

Why the Plan Doesn't Hold – a Study of Situated Planning, Articulation and Coordination Work in a Surgical Ward

Jakob E. Bardram

IT University of Copenhagen, Denmark
Rued Langaards Vej 7, 2800 Copenhagen
bardram@itu.dk

Thomas R. Hansen

Cetrea A/S, Denmark
Finlandsgade 10, 8200 Aarhus N
thomasr@cetrea.com

ABSTRACT

Most studies of plans and situated work have applied ethnographic methods and thus fail to provide any *quantitative* insight into the extent of this phenomenon. We present a study of planning and executing operations in an operating suite. Quantitative analysis of log data reveals the extent to which operation schedules are carried out as planned, and qualitative studies reveal the reasons behind changes to the plan, the consequences of such changes, and the strategies used to cope with them. 67% of the plan is changed and only 56% of all operations are planned ahead. We discuss how operation schedules are subject to “continuous planning”, and how this needs to be supported by technology.

ACM Classification Keywords

H.5.3 Information Interfaces and Presentation: Group and Organization Interfaces—*Computer-supported cooperative work*; J.3 Computer Applications: Life and Medical Science—*Medical information systems*

General Terms

Design, Human Factors

Author Keywords

Coordination, Peri-operative Coordination and Communication System, PoCCS, Hospital, Operating Room Scheduling

INTRODUCTION

The relationship between plans as coordinating artifacts, and the enactment of such plans under the constraints of specific contingencies and conditions in the work situation, has attracted much attention in CSCW. On the one hand, plans are absolutely essential to the coordination and execution of activities in collaborative workplaces such as a hospital. A number of studies have focussed on understanding the role of plans and other “Coordination Mechanisms” [15] in co-operative work. On the other hand, due to details and contingencies which cannot – and should not – be anticipated (or planned for), plans must necessarily be instantiated and

adjusted to the specific work situation in which they are executed. This is the core argument in Suchman's work on “Situated Action” [16], in which she shows the importance of differentiating between work and representations of work such as plans and process models. Plans are representations of situated actions produced in the course of action and they should therefore be seen primarily as resources for the work rather than as factors that play any decisive role in determining its course. Suchman emphasizes that action consists of essentially situated and ad hoc improvisations; thus plans can be seen as rational anticipations before the act, and post hoc reconstructions afterwards.

Several studies of planning and situated work have been carried out by CSCW, some of them within a hospital setting. In this paper, we would like to investigate more thoroughly the relationship between plans and situated actions and investigate *how often* and *why* plans are changed, the *consequences* of such changes, and how these changes are *handled*. More specifically, we would like to investigate the following questions:

1. what is the nature of the changes to the plan, i.e. how many changes occur and how significant are they?
2. what are the reasons for the changes, i.e. why are plans changed?
3. what are the consequences of these changes, i.e. how are changes experienced and what effect do they have?
4. what are the strategies used for coping with these changes, i.e. how do people handle and accommodate change?

Whereas other studies of plans, coordination mechanisms, and hospital work have applied a purely qualitative ethnographic approach, this paper presents quantitative as well as qualitative insights into the relationship between plans and the way in which they are carried out. On the basis of log data from scheduling and coordination systems at an operating (OR) suite, we have been able to determine how often plans are changed and the nature of the changes made. These quantitative data have been supplemented with qualitative data based on interviews and observations, which provide insight into the reasons behind changes to plans, the consequences of such changes, and how users cope with them.

Our study of a general-purpose OR suite over a period of 12 weeks shows that only 56% of all operations were known

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about and hence planned before the day of surgery; the remaining 44% acute operations had to be accommodated into the schedule during the day. Moreover, the plans made for 67% of all pre-scheduled operations were changed on the day of surgery. The majority of these changes involved moving an operation forward or back more than 30 minutes (the limit for what we regard as a significant change). The qualitative analysis showed that plans are changed primarily because of incoming acute patients, the condition of the patient, and illness among staff. Such changes lead to a significant amount of rescheduling and coordination, which we describe as “continuous planning”.

Even though the systems used at the OR suite provided good support for operation planning and execution, the implication of this study for system design is that, rather than maintain the present artificial divide between “planning” and “execution”, we should provide proper backing for continuous planning, along with efficient support for communicating the changes made to the staff involved.

