist between hospital departments.[28] Therefore, neither the team member's individual education nor the hospital's structure and culture support the development of multi-disciplinary expert teams, and this may have major implications for patient safety. One could ask why multi-disciplinary training in handling emergency situations is not widely implemented, when patient safety literature has indicated the need for such training.[3]

Simulation-based training in the medical domain

Simulation-based training – how to do it

Full-scale simulations include a realistic manikin (neonate, child or adult) and monitor(s) placed in a realistic clinical environment, such as an OR, a ward or an ambulance. Monitors and manikins

interface with a computer program to project and display vital signs, voice and, sometimes, movements. In 'full-scale simulation-based training', the team members participate in a scenario: a patient case develops according to a set of learning objectives and the participants' actions, while the instructors adapt to participants actions.[29] The learning objectives can be related to TSs, NTSs or a combination. The scenario is audio- and video-recorded and clips from the recordings are used in the debriefing session (see below).

Change of attitudes and working mode is difficult for adults; simulation appears to be a promising tool to facilitate this. Several publications have described a set of principles and provided guidelines for using simulation-based training most efficiently.[25,26,30] Simulation should be used when appropriate and in combination with traditional methods.

A review reported findings that medical simulations were educationally effective, and that simulation-based education complemented medical education in patient-care settings.[31] Essential factors for the success of simulation-based education include providing feedback, integrating simulation into a curriculum and providing practise situations with variable levels of difficulty.[31] Furthermore, it aims to create a valuable learning experience for the participants.[31,32] The most important aspects are considered to be: the preparation of the participants for the simulations, the design of scenarios with well-described learning objectives and the description of the roles in the scenarios. This requires that the communication between participants and instructors be refined and a safe learning environment created, wherein these individuals can meet on common ground.[32] Selection and training of the facilitators are essential. Simulation-based training comprises of different phases which influence each other and need to be optimised jointly to achieve the learning objectives[32]; if not, a bad experience in the simulation-based scenario might negatively influence the debriefing.

'The debriefing' is a very important part of the simulation session, where participants can reflect on actions taken in the scenario and discuss them within the team. The facilitator can use small sequences from the recording to illustrate learning objectives. The relationship between participants and trainers is different from that in the classroom. In simulation-based training, the simulation instructors' role is not to teach, but to facilitate learning. For the participants to grow professionally, they must develop meta-cognitive skills, and among these is the ability to analyse critically ones' own performance. In the debriefing session, the facilitator steers the discussion and, by the use of questions, provides insight into frames (mental models) behind the participants' reactions and actions. Most of the time, the duration for debriefing should be longer than the simulation scenario itself. Several papers describe facilitation allocated to methods and debriefing procedures[33–37] while also describing debriefing processes[33] and assessment of debriefers. One of the difficulties in a debriefing is the balance between, on the one hand, delivering critique while avoiding defensiveness and maintaining psychological safety and, on the other hand, being superficial.[36,37] Different techniques of debriefing, and their pros and cons, have been discussed in an overview.[38] The educational efficacy of oral feedback, videotape-assisted oral feedback or no feedback (no debriefing) has been studied in a randomised controlled study.[39] A significant improvement in the participants' NTSs were seen after oral feedback or videotape-assisted oral feedback.[39] There was no improvement observed in the control group.

Training of teams in the medical domain

The Institute of Medicine (IOM) Report[3] recommended the use of simulation-based training in the medical domain, developed on the basis of positive experiences from the aviation industry. This is because the aviation industry turned itself into a highly reliable organisation through the use of simulation.[40,41]

Several institutions have taken the IOM recommendations seriously, and have introduced simulation-based training, such as the Kaiser Permanente that was described by Leonard.[19] Private entities, including experts from the aviation industry, are developing courses to fulfil this demand. Experts, however, emphasise that hospitals and teaching centres must take the lead themselves in developing team training and CRM programmes within health-care[16] because training should be based on materials and lessons learnt from their own domain and need to be context specific.

