Developing a team performance framework for the intensive care unit

Published as: Reader, T., Flin, R., Mearns, K., & Cuthbertson, B. (2009). Developing a team performance framework for the Intensive Care Unit. Critical Care Medicine, 35, 1789-1793

Developing a team performance framework for the intensive care unit

Tom W Reader PhD*, Rhona Flin PhD*, Kathryn Mearns PhD*, Brian H Cuthbertson** MD FRCA,

*School of Psychology, University of Aberdeen, Kings College, Aberdeen, Scotland, UK, AB24 2UB

**Health Services Research Unit, University of Aberdeen and Intensive Care Unit, Aberdeen Royal Infirmary, Foresterhill, Aberdeen, Scotland, UK, AB25 2ZD.

Short title: Team performance in the ICU

Name of institution where worked performed: University of Aberdeen, Aberdeen Scotland, UK.

Address for correspondence: Dr Tom Reader, School of Psychology, University of Aberdeen, King's College, Aberdeen, Scotland, UK, AB24 2UB

Phone +44 1224 273212; Fax +44 1224 273211; E-mail tom.reader@abdn.ac.uk

Financial support: This work was supported by a PhD studentship from the College of Life Sciences and Medicine (University of Aberdeen) and the Scottish Funding Council.

Reprints: Will not be offered.

Conflicts of interest: None.

Financial interests: None of the authors have any financial interests relating to this work.

Abstract

Objective: There is a growing literature on the relationship between teamwork and patient outcomes in intensive care, providing new insights into the skills required for effective team performance. The purpose of this review is to consolidate the most robust findings from this research into an ICU team performance framework.

Data Sources: Studies investigating teamwork within the intensive care unit within Pubmed, Science Direct and Web of Knowledge databases.

Study Selection: Studies investigating the relationship between aspects of teamwork and ICU outcomes, or studies testing factors found to influence team working in the ICU.

Data Extraction: Teamwork behaviours associated with patient or staff-related outcomes in the ICU were identified.

Data Synthesis: Teamwork behaviours were grouped according to the team process categories of 'team communication', 'team leadership', 'team coordination', and 'team decision making'. A prototype framework explaining team performance in the ICU was developed using these categories. The purpose of the framework is to consolidate the existing ICU teamwork literature, and to guide the development and testing of interventions for improving teamwork.

Conclusions: Effective teamwork is shown as crucial for providing optimal patient care in the ICU. In particular, team leadership appears vital for guiding the way in which ICU team members interact and coordinate with others.

Key words: ICU; Teamwork; Team performance framework; Training interventions; Patient safety; Leadership

Teamwork refers to the way in which team members function and coordinate to produce 'synchronised' output (1). Patient safety research has demonstrated that poor teamwork is a causal factor underlying critical incidents in the intensive care unit (ICU) (2). Due to this, a growing amount of research has been conducted within the ICU in order to identify the specific components of teamwork that influence patient outcomes (3,4). The main purpose of this research is to guide the design of training materials and workplace interventions to improve teamwork. However, at present the findings from studies investigating ICU teamwork are disparate and lack synthesis, therefore the extent to which they can influence practice, training and future research is limited. This review takes an industrial psychology perspective to summarise the ICU teamwork literature, and develops a conceptual team performance framework tailored for intensive care medicine.

Team performance frameworks

Psychology researchers in high-risk industries (e.g. aviation, military, nuclear power) have found effective teamwork as crucial for maintaining safety within these domains (5,6). In order to better understand the relationship between teamwork and performance in these settings, team performance frameworks (or models) have been developed. These show team outputs (e.g. team effectiveness, performance, errors) to be influenced by group 'processes' related to team communication, leadership, coordination and decision-making (7-11). Furthermore, group processes are influenced by a range of 'inputs' (e.g. group structures, member characteristics, work tasks) (12-14). The purposes of team performance frameworks are three-fold. Firstly, they systematise the mechanisms that predict team performance, thus facilitating the

design and structure of evidence-based team training materials and interventions for improving teamwork. Secondly, they detail the conditions, structures and procedures known to be indicative of effective teamwork, therefore providing valuable information for the training and assessment of teamwork skills. Lastly, team frameworks guide the evaluation of teamwork interventions through developing a structure against which to test expected change (e.g. attitudes, behaviours, performance).

In aviation, team performance frameworks have been used to develop sets of team competencies for flight crews (15). With respect to healthcare, it is necessary to develop tailored team performance frameworks that reflect the demands of specialities such as intensive care medicine (16). This paper reviews the ICU teamwork literature in order to consolidate knowledge on the relationship between teamwork structures, behaviours and performance in the ICU, and to begin the development of a team performance framework. It uses a standard group process model from psychology to consider studies that have collected data on the relationship between teamwork behaviours and ICU outcomes.

Method

The identification of ICU teamwork related studies involved a search of the Pubmed, Science Direct and Web of Knowledge Psychology databases for papers on teamwork in the ICU published since 1990. The search terms, method and inclusion criteria are shown in figure 1. Articles captured by the search strategy (initially 984 articles) were selected (by TR) on the relevance of their titles and abstracts with respect to whether

the article considered the topic of teamwork and performance in the ICU. The remaining articles (n=59) were then filtered in order to ascertain whether they actually provided empirical information on the relationship between ICU teamwork and outcomes (whether quantitative or qualitative). An examination of reference lists from the filtered articles (n=31) uncovered a further 4 items.

