

Team coordination in an Intensive Care Unit

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Researchers have the need for improved coordination and continuity of care in health-care environments, but little research has been undertaken to better understand how coordination occurs and how it might be improved. Using Klein's (2001) phases of coordination this exploratory study provides a profile of the contributions of role-based communications to team coordination in an Intensive Care Unit. All communication events for five patients for five consecutive days were logged and analysed using a hierarchical loglinear analysis. Nurses to nurse communications were found to focus mainly on the planning phase of coordination of short-term time horizons. Doctor to doctor communication events were characterized as formal and involved the planning and direction phases of team coordination and informal nurse to doctor communication events focused on planning and team assessment phases of coordination. Further analysis is required to determine how these contributions interact and what the vulnerabilities might be.

INTRODUCTION

The US Institute of Medicine (1999) found that 11-15% of patient admissions in the US involved some form of error and noted that the multi-faceted nature of medical error requires a whole of system approach. Murff and Bates (2001) in a meta-analysis of adverse patient events involving information transfer recommended further research to better understand patient related communication and coordination processes. Some research has been undertaken to describe the nature of nursing shift handovers (Sherlock, 1995; Lally, 1999), but this research does not recognize the multidisciplinary nature of ICU care coordination and is not grounded in a theory that would guide recommendations for change. In more focused research involving ICUs Gopher et al (1989) and Donchin et al (1995) identified 1.7 errors per patient per day with a majority of these attributable to documentation and communication problems; findings supported by more recent research about the effects of information display on aspects of team decision making (Miller et al, 2007). In an extension of Donchin et al's (1995) study, Bracco et al (2001) identified planning and execution errors as significant contributors to patient harm and cost of care, but they did not define 'planning' or 'surveillance'. While Bracco et al's (2001) study usefully illustrates the incidence and effects of critical incidents it provides little guidance as to what might be done to reduce them.

Team coordination – a theoretical framework

Communication plays a central role in effective team coordination because it is the means by which teams achieve a common ground understanding about the patient's condition, the team's priorities and goals and the state of sub-team activities in relation to these (Klein et al 2005; Endsley & Jones 2001, Klein, 2000). However, common understand is only a part of effective coordination. Klein (2001) maintains that team coordination is a parallel process that is separate

from a team's primary purpose or objective. According to Klein (2001) team coordination is "the attempt by multiple entities to act in concert in order to achieve a common goal by carrying out a script/plan they all understand" (p.71). Coordination, by this definition is tied to a common script that aligns actors' activities within an agreed overall plan'. According to Klein (2001) acting in concert involves five phases of coordination which are summarised as follows:

- 1) *Preparation* – team members become familiar with the situation prior to formally discussing it. Preparation involves developing an general understanding of the nature of the situation, e.g., routine/non-routine, well resourced / not well resourced etc
- 2) *Planning* – team members formally discuss the situation; they recruit outside expertise, elaborate ideas, clarify goals, calibrate their common understanding of the situation, and negotiate sub-goals and sub-task timing. Planning involves developing a common ground understanding of the situation as it is and as it is expected to unfold
- 3) *Direction* – team members transform planning discussions into specific and agreed directions, plans or scripts for themselves and others;
- 4) *Execution* – team members monitor, trigger and align their individual efforts with those of others with the agreed plan or script;
- 5) *Assessment* – team members assess the current status of team efforts against the agreed script or plan and revise this in line with any deviations.

These definitions are a set of generic characteristics that can be used to describe and categorise team coordination efforts from the perspective of role-based contributions. However, they have been defined within teamwork contexts involving tasks with definable start and finish points e.g. flight missions where team membership is generally fixed. In contrast, ICU patient care is an ongoing process and while roles may not change specific role holders change across

multiple shifts (Miller & Sanderson, 2005). The purpose of this paper is to report the outcomes of an exploratory research protocol designed to assess the contributions of different role holders to team coordination in the ICU.

METHOD

Participants

Participants were 83 doctors and nurses in a large Melbourne metropolitan trauma hospital who agreed to participate in the study. This number included all doctors and approximately 45% of nurses working in the ICU at the time of the study. The next-of-kin of five critically ill patients agreed to have their relative passively participate in the study.

Materials

Materials used in the study included the following:

- 1) Audio-recording equipment, including three small microphones that were located in patient cubicles to capture patient related conversations, for example, above the patients' observation charts and notes, towards the front of the patients' bed cubicles and above the patients; an 8-channel audio mixing desk that was used to filter alarms and other background noise. The filtered sound stream was recorded using mini-tapes in a handheld Canon camera (with lens cap taped on). A second camera (also with lens cap taped on) was used to play back the audio recordings to correct manual transcriptions, and finally a set of headphones
- 2) A laptop computer with an Excel spreadsheet designed to allow research assistants to manually record the date and time of communication events, the roles (e.g. doctor, bedside nurse, physiotherapist etc) of the communicators; the overt purpose of the communication (e.g. shift handover, check medications) and its outcome (e.g. medications changed), the content of communications, the phase of team coordination reflected in the communication events and any artefacts used by the clinicians to support coordination.
- 3) A phase of coordination coding scheme devised from Klein's (2001) definitions.