RELATED STUDIES

Building on the research agenda and approach laid out in Suchman’s initial work [16], a number of ethnographic studies of work and coordination have been undertaken [14], including studies of workflow systems, which can be viewed as computerized plans [6]. The general evidence emerging from these studies is that while plans presuppose the embodied practices and changing circumstances of situated action, the efficiency of plans as representations derives from the fact that they do not represent those practices and circumstances in all their concrete detail. These studies provide rich insight into the contingencies of work and especially “the art of coordination”, which is particularly contingent on working conditions. Executing a plan often involves a significant amount of “work to make the plan work”, including rescheduling, negotiation, communication, persuasion, conflict management, etc. A common conclusion arising from these studies is to “support the articulation and coordination work necessary in situations where plans do not adequately work out.” [14].

However, as Kjeld Schmidt has argued in several places, the problem with articulation work is that it is inefficient, tedious, boring, frustrating and stressful, and scales very poorly. By re-interpreting some of the same studies on which the above arguments are based, he argues that there is a need for artifacts designed to help “cooperative ensembles [to] articulate their distributed activities more effectively and with a higher degree of flexibility and so that they can tackle an even higher degree of complexity in the articulation of their distributed activities” [15][p. 162–4]. Schmidt labels such artifacts “Coordination Mechanisms”; such mechanisms embody a protocol that stipulates and reduces the complexity of the articulations involved in distributed activities. Examples of such coordination mechanisms include standard operating procedures in administrative work, transportation timetables, aviation checklists, operations schedules, scientific classification systems, and software bug reporting systems.

A number of studies have investigated coordination in hospitals [1, 3, 10]. In this setting, stable coordination mechanisms are particularly useful because of the safety-critical nature of the work, because people work in a highly distributed and mobile way [4], and because efficient use of costly and scarce resources is essential. Nevertheless, several studies of work coordination in hospitals have revealed that plans are constantly changed to accommodate medical contingencies. In OR suites, for example, disruptions relating to lack of information, inaccurate information or status changes impact on the operating schedule, which in turn requires collaborative efforts on the part of all components in the system to formulate or reformulate a plan [10]. Large publicly available whiteboards in OR suites have proved essential in planning and coordination [17, 12, 13]. The charge nurse is critical to this information system because it is his/her responsibility to maintain the board as accurately as possible. In order to do so s/he needs to use persuasion and diplomacy to negotiate a viable plan for the day in a manner that is satisfactory to all the components involved. Similarly, on the basis of studies of nursing plans, Munkvold et al. [9] argue that “[t]here is planning but not plans” and that planning is “a collective, ongoing and heterogeneous achievement” [p. 21]. This is in line with our earlier findings [1], which – based on studies of unravelling plans on a medical ward – show that planning in hospitals is a continuous activity adjusted to the conditions of the specific situation.

Prior CSCW studies of coordination in general, and in hospitals in particular, have provided sophisticated qualitative insight into the work of executing plans that are adapted to the specific contingencies of real-world constraints. However, none of these studies has provided any *quantitative* insight into the extent of this phenomenon; how great is the discrepancy between “the plan” and “the (actual, situated) work”? Are all plans subject to change? Half of them? 10%? 1%? Precise figures may not be important, but some general objective indication of the extent of the problem is needed in order to determine more precisely the degree to which system design needs to take such changes into consideration.

EMPIRICAL BACKGROUND

The present study looks at the scheduling, execution, coordination, and articulation of operations at a medium-size hospital. The scheduling and execution of operations offer a particularly interesting case to study with respect to the relationship between plans and situated action. On the one hand, plans are absolutely essential in the planning, coordination and documentation of operations in a hospital and accountability for them. For example, patients need to know when to arrive at the hospital, and surgeons, nurses, operating rooms, equipment, etc. need to be booked and ready at the time of surgery. On the other hand, clinical work, and operations in particular, are subject to numerous contingencies. For example, operation plans are often changed in order to accommodate acute patients; they may be delayed due to unforeseen complications once the operation has begun, and they may be cancelled for all sorts of reasons, including the patient’s not being ready for surgery. Hence the paradox is that hospital surgery would never succeed without detailed

and meticulous planning, but neither would it succeed if executed strictly according to plan.