Training of established multi-disciplinary teams in hospitals does take place internationally, such as training of the cardiac arrest team,[42–44] the medical emergency team[45] and the trauma team.[46–48]

Training programmes have also been developed for teams from the emergency department, the operation theatre[49,50] and the obstetric team.[51–53] Some of these programmes have been developed based either on work analysis or by analysing which NTSs were needed.[44] The positive experiences from well-defined emergency teams have created an interest in training ward staff in handling patients at risk of developing critical illness, and this training of ward staff (doctors, nurses and nurse assistants) is becoming more widespread.[54] In general, it is important to train 'the real team' – to involve all the team members from different disciplines in the scenario.

One of the hot topics presently discussed is *in situ* training (training in the clinical setting) versus training in the simulation centre. Advantages and disadvantages of these different settings have been debated.[55,56] The advantages of *in situ* training include: training in the operational setting with the equipment used in daily life, wherein the entire organisation can be trained (secretaries, allied health professions, etc.; "train together, who works together") in procedures and guidelines. Furthermore, this type of training appears to be well suited for implementing change impulses and in instances where all staff members are to be trained in a short period of time to kick start an implementation procedure. Staff can use breaks and in-between shift time to train for procedures relevant to the shift. The disadvantages of *in situ* training include: interruptions of work; interruptions during training by work, logistical challenges and groups creating problems during training, if conflicts exists prior to the training. One major disadvantage pertains to the resources needed for the set-up, the availability of space for training and mobility of equipment. It can be difficult to actually step aside from patient treatment, especially during times of shortage of staff.

The major advantages of using a simulation centre are the preparedness of the room/equipment and the availability of human resources. In addition, staff members would enjoy a break from daily routine and have the ability to focus attention on new tasks together with team members. The risk of being drawn back to clinical work due to shortage of staff is minor.

In general, several of these disadvantages can be overcome if the simulation-based training is well planned, and these authors recommend that the location be chosen depending on the learning objectives and possibilities.

The development of a team training course

A systematic approach to course development can be recommended, for example, Harden's 10 steps for course development.[57] This approach has been used for planning a multi-disciplinary, full-scale, simulation-based course in the management of deteriorating hospital patients.[58] Guidelines for team training interventions have been described by Burke et al.[26] In Table 2, the 10 steps and the guideline are presented.

Any intervention should be based on a needs assessment and must be data driven. Patient safety data from incident reports and root-cause analyses are excellent sources of information. Simulation is used increasingly as an analysis (research) tool to analyse the working environment – often, in combination with interviews of staff members. It can be a valuable tool to analyse the interplay among humans, technology and organisation, and to uncover the system's weaknesses, which should be corrected; also in addition, it can demonstrate the competencies necessary for the multi-disciplinary team. Two papers have described this scenario in the obstetric environment.[59,60] Some studies have even tested the interventional changes in a simulated setting before they are introduced in the clinical setting. Simulation has also been used as an evaluative tool in the development of clinical research protocols and procedures.[61] Simulation is, therefore, seen as more than a new format for medical education; the simulation centre can be used as the institutional safety, and quality, laboratory.[43,62]

Based on analyses of such data, the learning objectives can be chosen and addressed by using different educational methods. Often, a combination of methods is used to optimise learning and address different learning styles. The principles of organising a multi-disciplinary group for CRM have been described by Murray and Foster, who strongly advocate the use of simulation for training CRM skills.[63] Some find it difficult to distinguish between the tool (the simulator) and the content (CRM), but CRM training can be imparted using other methods and a full-scale simulator can be used for other purposes.

Table 2
Guidelines for the development of training interventions according to Ref.[57] and for team training interventions by Ref.[26]

	Harden: 10 questions to ask	Burke and Salas 2006: 10 Guidelines
1.	Needs assessment	Design and development guided by team task analysis
2	Learning objectives	Ensure team training facilitates adaptive behaviours Ensure team members apply closed loop communication
3	Course Content	Develop team training to create systematic opportunities for practice of requisite team competencies
4	Organisation of content	Team training must emphasise key teamwork components
5	Educational strategies to be adopted	Design team training to facilitate shared understanding among team members
6	Teaching methods Course material	Pre practice tools to maximise the impact of training
7	Assessment	Evaluate team training and collect a variety of evidence as its impact
8	Communicating details of the curriculum to the students	Ensure latent organisational messages about the importance of team training match those that are spoken
9	Educational environment and climate	Team training must promote attitudes and behaviours that are indicative of a learning climate
10	How should the process be managed?	