INSERT FIGURE 1 HERE

Results

In total 35 studies were identified as having investigated teamwork in the ICU. This set incorporates 31 peer-reviewed articles (of which 29 were published in medical journals), two book chapters and two peer-reviewed conference papers. Among the articles was a human factors error analysis of critical incident data that reported on 10 studies of error in the ICU (17). This paper was included rather than the individual critical incident studies discussed in it. The data collection methods used for the 35 studies included in the review varied considerably, and are listed in table 1.

INSERT TABLE 1 HERE

Of the papers not included in the final selection, many did not empirically investigate teamwork, and focused on topics such as education, promoting multidisciplinary teamwork, decision-support mechanisms and communicating with patients. The sections below discuss the key findings from the 35 studies that were identified by the search strategy. The findings are considered in terms of four teamwork processes

(team communication, team leadership, team coordination and team decision-making) identified as crucial for predicting team performance within the psychology teamwork literature (7-14).

Team Communication

Team communication relates to the transfer of information, ideas and opinions between the members of a team (18). Observations of ICU teams (19) have shown errors in the ICU to be concentrated after communication events (e.g. shift changes and handoffs) and 37% of errors to be associated with communication between nurses and physicians. Pronovost's group at John Hopkins University have analysed ICU adverse event/critical incident data from incident reporting systems (20-22). Their analysis has identified recurring team communication failures that lead to patient harm, with written and verbal communications during routine care, hand-offs, and crises being found most susceptible to error. More specifically, they found critical incidents to occur due to a reluctance of nursing staff to report observed errors or patient care issues, a lack of communication between clinicians and nursing staff on treatment changes, inaccurate information transfer between different ICU care teams and poor information dissemination on newly admitted patients. Survey and interview research have also examined the relationship between ICU team communications and patient outcomes (23), with timely, accurate and open communication between nurses and physicians being shown as predictive of patient length of stay and staff turnover (24).

Observations in high-fidelity simulator studies have studied team communication behaviours. Video analysis of teamwork during simulated patient resuscitations has found the communication skills of ICU residents to be rated most highly if they communicate clearly at all times, encourage team member input, listen to staff feedback, and consistently use directed verbal and non-verbal communications. Conversely, the communication skills of residents are rated most poorly when they fail to acknowledge staff communications and do not use directed verbal and non-verbal communications (25). High-fidelity simulator research has also established a relationship between team communication and technical performance (26), with ICU teams being assessed during the management of septic shock. Teams were rated highly if team members made clear and direct requests, employed closed loop communications, communicated the urgency of patient problems and shared information on the patient care plan. Teams were rated poorly if team members did not request appropriate information, or did not communicate treatment priorities and problems with patients. Teams rather than individuals were assessed and correlations were found between ratings on technical performance (e.g. making diagnoses) and scores on the behavioural aspects of performance (e.g. communication).

Thomas and colleagues (27) have built on measurements for assessing teamwork in commercial aviation in order to develop an observational rating system for assessing teamwork skills during neonatal resuscitation. Their research has investigated the relationship between assessments of teamwork and non-compliance with Neonatal resuscitation standards during 132 videoed neonatal resuscitations (27). The frequency with which NICU teams were observed to demonstrate team behaviours related to communication (e.g. information sharing, asking questions about infant

status or treatment plans), and also management and leadership, were found to be weakly correlated with compliance for Neonatal resuscitation standards. Furthermore, interns who received team training as part of neonatal resuscitation training were shown to display more teamwork related behaviours (e.g. information sharing) than those who did not receive training (28).

Survey research has investigated aspects of team structure, and in particular how status hierarchies influence perceptions of teamwork (29,30). For example, a majority of physicians report highly positive perceptions of communication openness between nurses and physicians, as compared to just over a third of nurses (30). A similar difference was found between senior and junior physicians. Survey research has also shown that ICUs with teams reporting high levels of group development (e.g. whether team members trust one another, discuss goals. and are not in conflict) have lower risk-adjusted mortality rates (31). Observational research during the ICU round has shown team member roles to influence interruptive behaviours, with physicians interrupting other caregivers roughly twice as often as nurses do (32). Ethnographic work in Canada has identified factors that influence whether ICU team members communicate collaboratively (33). These include whether the team has a shared perception of who was in the decision-making role during a specific scenario; whether team members work together to reach an understanding on patient conditions, and whether there are demanding time constraints on the delivery of care.

Team communication research in the ICU has shown communication to be linked to safety and performance, and that team structures and characteristics influence teamwork. Research in military and aviation has found similar trends (34), with team

leadership being identified as particularly important for structuring and regulating team communication processes (35).

Team Leadership

Data from ICU critical incident studies have indicated the importance of effective *team leadership* for safety (17,22). Team leadership refers to the guidance of a team (36), and involves defining goals, setting expectations, organizing team resources and coordinating team activities (37). Studies of leadership in industry and acute medicine tend to concentrate on four levels; action leaders (e.g. ad-hoc emergency teams), operational leaders (e.g. unit-level supervisors), tactical leaders (e.g. departmental managers) and strategic leaders (e.g. board level directors) (38-40). Leadership research in the ICU mostly focuses on the 'action' level. For example, simulator and real-life observations have shown associations between ratings of performance and leadership behaviours such as encouraging team member input, stating and evaluating plans, asserting opinions when appropriate, listening to staff feedback, delegating tasks effectively, prioritising aspects of care and ensuring team member comfort with allotted duties (25-27).