Research Site

The study was carried out at Horsens Hospital in Denmark and focused on activities in the in-patient OR suite which contains nine operating rooms. One of the operating rooms is reserved for highly acute patients and emergency cases (e.g. traffic accidents). The OR suite hosts operations from three different surgical departments dealing respectively with organ, orthopedic, and gynecological/obstetric surgery. Around 150 clinicians work in the operating department, and on average 22.4 operations are performed every day, amounting to approximately 8,000 operations per year.

The OR suite uses two computerized systems for planning and performing operations. The first is a booking system that is used by secretaries for booking and scheduling operations and resources, such as operating rooms, surgeons, equipment, etc. The system is designed to create an efficient operation plan, making optimal use of the available resources through mathematical optimization approaches. The optimization is centered around so-called “critical resources”, which are defined primarily as operating rooms and surgeons. Other resources, such as operating nurses, operation technicians, and equipment are assumed to be available on the day of surgery. The booking system is used primarily by the secretaries responsible for booking so-called “elective” operations, i.e. those based on pre-admission assessment from surgeons. The system runs on regular PCs located in the secretaries’ offices, and planning takes place remotely from the operating ward.

The second system is a peri-operative communication and coordination system (PoCCS) [5] that is used to support the performance of operations during the day. This system allows for distributed awareness of how the various operations are going by showing a constantly updated operation schedule and giving status information on each operation. It also supports text-based communication and live video broadcasting from the operating rooms. This system runs on large interactive displays situated in key locations around the hospital. Currently these dedicated displays are situated in the operating rooms, the coordinating centre at the OR suite, the patient wards, the recovery department, the intensive care unit, the reception, and the sterile department. A picture of the deployment of this PoCCS system in the coordination centre at the OR suite is shown below. Figure 1 shows how the PoCCS system is deployed as an array of large touch screens in the coordination centre at the OR suite, and Figure 2 shows how the system is installed on smaller displays in some of the remote locations. Moreover, the system runs on mobile devices such as smart phones and PDAs which are carried around by key personnel at the hospital.

The two systems are integrated in such a way that the operation plan from the booking system is transferred to the PoCCS system at 6 am. every morning. This is defined as the time when planning stops and execution starts. Changes made in the planning system during the day of execution are



Figure 1. The Peri-operative Communication and Coordination System (PoCCS) as deployed in the coordination centre in the OR suite. Two charge nurses are standing in front of the public displays.

sent on an ongoing basis to the PoCCS system. But since the booking system is primarily a tool for secretaries to plan ahead, very few changes to the schedule of the day are made in this system. Changes to the plan during execution are primarily made in the PoCCS system and then synchronized with the booking system.

The charge nurses play a key role in the OR suite. They are specially trained nurses who are responsible for coordinating the operating program in dialog with the anaesthesia coordinator. They are the only ones who are allowed to make changes to the operation schedule in the PoCCS system, and it is their job to adjust the plan according to unforeseen events such as cancellations, acute operations, prolonged surgery, illness amongst staff, and similar events. It is also their responsibility to make sure that everybody is informed about such changes to the schedule.

Research Methods

The study applied both quantitative and qualitative methods. The log file from the PoCCS system provides the quantitative basis for analyzing the number of scheduled, elective, and new acute operations; changes to operations; and cancellations. The log files were analyzed over a period of 133 days from October 9, 2008 to February 19, 2009. Except for the days around Christmas this period is typical, with no exceptional increases or reductions in the number of operations. All days including Saturdays and Sundays were included, even though only acute (i.e. non-elective) operations took place during weekends. The log files were analyzed according to the following parameters:

1. Total number of operations, divided into elective, acute, and cancelled operations.
2. How many of the elective operations were changed during the day of execution.
3. Number of cancellations.
4. Reasons for cancellations.



Figure 2. The PoCCS system at the patient ward (left), the recovery department (centre) and the sterile department (right)

A “change” is defined as a modification to an operation once it has been transferred from the “planning” to the “execution” mode, i.e. once the schedule from the booking system has been transferred to the PoCCS system. For example, if the starting time of an operation is changed in the PoCCS system this counts as a change.

The qualitative research methods included participant observations and a group interview. In the spring of 2008, two researchers each carried out observations of the work at the OR suite over three days. On the first day they focused on studying the coordination centre (see Figure 1), which is the centre of coordination and communication while the schedule is unfolding. Observations over the subsequent two days focused on the rest of the surgical department, including the operation rooms. Three experienced charge nurses were interviewed in a semi-structured group interview concerning coordination in the OR suite. The interview followed an interview guide focusing on three main questions: What are the *reasons* for changing the plan? What are the *consequences* for the people involved when the plan is changed? How do you, as the person responsible for coordination, *handle* such changes? The interview lasted 30 minutes. All observations and interviews were transcribed.