Procedure

The senior researcher and three research assistants worked as data collectors in eight-hour shifts each to record all patient related communication events for five days continuously per patient. The data collectors' shifts approximately coincided with nursing shift changes. Data collectors were located at a small table in an 'out of the way' back corner of the patient's cubical. Communication events were listened to through the headphones and audio and manually recorded. The senior researcher worked the night shift. During this time audio recordings for the preceding day were replayed and manual recordings were checked, corrected and de-identified where relevant. The audio-tapes were reused the following day. Data collectors absented themselves during private family conversations and on rare occasions when asked to by a nurse or doctor. Given the longitudinal nature of the study data collectors were quickly assimilated into the environment after some initial self-consciousness on the part

of staff. The openness of the data collection process, together the obvious checking of recordings overnight and the reuse of audio-tapes were central factors in developing trust. There was no evidence to suggest that staff censored or constrained their communications.

Data collation and screening

1772 communication events were logged for five patients for a total of 24 days (patient 5 was discharged to the ward on day 4).

1. Inter-coder reliability

An inter-coder reliability analysis for the phases of coordination was undertaken using a randomly selected 10% of the communication events. Coders were the senior researcher and an independent anaesthetist/intensive care physician. The selected communication events were separately coded by both coders and Cohen's kappa for inter-coder reliability was calculated as 0.89 which suggests moderate to strong agreement between the coders. The coding schemes for the remaining variables were unambiguous and thus not contentious.

2. Variables and levels

In addition to the phases of coordination data was collated from the Excel spreadsheets according to the following variables and levels.

- **from-to:** a composite variable created by merging the role code of the person initiating the communication with role code of the person receiving the communication, for example, a communication event initiated by a bedside nurse (BN) to a registrar (Reg) was coded as BNReg, All combinations of from-to communications were collated resulting initially in 21 levels of this variable.
- **Type:** this variable had three levels – 1. formal communication events including ward rounds and shift handovers; 2. informal communication events which included person to person communications that were not formal events, and 3. other communication events including telephone conversations, responses to pagers, and written notes as implied communications.
- **Time horizon:** the time frame over which a communication event was effective that included three levels: 1. immediate - communication events involving the immediate present (e.g. what's this patient's blood pressure now); 2. short-term - communication events involving up to 12 hours (e.g., lets wait for a couple of hours and reassess); and 3. long-term - the communication event involved time frames beyond 12 hours (e.g. I wouldn't expect to see any improvement until at least tomorrow).
- **Artefacts:** devices or tools used to support team coordination, including patient monitors, patient histories and charts, personal note books, post-it notes. Once collated 13 different artefacts were identified.

3. Data screening

Data was screened to meet the requirements of multivariate contingency table analysis (Tabachnick & Fidell, 2002). Two-way cross tabulation tables were used to evaluate the adequacy of expected frequencies for all variables. Two of the initial variables (from-to and artefacts) resulted in

expected frequencies of less than the five in many cells. The 21 levels of the from-to variable which included uncommon combinations such as dietician to ward clerk, consultant to medical student and registrar to physiotherapist were collapsed to four levels: 1. nurse to nurse communication events; 2. nurse to doctor/doctor to nurse communication events, 3. doctor to doctor communication events and 4. other events. In relation to the Artefact variable, 47% of all communication events were found NOT to involve the use of artefacts, but rather proceeded by unaided memory. This finding is itself meaningful. The remaining 12 levels of this variable were collapsed into three, but expected frequencies in many cells were low and this variable was deleted from further analysis. Finally, few communication events were coded as the 'execution' phase of team coordination, largely because this phase often did not involve verbalisation. This level was thus collapsed into the 'direction' level of team coordination.

Following data screening four variables remained including: From-to with 4 levels; type with 3 levels; horizon with 3 levels, and phases of coordination with 4 levels). The number of cells in the multivariate contingency table was therefore 144 with a resulting case to cell ratio well exceeding 5:1 with less than 20% of the expected frequencies in the cells less than 5 (Tabachnick & Fidell, 2002; Gottman & Roy, 1990).

RESULTS

Four variables (from-to, type, horizon and theory) were entered into the analysis as dependent variables. A two step analysis approach was used: 1. model selection and significance testing using SPSSv15 (HiLoglinear) and 2. cross-tabulation table and analysis of residuals.