Simulator research has shown that team performance during cardiovascular resuscitation is optimal when the first arriving team leader (e.g. senior nurse, junior physician) demonstrates more immediate directive leadership behaviours (i.e. coordinating the teams), and when the late arriving senior physician systematically evaluates the situation and guides the team rather than taking charge immediately (41). Stockwell and colleagues (42) have investigated the impact of physician

management skills on the care provided to paediatric ICU patients. Using the Physician Management Index (PMI), 827 residents and fellows rated daily the ability of 8 attending physicians on 20 dimensions, including their ability to effectively lead and communicate with the ICU team, to manage resources, to set high standards, and to provide support on issues of performance and team development. The study found higher overall daily ratings by staff for attending physicians on the PMI were associated with higher numbers of patient goals being completed during NICU shifts. However, due to the small sample of physicians being assessed, it is not clear which specific attitudes/behaviours lead to this association.

Although effective team leadership appears important for the ICU, there are still relatively few in-depth investigations of senior physician leadership skills (43). Data from trauma centres, which face many similar challenges to the ICU, provide interesting insights into the nature of team leadership in acute healthcare teams. Observational and interview research with trauma centre teams has shown that team leaders demonstrate 'dynamic delegation' behaviours, whereby the senior physician delegates and withdraws the leadership role to junior physicians in order to spread the intense workload and to build junior physician confidence (44). Furthermore, scenario-based research investigating leadership during trauma resuscitation has indicated that leadership behaviours vary according to the situation. Team leaders show more directive leadership behaviours when the severity of trauma is high, or when a team is inexperienced (45). However, when trauma severity is low, or teams are highly experienced, team leaders delegate more responsibility to junior team members. This indicates the 'contingent' nature of team leadership within the ICU, whereby leadership behaviours are adapted according to the situation (46).

Research in neonatal ICUs has also indicated that the leadership style of the *team leader* influences teamwork. Specifically, leader inclusiveness (e.g. listening and encouraging junior team member ideas) has been shown to result in team members becoming more involved in ICU quality improvement programmes (47). Such research resonates with a long tradition of psychology research investigating leadership style (48,49). Additionally, leadership oriented interventions that focus on training teamwork skills (e.g. conflict management) to senior nurses and physicians are shown to result in staff having positive perceptions of unit leadership (50). However very little research has been published on how ICU senior physicians lead medical teams whilst managing ICUs on a day-to-day basis, and a better understanding is required of how team leadership behaviours influence the communication and coordination behaviours of ICU team members.

Team coordination

Team coordination refers to the concerted and synchronous performance of work activities by team members, with each team member maintaining an awareness of one another's work (51). Researching team coordination can be challenging, as it is difficult to distinguish between these behaviours, and team communication and leadership behaviours. Both of these are precursors (e.g. distributing workloads) and integral (e.g. information transfer) for effective team coordination, yet do not fully account for how team members adapt their activities to dovetail with one another.

Analyses of teams managing critical events during crisis management training has indicated errors to result from poor coordination, for example nurses being overloaded with requests, poor task delegation and a lack of prioritisation for care activities (52). Additionally, attitudinal research with ICU staff has found positive perceptions of team coordination (e.g. timely information transfer, awareness of team member activities, team member role clarity) to be associated with lower error rates (53). Survey research has also shown high levels of cooperation between ICU nurses and physicians to reduce reports of staff burnout (54). Observations during the real-life provision of ICU care have been used to study the behaviours ICU team members use to coordinate activities together. These behaviours include nurses cross checking physician-generated patient care plans, physicians and nurses providing 'heads-up' alerts to each other about pertinent information outside of the rounds and patient summaries being used to recap the discussion and highlight the core duties of team members (55,56). Lastly, structured observations in the NICU have shown effective workload management (i.e. task distribution and prioritisation) to be associated with independent measures of neonatal resuscitation quality (27).

Although team coordination is determined by factors such as team communication and team leadership, attempts have been made to restructure ICU tasks to improve coordination. For example, an intervention to improve patient transfers between surgery and ICU has adopted coordination principles from *Formula 1* racing pit-stop teams (57). Through segmenting the handover process into different stages (pre-handover, equipment and technology handover, information handover, discussion and planning), using checklists, and assigning ICU and surgical team members clear roles, there were improvements in teamwork (e.g. less omissions of patient information) and

fewer technical errors (e.g. equipment preparation) during intra-team handovers. Interventions have also focused on ICU rounds to make them more concise; to ensure patient care plan information is explicit; to ensure decision-makers are present, and to generate a secure team-based environment (58). This resulted in ICU staff reporting a better understanding of patient care plans alongside higher levels of satisfaction with rounds. Furthermore, adopting daily goal sheets (which structure the round process) has been shown to result in ICU residents and nurses better understanding their patient care duties, and in turn reduced patient lengths of stay (59). This resonates with the psychology 'shared mental model' literature, whereby teams communicate and coordinate more effectively when members form a shared mental model for goals, tasks and team member roles and responsibilities (60). These shared mental models facilitate team decision-making, which has also been of interest to ICU researchers.