Several CRM training programmes, that are based on classroom teaching, are available, but they are often used in combination with simulation-based training. A recent review article indicates the limited effect of classroom-based teaching for team training.[64] Theories on adult learning support the use of simulation-based training.[65] Adult learners prefer to learn through experience, and their biggest motivational factor is a need for knowledge that can improve their skills. Feedback is shown to be an important factor for learning to take place. Pre-course material is important to prepare the team members for the simulations and, hence, to optimise learning. The scenarios should be developed based on patient cases relevant for that particular team. Developing a course manual is essential to avoid major deviations from the learning objectives.

Overall, there is a need for studies demonstrating how to use simulation-based training optimally. Although the use of this type of training is burgeoning, our understanding of how simulation-based training influences team members, how their learning processes can be facilitated and the implementation of the learning in practise is limited.

Evaluation of simulation-based team training

Kirkpatrick's four-level model is often used for evaluation of educational or training interventions.[66] Level one, the reaction level, measures the participants' responses to the intervention. This can be used as a guide for further adjustment of the intervention. Level two, the learning level, illustrates the degree of change in the participants' knowledge, skills or attitudes. Self-assessment has been used as an indicator of the effectiveness of training, but the reliability of this method has been questioned.[67] Level three, the behavioural or organisational level, illustrates change of behaviour, impact on operating procedures or both. Level 4, the patient-outcome level, describes the benefit for the patients or the consequences of the training programme.

There are, however, several challenges in evaluating teams: which skills to measure (TSs, NTSs or both), who to evaluate (the individual or the team) and how to do it (develop validated evaluation tools). Furthermore, to ensure reliability, courses for evaluators have been developed and trainers' ratings compared. As described previously, behavioural marker systems have been developed for anaesthetists and surgeons.[22,23] Attempts have been made to design systems, such as the OTAS, for the evaluation of team performance in the operating theatre.[24] One of the challenges described is how to evaluate the effect if the team performance varies during the scenario or if one of the team members performs significantly different from the rest of the team.

Overall, there are numerous studies that describe the positive effects of simulation-based team training at the reaction level, but although the use of this technology is increasing, there are only a limited number of high-quality studies demonstrating the effect on learning and on patient safety.

In general, training appears to change the clinicians' reactions and attitudes in a positive way towards patient safety and CRM.[49,53,58] Self-reported change of CRM behaviours in managing an event had significantly, or to some extent, improved following 1 year or later after a simulation-based course.[53] Several studies have shown an effect on skills[51,59] following obstetric team training. Fewer mistakes were seen 6 months later in simulated scenarios.[59] Communication has been shown to be more directed and tasks more likely to be acknowledged and performed following obstetric team training.[68]

Only a few studies have focussed on the effect on patient outcome. Improved quality of care provided by residents during actual cardiac arrests has been demonstrated in a randomised controlled study.[42] The simulator-trained residents showed significantly higher adherence to standards than residents who underwent conventional training. In a large study including approximately 20 000 neonates, an improvement in perinatal outcome was shown after simulation-based team training.[51] The number of children with Apgar scores $\leq$6 decreased significantly after the intervention. A recent systematic review on the effectiveness of multi-disciplinary obstetric team training finds this type of education to be potentially effective, but recommends new studies on its effectiveness and cost effectiveness before a broader implementation is undertaken.[69]

Training with the 'real team' is considered to be important, and a positive effect on outcome with this type of training has been described[42,49]; however, others have failed to show an influence on outcome.[54,70] In the latter study, ward staff, doctors, nurses and nurse assistants were trained in identifying the critically ill patient. An incidence of one out of five patients at risk was observed in both the pre- and post-intervention periods. No difference in staff awareness of patients at risk, 30-day mortality or 180-day mortality was identified.[54] Larger-scale studies might be necessary to demonstrate an effect of simulation-based team training. Recently, the association between implementation of a medical-team training programme and surgical mortality has been demonstrated in a large-scale study involving 180 000 patients.[50] The training programme required briefings and debriefings in the operating theatre and introduces checklists as a part of the process. The training did not include simulation. An 18% reduction in mortality was seen after the training programme as compared with a 7% decrease in facilities where personnel had not undergone training.