Model selection and significance testing

The overall effect was highly significant (likelihood ratio, $G^2_{(df=133)} = 1601.81$; $p < 0.00001$; Pearson's $\chi^2_{(df=133)} = 2,053.67$; $p < 0.00001$).

Table 1. Tests of significance for partial associations

Effect Name	df	Partial χ^2	Prob
From-to x type x theory	18	36.947	.0053**
From-to x type x horizon	12	43.967	.0000***
From-to x theory x horizon	18	18.865	.4002 ^{NS}
Type x theory x horizon	12	19.089	.0864 ^{NS}
From-to x type	6	458.299	.0000***
From-to x theory	9	66.169	.0000***
type x theory	6	52.837	.0000***
from-to x horizon	6	8.155	.2270 ^{NS}
type x horizon	4	101.141	.0000***
theory x horizon	6	420.740	.0000***
from-to	3	101.819	.0000***
type	2	272.764	.0000***
theory	3	259.896	.0000***
horizon	2	897.120	.0000***

significant at $p < 0.01$; * significant at $p < 0.001$; NS not statistically significant

Simultaneous (combined or k-way) interaction effects were then tested to determine the simplest interaction model; the 4-way interaction effect was not significant leaving three and lower order interactions as the most parsimonious models. Tests of partial association (Table 1) show significant effects for all interactions except two three-way and one two-way effect.

Cross-tabulation tables and analysis of residuals

The following cross-tabulation tables of role-based communications provide a basis for better interpreting the results of significance testing. Table 2 shows the percentage frequencies and standardised residuals for nurse to nurse communication events. Note that standardised residuals of $< \pm 3.0$ are not considered to be significant given the requirement for Bonferroni type adjustment against the risk of inflated Type I errors.

1. *Nurse to nurse communications*. Nurse to nurse communication events (Table 2) made up 34% all communication events. Of these, the majority (52%) were informal and 29% involved other contexts (e.g., telephone communications). Nurse to nurse conversations typically involve short-term (<12 hours) effective time horizons. Standardised residuals within these cells suggest significantly higher than expected values for the planning phase of coordination independently of whether communication occurs during formal or informal contexts. However, lower than expected residuals for planning occurred over immediate and long-term time horizons. Thus nurse to nurse conversations are positively associated with the short-term planning independently of context.

Table 2. Standardised residuals for nurse to nurse communications

1. Nurse to nurse communication events 34% of total

	2a. Formal 18%	2.b Informal 52%	2c. Other 29%
3a. Immed	13.04%	42.77%	32.42%
Prep	-1.03*	9.32	2.44
Plan	-4.54	-4.05	-3.03
Direct	-3.33	5.10	5.14
Asses	-2.91	0.35	3.4
3b. Short	77.39%	51.07%	61.54%
Prep	-1.74	2.59	4.75
Plan	10.42	6.29	9.8
Direct	-3.08	-1.68	-0.59
Asses	-2.64	4.79	9.31
3c. Long	9.56%	6.15%	6.04%
Prep	-1.03	-3.29	-1.71
Plan	-4.54	-5.17	-3.29
Direct	-3.57	-4.39	-2.82
Asses	-3.72	-3.46	-1.13

*(% : Std Res) Percentages are nested, thus 13.04% of immediate time-frame conversations were formal

2. *Doctor to doctor communication events.*

Doctor to doctor communication events (Table 3) comprise 17% of all conversations and differ substantially from the conversations involving nurses. Nearly 80% of conversations between doctors occurred during formal ward rounds. Formal conversations tended to cover short-term effective horizons and involved the planning and direction phases of coordination.

Table 3. Percentage frequencies and std residuals for doctor to doctor communications

1. Doctor to doctor communication events 17% of total

	2a. Formal 77%	2.b Informal 19%	2c. Other 4%
3a. Immed	7.6%	35.48%	50%
Prep	-1.01	-0.19	-1.55
Plan	-1.83	-4.04	-2.73
Direct	-0.49	-1.52	-0.46
Asses	-1.9	-2.19	-1.56
3b. Short	82.8%	53.22%	35.71%
Prep	-0.51	-1.76	-1.55
Plan	30.73	0.42	-1.99
Direct	18.8	-3.15	-1.8
Asses	-1.9	-1.89	-2.05
3c. Long	9.6%	11.29%	14.28%
Prep	-1.01	-2.55	-1.55
Plan	-1.55	-4.04	-2.73
Direct	0.89	-3.42	-2.24
Asses	-1.9	-2.78	-2.05

3. Doctor to nurse/nurse to doctor communication events. 26% of all communication events involved nurses and doctors. Of these nearly three quarters (72.4%) were informal, that is occurred between ward rounds and shift handovers.