Team decision-making

Team decision-making relates to decision-making (either by the leader on behalf of the team or amongst the members of a team) through integrating information and perceptions from the members of a team (61). As with team coordination, team decision-making is influenced by team communication and leadership. In the ICU, collaborative decision-making has been linked to improved patient outcomes. For example, units with higher levels of collaboration between nurses and physicians during patient-transfer decisions have lower rates of risk-adjusted mortalities and higher levels of nurse and resident job satisfaction (62). High levels of collaboration have also been suggested to potentially improve end-of-life care (63). Poor decision-making processes, for example the application of inappropriate plans and the use of

unsuitable techniques, have been shown to contribute to the occurrence of critical incidents (17). Clinician encouragement of team member communication and contributions during the ICU round patient decision-making process is associated with a reduction in adverse event rates (64). Furthermore, nurses and physicians tend to agree that junior team members should be able to question senior physician decision-making and that decision-making should include junior team member input (65).

Observational research in the ICU by Patel and Arocha (66) has shown that levels of collaboration during decision-making processes are influenced by the severity of patient conditions. When patient illnesses are well understood, team communication processes tend to be more 'democratic', and decisions are made after contributions from all team members. However, for more complicated patients, senior physicians tend to make key decisions autocratically, and with nurses communicating after performing information-gathering tasks. This reflects findings from trauma centres, which indicate team leaders to adapt their behaviours according to the situation. In particular, during high pressure phases of work, senior physicians adapt their behaviours to effectively lead the team (e.g. through adopting a swift and autocratic decision-making style) (45,67). This is aligned with the literature on decision-making and incident command within the military, emergency services, and aviation industries (68). Perceptions of caregiver involvement during decision-making in the ICU have also been shown to be influenced by team member-role. When asked to report perceptions of involvement in patient decision-making during the ICU round, senior nurses and junior physicians tend to report feeling uninvolved compared to senior physicians (69). This is consistent with survey research showing that nurses report finding it difficult to speak-up during decision-making, with fewer nurses than

physicians feeling that disagreements in the ICU are properly resolved, or that input from nurses about patient care is well received (70). Furthermore, ICU management tend to overestimate the extent to which nurses will have positive attitudes towards teamwork, with variations in attitudes even existing between the ICUs of a single institution (71).

Discussion

The findings from the ICU research investigating teamwork are incorporated into a prototype team performance framework for the ICU (Figure 2). In the framework, team processes are sub-divided into the processes of communication, leadership, coordination and decision-making. These processes (and behaviours drawn from the literature that are indicative of effective team processes) are shown as influencing ICU 'outputs'. Additionally, the inputs of 'team', 'task', and 'leader' are listed. These are factors which have been shown in either the ICU or general psychology literature to influence teamwork processes (7-14). The concepts included in the framework are limited to those that have been directly addressed in the ICU teamwork literature. However, it must be noted that there a number of teamwork concepts within the applied psychology literature that have yet to be investigated within the ICU, yet have been shown as important for safety and performance in other high-risk settings. For example, shared mental models for teamwork and taskwork information (72), team adaptability to changing circumstances (73), and the influence of organisational culture upon teamwork behaviours (74,75) are just some of the additional factors known to influence team performance. Furthermore, the framework does not necessarily illustrate the frequent changes in team composition that occur in ICU, the

influence this can have on performance (73), or the techniques that are used to mitigate the impact of constant changes in team personnel (e.g. having a well-established understanding of team roles (76)). Lastly, it is worth noting that the framework better reflects the leadership structure in 'closed' ICU, where unlike in 'open' ICUs, leadership and decision-making tends to rest with the intensivist (77).

There are a number of issues for discussion regarding this literature review. Firstly, the article search strategy focused on the relationship between teamwork and performance outcomes. It did not fully consider the consistency or quality of the ICU teamwork measurement tools. For example, data have been published on safety climate surveys containing subscales that focus on attitudes towards teamwork (65,71 78), and several observational measures have been developed to assess teamwork (25-27). It was beyond the scope of this review to assess or compare measures for their reliability or validity. However, there does exist a need to develop a comprehensive listing and review of the various tools available for measuring teamwork in the ICU.

It is also necessary to consider the types of data (self-report, observational, attitudinal, interviews) that have been collected to understand teamwork in the ICU (table 1). Each have well-documented limitations (79), such as the Hawthorn effect (80) or common method bias (81), and studies vary considerably in design, sampling strategies and statistical analysis. For example, surveys and observations in simulators tend to associate quantitative data measuring teamwork and patient/team outcomes, whereas real-life observations and interviews tend to generalise from the behavioural patterns observed by investigators or practioner reflections on teamwork. This makes

it difficult for this review to compare the weight or significance of individual study findings.

Lastly, it was found that the majority of reviewed studies supported the relationship between teamwork and ICU performance. As with any review of published literature, it is likely to be influenced by a publication bias (82). However, it is noticeable that a number of papers reported non-significant relationships between teamwork and outcome data. For example, although teamwork interventions and perceptions of teamwork are often associated with reduced patient length of stay, they are rarely associated with risk-adjusted mortality (24, 42). Furthermore, when ICUs are compared against one another, units with higher ratings of teamwork do not necessarily perform better on measures of unit performance (23). Lastly, many studies use correlation analyses to test the relationship between measures of teamwork and measures of performance. More complicated predictive analyses are required to fully understand the relationship between teamwork processes and technical or organisational outcomes. This in itself poses numerous difficulties, for example ensuring that study sample sizes are adequate and that teamwork metrics are reliable. Furthermore, there is need to develop longitudinal research designs and to identify a wider range of ICU outcome data that can be used for assessing team performance (16,83).