The implementation of simulation-based team training

Following the study by Draycott et al. showing the impact on patient safety, hospitals in the region actually implemented this type of training.[51] Often, however, this was not the case. Simulation-based courses for the multi-disciplinary team are developed and conducted by enthusiastic simulation experts. Sometimes, this is conducted in collaboration with patient safety and human factors experts. The team members participating in the course often find the training very useful, but very few organisations actually move to an implementation phase. One explanation might be that, although clinicians see the benefit of the course – the need to change the way teams work together – the organisation has not reached that level of awareness. One reason might be that the effect of a given course or initiative on patient outcome in their organisation is not measured.

The study presented by Neily et al.[50] indicates that large-scale studies are necessary to show an impact on patient safety; the question is, whether we all need to conduct this type of studies in our organisations before CRM training is implemented.

Implementation of guidelines has proven to be difficult in the medical domain. To overcome the barriers for change, organisational programmes should be developed according to theories of change management. Facilitators in each department must be motivated and trained in order to be role models for other staff members and change culture. These authors strongly believe in using such facilitators as instructors in the simulation-based training programmes to link to clinical training. The involvement of staff in the development process, the conduction of the training and the implementation is vital, although the training to be a simulation instructor can be demanding. The main challenge is the involvement of key players and leaders, who can set the priorities.

Parallel to what is done in specialist training, simulation needs to be integrated in the training of staff.

Conclusion

First, based on the existing literature, it appears obvious to integrate sessions introducing CRM and NTSs to all staff members of the hospitals in order to increase awareness of the importance of human factors and to change attitudes. Second, it seems to be important to establish training for the real team(s) and evaluate the effectiveness. At present, this is not performed in a systematic way, and not all staff members participate in relevant team training courses. The challenge is to develop training programmes for the individual teams based on the knowledge of challenges and deficiencies and to monitor behavioural change. Several methods, including patient safety data, interviews with team members, observational studies, simulations in the clinical setting or combinations of the above, can be used to set learning objectives.

Programmes addressing generic CRM competencies and specific team-training programmes for all team members are necessary. Furthermore, there is a need to involve leaders and key players in the field to implement this type of training in the organisation and establish databases (and links to existing ones) that make it possible to monitor the impact on patient outcome. Finally, CRM might also help in designing work systems to be safer, when it spreads beyond the individual into organisational learning and development.

Practice points

- CRM/NTS training should be developed based on needs assessment.
- Learning objectives can be related to technical skills/non-technical/and combinations of both.
- Combinations of different methods can be used.
- Simulation-based training appears to be effective.
- Training of the actual team is essential.
- Training the organisation is necessary in order to change culture and not only the CRM skills.
- Involvement of leadership and key persons is necessary.
- Establishment of a multi-disciplinary research and development team is important.

Research agenda

- There is a need to strengthen research in medical education. Many of the publications present data illustrating a population of course participants without a thorough discussion of the generalisability of the data. Often, the studies lack a theoretical framework.
- There is a need to design studies to elucidate how to use simulation-based training and debriefing most efficiently and to provide an understanding of the benefits of this type of training – how does it support learning?
- There is a need to develop validated tools to assess effect of training and to train facilitators (raters) in how to use these tools.
- There is a need to establish multi-disciplinary research teams to be capable to conduct these types of studies and to obtain funding.

Conflict of interest statement

None declared.

References

1. Cooper JB, Newborner RS, Long CD et al. Preventable anesthesia mishaps: a study of human factors. *Anesthesiology* 1978; **49:** 399–406.