Table 4. Percentage frequencies and standardised residuals for doctor - nurse communications

1. Nurse to doctor/doctor to nurse communication events 26% of total

	2a. Formal 22%	2.b Informal 72%	2c. Other 5.3%
3a. Immed	12.4%	31.37%	52%
Prep	-1.6	2.73	-0.81
Plan	-4.01	-4.52	-2.7
Direct	-1.25	7.82	-0.88
Asses	-3.2	2.5	-1.68
3b. Short	77.14%	61.29%	36%
Prep	-1.61	-1.15	-1.88
Plan	5.76	12.75	-2.7
Direct	2.16	2.46	-2.72
Asses	1.12	13.25	-0.48
3c. Long	10.47%	7.33%	12%
Prep	-2.02	-2.44	-1.88
Plan	-3.58	-4.34	-3.31
Direct	-2.67	-2.91	-2.72
Asses	-2.6	-2.14	-2.09

The majority of communication events involved short-term effective time horizons. Standardised residuals suggest much higher than expected frequencies of short-term, informal planning and for team assessment phases. Also noteworthy are the higher than expected frequencies for the direction phase of coordination in informal conversations that are have immediate effective time horizons. Thus doctor-nurse

conversations are typically informal and involve short-term planning and assessment.

DISCUSSION

The purpose of this study was to describe the contributions of medical and nursing roles to overall team coordination in the ICU and how these roles are supported. In ICUs professional groups make different but interlocking contributions to team coordination.

A notable finding from this study is the observation that 47% of conversations were unsupported by any form of artefact. The role that artefacts play in team coordination is currently unclear, however, Miller et al (2007) in their evaluation of a prototype clinical information system observed that the mean proportion of agreement about patients' future goals was remarkably low independently of whether conventional or alternative displays were used. It is possible that clinical information systems that better represent the script or plan may better support team coordination. This hypothesis remains to be tested.

The planning phase of team coordination features in all communication events and involves discussions about the patient situation. However, the patterns of focus on planning are different depending on contributing roles. Planning dominates short-term nurse to nurse communications in formal and informal conversations. During formal conversations (e.g. shift handovers) planning involves the detailed presentation of information about the patients state over the last shift. During informal conversations planning involves the maintenance of a shared understanding about what the patient situation is. Informal conversations between bedside nurses and charge nurses assist in maintaining an understanding of particular patients in relation to other patients, whereas conversations between adjacent bedside nurses assist in maintaining continuity of patient monitoring during breaks. This finding is consistent with findings reported by Miller and Sanderson (2005) that nurses focus more than doctors on patient related information.

Conversations between doctors occur predominantly during formal ward rounds and focus mainly on planning and direction over short-term (12 hour) timeframes. Planning in this context involves diagnostic discussions, which tend to be more interpretive of information than nurses' conversations. Miller and Sanderson (2005) reported that doctors tend to focus on future patient states, however the short-term nature of discussions identified in this study would suggest a narrower time horizon. In formal doctors' discussions directions were negotiated. However, these were more typically limited to directions about what tasks needed to be performed without discussion about logistical issues such as who would perform these tasks and when. This observation will be explored and reported in further analyses.

Short-term team assessment and immediate direction conversations occur informally during doctor-nurse/nurse/doctor conversations. While team assessment is not a strong feature of doctor to doctor or nurse to nurse communication events, it is a strong feature of nurse to doctor communication events. Rather than assess the team's performance during formal conversations as may be expected

given the cyclical nature of shift change-overs and ward rounds which would be expected to include an update of how plans are progressing and by whom, this function appears to be informally negotiated between doctors and nurses throughout the day. In short while specific directions are provided as an outcome of formal doctor to doctor communications the manner in which these are carried out appears to be negotiated between doctors and nurses 'as you go'.

This analysis provides an overview of the structure of team coordination in terms of the contributions of the primary roles involved in ICU patient care, but is an incomplete and preliminary picture. Team coordination is more than the contributions of its various members, rather it is a process that involves active interaction between roles through different types of conversations. Klein's model implicitly assumes that team coordination is a conditional process: that planning depends on preparation, that direction depends on planning and so on. Markov analyses are currently underway to determine the validity of this assumption (Gottman & Roy, 1990). A finding that this data does not support the conditional dependencies between phases of coordination in Klein's model need not invalidate the model or its application. First, lack of technological support for team coordination (47% of communication events are unsupported) may limit role-holders' ability engage in some phases especially over multiple changes of shift. Second, overall team coordination may be an emergent property of interactions between sub-team members, or in other words sub team interactions are nested within overall team coordination. Overall team coordination may not be a conditional process but coordination may be a conditional process at the level of sub-team coordination. these hypotheses remain to be tested.

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