Conclusions

The prototype team performance framework (figure 2) consolidates the existing knowledge regarding teamwork and outcomes in the ICU, and provides a structure

against which to design and evaluate teamwork interventions. An emerging direction for future research is the relationship between team leadership and team performance. Due to the hierarchical nature of acute medical teams, the behaviours of senior physicians appear to significantly influence the perceptions and behaviours of other team members. In developing interventions and team training programmes, it is therefore critical to fully understand the role of leadership in ICU teams.

References

1. Paris C, Salas E, Cannon-Bowers J: Teamwork in multi-person systems: A review and analysis. *Ergonomics* 2000;43: 1052-1075

2. Wright D, Mackenzie M, Buchan I, et al: Critical incidents in the intensive therapy unit. *Lancet* 1991; 14:676-681

3. Institute of Medicine: To err is human: Building a safer health system. Washington DC, Institute of Medicine, 2000

4. Reader T, Flin R, Cuthbertson B: Communication skills and error in the intensive care unit. *Curr Opin Crit Care* 2007; 13:732-736

5. Lucas D: The causes of human error. *In:* Human factors in safety critical systems. Redmill R (Ed). Oxford, Butterworth Heinemann, 1997, pp 37-65

6. Helmreich R, Foushee H: Why crew resource management? Empirical and theoretical bases of human factors training in aviation. *In:* Cockpit crew resource management. Weiner E, Kanki B, Helmreich R (Eds). San Diego, Academic Press, 1993, pp 3-45

7. Weiner E, Kanki B, Helmreich R: Cockpit resource management. San Diego, Academic Press, 1993

8. O'Connor P, HoÈrmann J, Flin R, et al: Developing a method for evaluating crew resource management skills: A European perspective. *Int J Aviat Psychol* 2002; 12:263-285

9. McGrath J: Social psychology: A brief introduction. New York, Holt, Rinehart and Winston, 1964

10. Brown R: Group processes : Dynamics within and between groups. Oxford, UK, Blackwells, 1988

11. Steiner I: Group processes and productivity. New York, Academic Press, 1972

12. Salas E, Dickinson T, Converse S, et al. Towards an understanding of team performance and training. *In:* Teams: their training and performance. Swezey R and Salas E (Eds). Norwood, NJ, Ablex, 1992, pp 3-29

13. Tannenbaum S, Beard R, Salas E: Team building and its influence on team effectiveness: An examination of conceptual and empirical developments. *In:* Issues, Theory, and Research in Industrial/Organizational Psychology. Kelley K (Ed) Amsterdam, Elsvier, 1992, pp 117-153

14. Unsworth K, West M: Teams: The challenges of cooperative work. *In:* Introduction to work and organizational psychology. Chanel N (Ed). Cornwall, Blackwell, 2000, pp 327-346

15. Bowers C, Jentsch F, Salas E: Establishing aircrew competencies: A comprehensive approach for identifying CRM training needs. *In*: Aircrew training and assessment. O'Neil H and Andrews D (Eds). NJ, LEA, 2000, pp 67-83

16. Manser T: Team performance assessment in healthcare: Facing the challenge. *Simulation in Healthcare* 2008;3:1-3

17. Reader T, Flin R, Lauche K, et al: Non-technical skills in the intensive care unit. *Br J Anaesth* 2006;96:551-559

18. Flin R, O'Connor P, Crichton M: Safety at the sharp end. A guide to non-technical skills. Aldershot, Ashgate, 2008

19. Donchin Y, Gopher D, Olin M, et al: A look into the nature and causes of human errors in the intensive care unit. *Crit Care Med* 1995; 23:294-230

20. Pronovost P, Wu A, Dorman T, et al: Building safety into ICU care. *J Crit Care* 2002; 17:78-85

21. Pronovost P, Wu A, Sexton J: Acute decompensation after removing a central line: Practical approaches to increasing safety in the intensive care unit. *Ann Intern Med* 2004; 140:1025-1033

22. Pronovost P, Thompson D, Holzmueller C, et al: Toward learning from patient safety reporting systems. *J Crit Care* 2006; 21:305-315

23. Zimmerman J, Shortell S, Rousseau D, et al: Improving intensive care: Observations based on organizational case studies in nine intensive care units: A prospective, multicenter study. *Crit Care Med* 1993; 21:1443-1451

24. Shortell S, Zimmerman J, Rousseau D, et al: The performance of intensive care units: Does good management make a difference? *Med Care* 1994; 32:508-525

25. Kim J, Neilipovitz D, Cardinal P, et al: A pilot study using high-fidelity simulation to formally evaluate performance in the resuscitation of critically ill patients: The university of Ottawa critical care medicine, high-fidelity simulation, and crisis resource management I study. *Crit Care Med* 2006; 34:2167-2174

26. Ottestad E, Boulet J, Lighthall G: Evaluating the management of septic shock using patient simulation. *Crit Care Med* 2007; 35:769-775

27. Thomas EJ, Sexton J, Lasky R, et al: Teamwork and quality during neonatal care in the delivery room. *J Perinatol* 2006;26:163-169

28. Thomas EJ, Taggart B, Crandell S, et al: Teaching teamwork during the neonatal resuscitation program: A raondmized trial. *J Perinatol* 2007;27:409-414