2. Gaba DM & DeAnda A. A comprehensive anesthesia simulation environment: re-creating the operating room for research and training. *Anesthesiology* 1988; **69**(3)**:** 387–394.
3. Kohn LT, Corrigan JM & Donaldson MS. *To Error is Human - Building a Safer Health System*. Washington, DC: National Academy Press, 1999.
4. Lagasse RS. Anesthesia safety: model or myth? A review of the published literature and analysis of current original data. *Anesthesiology* 2002; **97**(6)**:** 1609–1617.
5. Gaba DM. Anesthesiology as a model for patient safety in health care. *British Medical Journal* 2000; **320:** 785–788.
6. Cooper JB & Gaba D. No myth: anesthesia is a model for addressing patient safety. *Anesthesiology* 2002; **97**(6)**:** 1335–1337.
*7. Gaba DM, Howard SK, Fish KJ et al. Simulation-based training in anesthesia crisis resource management (ACRM); a decade of experience. *Simulation and Gaming* 2001; **32:** 175–193.
8. Howard SK, Gaba D, Fish KJ et al. Anesthesia crisis resource management training: teaching anesthesiologists to handle critical incidents. *Aviation, Space & Environmental Medicine* 1992; **63**(9)**:** 763–770.
9. Wu AW. Medical error: the second victim. The doctor who makes the mistake needs help too. *British Medical Journal* 2000; **320**(7237)**:** 726–727.
*10. Manser T. Teamwork and patient safety in dynamic domains of healthcare: a review of the literature. *Acta Anaesthesiologica Scandinavica* 2008; **52:** 1–9.
11. Lingard L, Garwood S & Poenaru D. Tensions influencing operating room team function: does institutional context make a difference. *Medical Eduation* 2004; **38:** 691–699.
12. Lewis G & Drife J. *Why mothers die 2000–2003. The sixth report of the confidential inquiries into maternal deaths in the United Kingdom*. London (UK): Royal College of Obstetricians and Gynecologists Press, 2004.
13. Joint Commission on Accreditation of Health Care Organizations. *Sentinel Event Alert* July 21, 2004. p. 30.
14. Rall M, Gaba DM, Howard SK & Dieckmann P. Human performance and patient safety. In Miller RD (ed.). *Miller's Anaesthesia*. Philadelphia: Elsevier Churchill Livingston, 2009a, pp. 93–149.
15. Preston PG. Patient safety in labour and delivery: a team approach to high reliability. *The American Society for Aesthetics Newsletter* 2007; **71**. www.asahq.org/Newsletters/2007/02-07/preston02_07.html.
*16. Musson DM & Helmreich RL. Team training and resource management in health care: current issues and future directions. *Harvard Health Policy Review* 2004; **5**(1)**:** 25–35.
17. Flin R, ÓConnor P & Crichton M. *Safety at the sharp end. A Guide to non-technical skills*. Aldershot, England: Ashgate Publishing Company, 2008.
18. Helmreich RL & Foushee HC. Why crew resource management? Emperical and theoretical bases of human factors training in aviation. In Wiener E, Kanki B & Helimreich RL (eds.). *Cockpit resource management*. San Diego, CA: Academic Press, 1993, pp. 3–45.
19. Leonard M, Graham S & Bonacum D. The human factor: the critical importance of effective teamwork and communication in providing safe care. *Qual Saf Health Care* 2004; **13:** 85–90.