29. Miller PA: Nurse-physician collaboration in an intensive care unit. *Am J Crit Care* 2001; 10:341-350

30. Reader T, Flin R, Mearns K, et al: Interdisciplinary communication in the intensive care unit. *Br J Anaesth* 2007; 98:347-352

31. Wheelan S, Burchill C, Tilin F: The link between teamwork and patients' outcomes in intensive care units. *Am J Crit Care* 2003; 12:527-534

32. Alvarez G, Coiera E: Interruptive communication patterns in the intensive care unit ward round. *Int J Med Inf* 2005; 74:791-796

33. Hawryluck LA, Espin SL, Garwood KC, et al: Pulling together and pushing apart: Tides of tension in the ICU team. *Acad Med* 2002; 77:73-76

34. Guzzo R, Dickson MW: Teams in organizations: Recent research on performance and effectiveness. *Annu Rev Psychol* 1996; 47:307-338

35. Salas E, Burke C, Stagl K: Developing teams and team leaders: Strategies and principles. *In:* Leader development for transforming organizations. Growing leaders for tomorrow. Day D, Zaccaro S, Halpin S (Eds). New Jersey, Lawrence Erlbaum Associates,2004, pp 325-355

36. Stewart G, Manz C: Leadership for self-managing work teams: A typology and integrative model. *Hum Relat* 1995; 48:747-770

37. Salas E, Wilson-Donnelly K, Sims D, et al: Teamwork training for patient safety: Best practices and guiding principles. *In:* Handbook of human factors and ergonomics in health care and patient safety. Carayon P (Ed). New Jersey, Lawrence Erlbaum Associates,2007, pp 803-822

38. McCormick S, Wardrope J: Major incidents, leadership, and series summary and review. *Emerg Med J* 2003; 20:70-74

39. Flin R, Yule S, Perry S: Leadership behaviours and safety in the emergency department. In Croskerry P, Cosby K, Schenkels, Wears R (Eds.) *Patient Safety in Emergency Medicine.* Philadelphia: Lippinicott Williams & Wilkins, *In Press*

40. Yukl G: Leadership in organisations. New Jersey, Prentice Hall, 2006

41. Tschan F, Semmer N, Gaustchi D, et al: Leading to recovery: Group performance and coordinative activities in medical emergency driven groups. *Human Performance* 2006; 19:277-304

42. Stockwell D, Slonim A, Pollack M': Physician team management affects goal achievement in the intensive care unit. *Pediatr Crit Care Med* 2007;8:840-845

43. Strach van Schijndel R, Burchardi H: Bench-to-bedside review: Leadership and conflict management in the intensive care unit. *Crit Care* 2007; 234:

44. Klein K, Ziegert J, Knight P, et al: Dynamic delegation: Shared, hierachical, and deinidivudalized leadership in extreme action teams. *Adm Sci Q* 2006; 51:590-621

45. Yun S, Faraj S, Sims H: Contingent leadership and effectiveness of trauma resuscitation teams. *J Appl Psychol* 2005; 90:1288-1296

46. Hersey P, Blanchard K, Johnson D: Management of organizational behavior. Upper Saddle River, NJ, Prentice Hall, 1996

47. Nembhard I, Edmondson AC: Making it safe: The effects of leader inclusiveness and professional status on psychological safety and improvement efforts in health care teams. *J Organ Behav* 2006; 27:941-966

48. Bass B, Avolio B, Jung D, et al: Predicting unit performance by assessing transformational and transactional leadership. *J Appl Psychol* 2003; 88:207-218

49. Stodgill R: Personal factors associated with leadership: A review of the literature. *J Appl Psychol* 1948; 24:35-71

50. Boyle D, Kochinda C: Enhancing collaborative communication of nurse and physician leadership in two intensive care units. *J Nurs Adm* 2004; 34:60-70

51. McIntyre J, Salas E: Measuring and managing for team performance: Emerging principles from complex environments. *In:* Team effectiveness and decision-making in organizations. Guzzo R and Salas E (Eds). San Francisco, Jossey-Bass, 1995, 9-45

52. Lighthall G, Barr J, Howard S, et al: Use of a fully simulated intensive care unit environment for critical event management training for internal medicine residents. *Crit Care Med* 2003; 31:2437-2443

53. van Beuzekom M, Akerboom SP, Boer F: Assessing system failures in operating rooms and intensive care units. *Qual Saf Health Care* 2007; 16:45-50

54. Poncet M, Toullic P, Papazian L, et al: Burnout syndrome in critical care nursing staff. *Am J Respir Crit Care Med* 2007; 175:698-704

55. Albolino S, Cook R, O'Connor M: Sensemaking, safety, and cooperative work in the intensive care unit. *Cognition, Technology and Work* 2007; 9:131-137

56. Patterson E, Hofer T, Brungs S, et al: Structured interdisciplinary communication strategies in four ICUs: An observational study. Paper presented at the *Human Factors and Ergonomics Society 50th meeting*; San Francisco, 2006

57. Catchpole K, de Leval M, McEwan A, et al: Patient handover from surgery to intensive care: using Formula 1 pit-stop and aviation models to improve safety and quality. *Paediatr Anaesth* 2007; 17:470-8

58. Dodek P, Raboud J: Explicit approach to rounds in an ICU improves communication and satisfaction of providers. *Intensive Care Med* 2003; 29:1584-1588

59. Pronovost P, Berenholtz S, Dorman T, et al: Improving communications in the ICU using daily goals. *J Crit Care* 2003; 18:71-75

60. Mathieu J, Heffner J, Goodwin G, et al: The influence of shared mental models on team process and performance. *J Appl Psychol* 2000; 85:273-283

61. Zsambok C: Naturalistic decision making research and improving team decision making. *In:* Naturalistic decision making research and improving team decision making. Zsambok C, Klein G (Eds). New Jersey, Lawrence Erlbaum Associates, 1997, pp 111-120

62. Baggs J, Schmitt M Mushlin A, et al: Association between nurse-physician collaboration and patient outcomes in three intensive care units. *Crit Care Med* 1999; 31:1991-1998

63. Puntillo K, McAdam A: Communication between physicians and nurses as a target for improving end-of-life care in the intensive care unit: Challenges and opportunities for moving forward. *Crit Care Med* 2006; 34:S332-S340

64. Jain M, Miller L, Belt D, et al: Decline in ICU adverse events, nosocomial infections and cost through a quality improvement initiative focusing on teamwork and culture change. *Qual Saf Health Care* 2006; 15:235-239

65. Sexton J, Thomas EJ, Helmreich RL: Error, stress and teamwork in medicine and aviation: Cross sectional surveys. *Br Med J* 2000; 320:745-749

66. Patel VL, Arocha JF: The nature of constraints on collaborative decision making in health care settings. *In:* Linking expertise and naturalistic decision making. Salas E and Klein GA (Eds). New Jersey, Lawrence Erlbaum Associates, 2001, 383-405

67. Xiao Y, Seagull J, Mackenzie C, et al: Adaptive leadership in trauma resuscitation teams: a grounded theory approach to video analysis. *Cogn Tech Work* 2004; 6:158-164

68. Flin R, Arbuthnot, K (Eds.): Incident Command: Tales from the hot seat. Aldershot, Ashgate, 2002

69. Reader T, Flin R, Mearns K, et al: Team cognition in the intensive care unit. Paper presented at the *Society of Industrial and Organizational Society 22nd annual meeting*, New York, 2007

70. Thomas EJ, Sexton J, Helmreich RL: Discrepant attitudes about teamwork among critical care nurses and physicians. *Crit Care Med* 2003; 31:956-959

71. Huang D, Clermont G, Sexton J, et al: Perceptions of safety culture across the intensive care units of a single institution. *Crit Care Med* 2007;35:165-176

72. Smith-Jentsch K, Mathieu J, Kraiger K: Investigating linear and interactive effects of shared mental models on safety and efficiency in a field setting. *J Appl Psychol* 2005; 90:523-535

73. LePine J: Team adaptation and postchange performance: Effects of team composition in terms of members cognitive ability and personality *J Appl Psychol* 2003; 88:27-39

74. Ilgen D, Hollenbeck J, Johnson M, et al: Teams in organizations: From input-process-output models to IMOI models. *Annu Rev Psychol* 2005;56:517-543

75. Carrol J, Quijada M: Tilting the culture in health care: Using culture strengths to transform organizations. *In:* Handbook of human factors and ergonomics in health care and patient safety. Carayon P (Ed). New Jersey, Lawrence Erlbaum Associates,2007, pp 823-832

76. Marks M, Sabella M, Burke C, et al: The impact of cross-training on team effectiveness. *J Appl Psychol* 2002; 87:3-13

77. Carson S, Stocking C, Podsadecki T, et al: Effects of organizational change in the medical intensive care unit of a teaching hospital: a comparison of 'open' and 'closed' formats. *JAMA* 1996; 276:322-328

78. Sexton J, Helmreich R, Neilands T, et al: The safety attitudes questionnaire: Psychometric properties, benchmarking data, and emerging research. *BMC Health Serv Res* 2006;6:44

79. Rogelberg S: Handbook of research methods in industrial and organisational psychology. Oxford, Blackwell Publishing, 2004

80. Adair G: The Hawthorne effect: A reconsideration of the methodological artefact. *J Appl Psychol* 1984;69:334-345

81. Podsakoff P, Scott B, Mackenzie J, et al: Common Method Biases in Behavioral Research: A Critical Review of the Literature and Recommended Remedies. *J Appl Psychol* 2003;88:879-903

82. Dickersin K: The existence of publication bias and risk factors for its occurrence. *JAMA* 1990;263:1385-1389

83. Scott T, Mannion R, Marshall M: Does organisational culture influence health care performance? A review of the evidence. J Health Serv Res Policy 2003;8:105-17