20. Helmreich RL. On error management: lessons from aviation. *British Medical Journal* 2000; **320:** 781–784.
21. Glavin RJ & Maran NJ. Integrating human factors into the medical curriculum. *Medical Education* 2003; **37**(1)**:** 59–64.
*22. Fletcher G, Flin R, McGeorge P et al. Anaesthetists' Non Technical Skills (ANTS): evaluation of a behavioural marker system. *British Journal of Anaesthesia* 2003; **90**(5)**:** 580–588.
23. Yule S, Flin R, Paterson-Browne S, Maran N & Rowley D. Development of a rating system for surgeon's non-technical skills for surgeons. *Medical Education* 2006; **40:** 1098–1104.
24. Undre S, Sevdalis N, Healey AN et al. Observational teamwork assessment for surgery (OTAS): Refinement and application in urological surgery. *World Journal of Surgery* 2007; **31:** 1373–1381.
25. Rall M, Gaba DM, Dieckmann P & Eick C. Patient simulation. In Miller RD (ed.). *Miller's Anaesthesia*. Philadelphia: Elsevier Churchill Livingston, 2009b, pp. 151–192.
*26. Burke CS, Salas E, Wilson-Donelly K & Priest H. How to turn a team of experts into an expert medical team. *Qual Saf Health Care* 2006; **13**(1)**:** 96i–104i.
27. DeVita MA, Hillman K & Bellomo R (eds.). *Medical Emergency Teams*. USA: Springer, 2006.
28. Flin R, Burns S, Mearns K, Yule S & Robertson EM. Measuring safety climate in health care. *Qual Saf Health Care* 2006; **15:** 109–115.
*29. Dieckmann P, Lippert A, Rall M & Glavin R. When things do not go as expected: scenario Life Savers. *Simulation in Health Care* 2010; **5**(4)**:** 219–225.
*30. Dieckmann P, Gaba D & Rall M. Deepening the theoretical foundations of patient simulation as social practise. *Simulation in Health Care* 2007; **2:** 183–193.
*31. Issenberg SB, McGaghie WC, Petrusa ER et al. Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. *Medical Teacher* 2005; **27:** 10–28.
32. Dieckmann P. "Ein Bisschen wirkliche Echtheit simulieren": über Simulatorsettings in der Anästhesiologie. Doctoral Dissertation, Carl-von-Ossietzky Universitet Oldenburg 2005. http://docserver.bis.uni-oldenburg.de/publikationen/dissertation/2005/diebis05.html.
33. Dieckmann P, Friis SM, Lippert A & Østergaard D. The art and science of debriefing in simulation: ideal and practise. *Medical Teacher* 2009; **31:** 287–294.
34. Dismukes RK, Gaba DM & Howard SK. So many roads; Facilitated debriefing in health care. Editorial. *Simulation in Health Care* 2006; **1:** 23–25.
35. Steinwachs B. How to facilitate a debriefing. *Simulation and Gaming* 1992; **23:** 186–195.
*36. Rudolph JW, Simon R, Dufresne RL & Raemer DB. There's no such thing as "nonjudgemental" debriefing: a theory and method for debriefing with good judgement. *Simulation in Health Care* 2006; **1:** 49–55.
37. Rudolph JW, Simon R, Raemer DB & Eppich WJ. Debriefing as formative assessment: closing the performance gaps in medical education. *Academic Emergency Medicine* 2008; **15:** 1–7.
*38. Fanning RM & Gaba DM. The role of debriefing in simulation-based learning. *Simulation in Health Care* 2007; **2:** 115–125.
39. Salvoldelli GL, Nail VN, Park J et al. Value of debriefing during simulated crisis management. Oral versus video-assisted oral feedback. *Anesthesiology* 2006; **105:** 279–285.