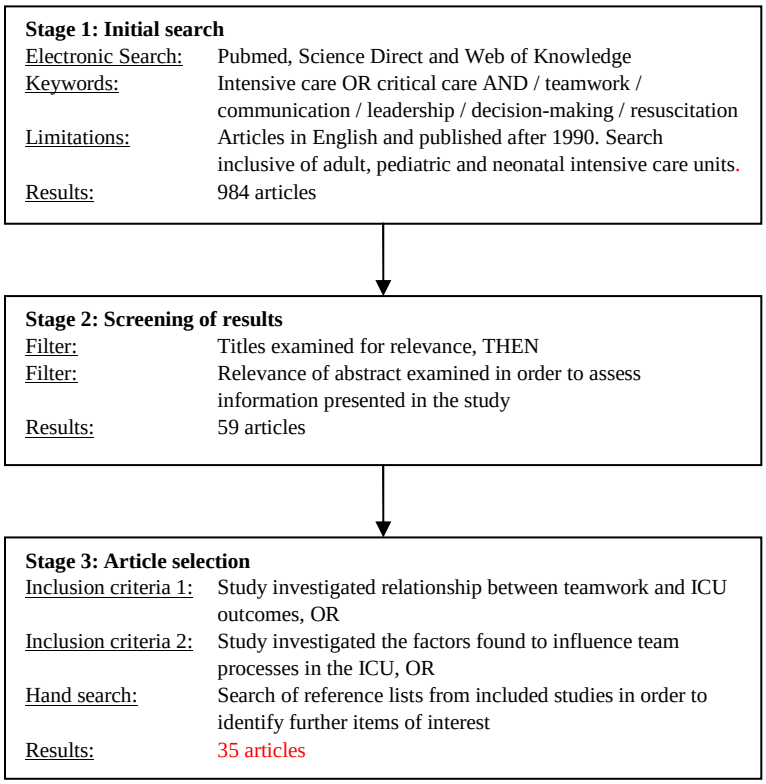

Figure 1. Literature review flow diagram

Table 1. Methods used to study teamwork in the literature review

Methods used to study teamwork	Total number of articles	Study reference number
Observations in real-life	8	19, 27, 28, 32, 55, 56, 57, 66
Observations in a simulator	4	25, 26, 41, 52
ICU staff interviews	2	23, 33
ICU staff surveys	17	24, 29, 30, 31, 42, 47, 50, 53, 54, 58, 59, 62, 64, 65, 69, 70, 71
Error analysis	4	17, 20-22

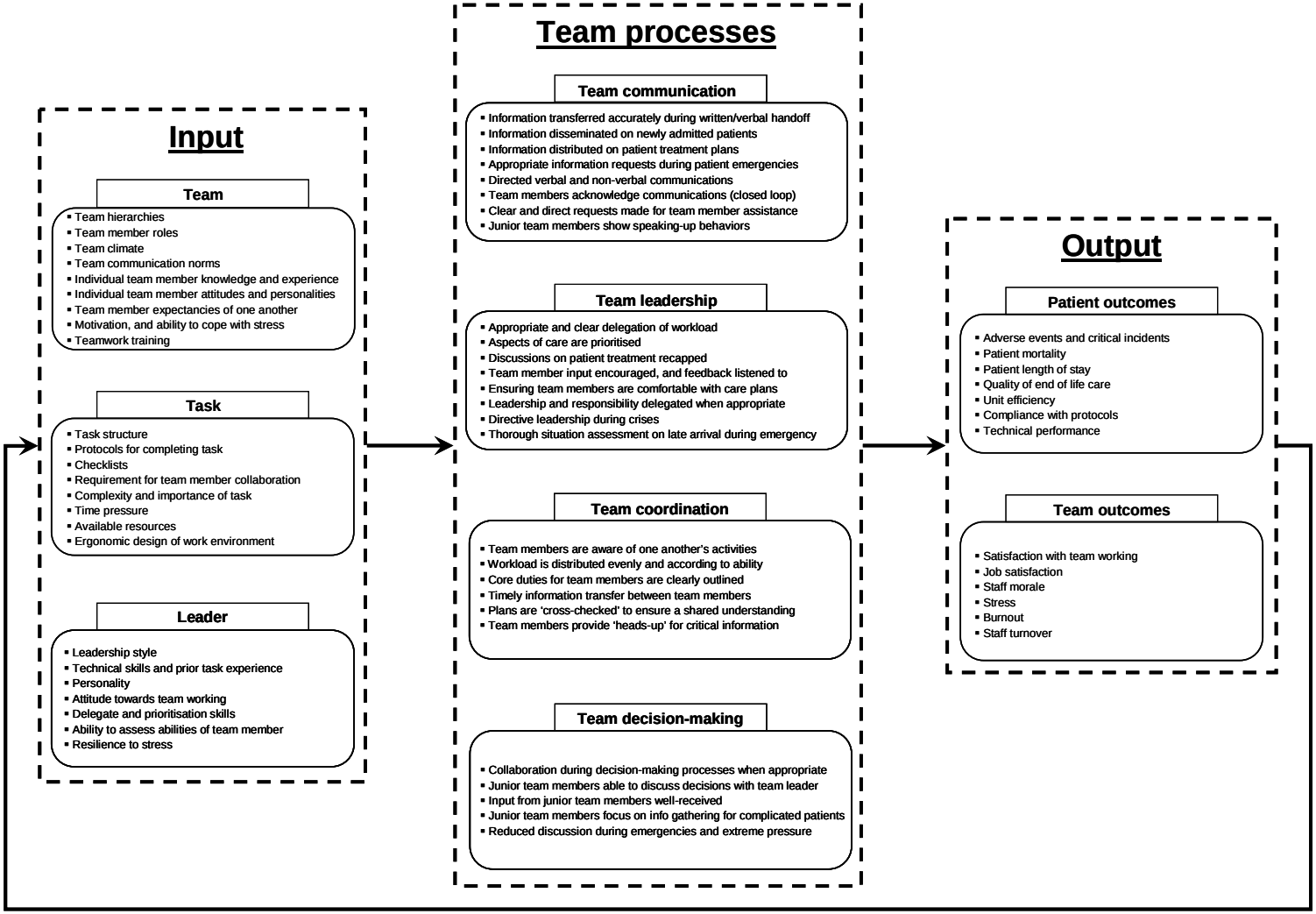

Figure 2. ICU team performance framework