40. Salas E & Burke CS. Simulation is effective when …. *Qual Saf Health Care* 2002; **11:** 119–120.
41. Salas E, Wilson KA, Burke CS & Priest HA. Using simulation-based training to improve patient safety. What does it take? *Journal on Quality and Patient Safety* 2005; **31:** 363–371.
42. Wayne D, Didwania A, Feinglass J et al. Simulation-based education improves quality of care during cardiac arrest team responses at an academic teaching hospital. A case-control study. *Chest* 2008; **133:** 56–61.
43. Dunn W & Murphy JG. Simulation. About safety, not fantasy. Editorial. *Chest* 2008; **133:** 6–9.
44. Andersen PO, Jensen MK, Lippert A et al. Development of a formative assessment tool for measurements of performance of multi-professional resuscitation teams. *Resuscitation* 2010; **81:** 703–711.
45. DeVita M, Schaefer J, Lutz J et al. Improving medical crisis team performance. *Critical Care Medicine* 2004; **32**(2)**:** S61–S65.
46. Knudson MM, Khaw L, Bullard MK et al. Trauma training in simulation: translating skills from SIM time to real time. *The Journal of Trauma: Injury, Infection and Critical Care* 2008; **64**(2)**:** 255–264.
47. Wisborg T, Brattebø G, Brattebø J & Brinchmann-Hansen A. Training multiprofessional trauma teams in Norwegian hospitals using simple and low cost local simulations. *Education for Health* 2006; **19**(1)**:** 85–95.
48. Yun S, Faraj S, Xiao Y & Sims HP. Team leadership and coordination on trauma resuscitation. In: . *Team Based Organizing* 2003; **9:** Elsevier Science Ltd, 2003, pp. 189–214.
49. Morey JC, Simon R, Jay GD et al. Error reduction and performance improvement in the emergency department through formal teamwork training: evaluation results of the med teams project. *Health Services Research* 2002; **37**(6)**:** 1553–1581.
50. Neily J, Mills PD, Young-Xu Y et al. Association between implementation of a medical team training program and surgical mortality. *Journal of The American Medical Association* 2010; **304:** 1693–1700.
51. Draycott T, Sibanda T, Owen L et al. Does training in obstetric emergencies improve neonatal outcome? *BJOG An International Journal of Obstetrics & Gynaecology* 2006; **113:** 177–182.
52. Robertson B, Schumacher L, Gosman G et al. Simulation-based crisis team training for multi-disciplinary obstetric providers. *Simulation in Health Care* 2009; **4:** 77–83.
53. Gardner R, Walzer TB, Simon R & Raemer D. Obstetric simulation as a risk control strategy. *Simulation in Health Care* 2008; **3:** 119–127.
54. Fuhrmann L, Perner A, Clausen T et al. The effect of multi-professional education on the recognition of patients at risk on general wards. *Resuscitation* 2009b; **80:** 1357–1360.
55. Rall M, Stricker E, Reddersen S & Dieckmann P. *Train where you work Mobile "in-situ" simulation training with video-assisted debriefing in different acute care settings* 2005. http://www.euroanesthesia.org/education/refreshcourses.php. Available at: ESA Refresher Course.
56. Rall M, Stricker E, Reddersen S et al. Mobile "in-situ" crisis resource management training: simulation courses with video-assisted debriefing where participants work. In R. Kyle & B.W. Murray (Eds.), Clinical Simulation: Operations, Engineering, and Management (pp. 565–581). Burlington: Academic Press.
57. Harden RM. Ten questions to ask when planning a course or curriculum. *Medical Education* 1986; **20:** 1700–1706.
58. Fuhrmann L, Østergaard D, Lippert A & Perner A. A multi-professional simulation based course in the recognition and management of the deteriorating patient. *Resuscitation* 2009a; **80:** 669–673.
59. Mazlovitz S, Barkai G, Lessing JB et al. Recurrent obstetric management mistakes identified by simulation. *Journal of Obstetrics and Gynecology* 2007; **109:** 1295–1300.
60. Daniels K, Lipman S, Harney K et al. Use of simulation based team training for obstetric crisis in resident education. *Simulation Health Care* 2008; **3:** 154–160.
61. Wright MC, Taekman JM, Barber L et al. The use of high-fidelity human patient simulation as an evaluative tool in the development of clinical research protocols and procedures. *Contemporary Clinical trials* 2005; **26:** 646–659.
62. Mehl K. Simulation as a tool for training and analysis. In Dieckmann P (ed.). *Using Simulations for Education, Training and Research*. Lengerich: Pabst, 2009, pp. 157–179.
63. Murray WB & Foster PA. Crisis resource management among strangers: principles of organizing a multi-disciplinary group for crisis resource management. *Journal of Clinical Anesthesia* 2000; **12:** 633–638.
64. Rabøl LI, Østergaard D & Mogensen T. Outcomes of classroom-based team training interventions for multiprofessional hospital staff. A systematic review. *Qual Saf Health Care* 2010; **19:** 1–11.
65. Knowles M. *The Adult Learner: A Neglected Species*. 4th ed. Houston, TX: Gulf Publishing Company, 1990.
66. Kirkpatrick DL. *Evaluating Training Programs*. San Francisco: Berrett-Koehler Publishers, Inc., 1998.
67. Colthart I, Bagnall G, Evans A et al. The effectiveness of self-assessment on the identification of learner needs, learner activity, and impact on clinical practice: BEME Guide no. 10. *Medical Teacher* 2008; **30**(2)**:** 124–145.
68. Siassakos D, Draycott T, Montague I & Harris M. Content analysis of team communication in an obstetric emergency scenario. *Journal of Obstetrics and Gynecology* 2009; **29**(6)**:** 499–503.
69. Merién AER, Van de Ven J, Mol BW et al. Multi-disciplinary team training in a simulation setting for acute obstetric emergencies. *Journal of Obstetrics and Gynecology* 2010; **115**(5)**:** 1021–1027.
70. Nielsen PE, Goldman MB, Mann S et al. Effects of teamwork training on adverse outcomes and process of care in labour and delivery: a randomized controlled trial. *Journal of Obstetrics and Gynecology* 2007; **109**(1)**:** 48–55.