RESULTS

Quantitative Results

The quantitative results are summarized in Table 1–4. Table 1 shows that 92% of all operations scheduled on a given day are executed; 56% originate from the booking system as elective operations; 44% are acute operations scheduled on the same day; and 8% of the operations are cancelled at some point during the work day. Thus only approximately half of the day’s operation program is known at the point when the planning has stopped and the schedule is transferred to the PoCCS system (6 a.m.). Table 1 also shows that on average 22.4 operations are executed daily, and that almost 2 (1.8) operations are cancelled every day.

Table 2 focuses on changes made to operations during the day of execution. “Changes” include rescheduling – i.e., changing start and/or end time – and so-called “minor” changes, which encompass changes to the operation description, type of anaesthesia, participants in the operation, and the operating room (OR). The analysis of rescheduling focuses only on operations where the start and/or end time are moved respectively 30 or 60 minutes forward or backward, i.e. where

Table 1. Scheduled, Acute, and Cancelled Operations.

	Total	%
No. of days (D)	133	
Total no. operations (N)	3,221	100%
No. operations executed (E)	2,979	92%
No. elective operations (S)	1,801	56%
No. acute operations ($A = N - S$)	1,420	44%
– day shift (07:00–16:00)	646	20%
– night shift (16:00–07:00)	488	15%
– weekends	286	9%
No. cancelled operations ($C = N - E$)	242	8%
No. operations executed pr. day (E/D)	22.4	
No. cancellations pr. day (C/D)	1.82	

an operation is started 30 (60) minutes earlier or later than planned, or is ended 30 (60) minutes before or after it was scheduled to do so. We took 30 minutes as a reasonable lower limit, since some slack in the schedule is to be expected in an OR suite. Still, Table 2 shows that in 67% of all operations there are minor changes of the kind mentioned above, and/or the the operation starts or ends 30 min. or more before or after schedule. Similarly, 62% of all operations are subject to time changes of over 60 minutes. The results also show that the vast majority of changes are due to alterations in the start or end time of the operation, and only 5% are due to minor changes such as changes to the operation description.

Table 2. Changes to Operations.

	Total	%
Total no. of changed operations:		
– start/stop time +/- 30 min.	2,172	67%
– start/stop time +/- 60 min.	1,990	62%
No. of minor changes	167	5%

Table 3 focuses on changes to the elective operations, which are transferred from the booking system to the PoCCS system. The purpose is to investigate how accurately the duration of operations is estimated. The table shows that 31% of all elective surgeries deviate from the plan by more than 30 minutes, while 11% deviate by more than 60 minutes. In two out of three cases where operations deviate from the plan by more than 30 min. they take longer than expected ($316/481 = 66\%$). However, in one out of three cases the

operation is actually finished ahead of time. We do not have enough information in the current data to see if specific types of surgery or specific surgeons tend to run behind or ahead of schedule.

Table 3. Duration of Elective Operations.

	Total	%
No. of elective operations ($E - A$)	1,559	100%
Duration changed by more than 30 min.	481	31%
– extended by > 30 min.	316	20%
– reduced by > 30 min.	165	11%
Duration changed more than 60 min.	174	11%
– extended by > 60 min.	121	8%
– reduced by > 60 min.	53	3%

If one bears in mind the serious consequences and costs associated with cancellations, the figure of 8% of operations cancelled – almost 2 per day – is still relatively high. Since the clinicians are required to give a so-called “Cancellation Code” every time they cancel an operation in the PoCCS system, we are able to analyze the reasons for these cancellations. The results are shown in Table 4. Amongst other things, this table shows that the patient’s condition is one of the main reasons for cancelling an operation (33%),

Table 4. Reasons for Canceling Operations.

	Total	%
Patient non-attendance	10	4%
Patient cancellation	16	7%
Patient’s condition	79	33%
Hospital-related	54	22%
Staff-related	5	2%
Operation moved to out-patient clinic	9	4%
Other reasons	69	29%

Taken together, these tables reveal that the plan is extensively adjusted to accommodate additional acute operations and is constantly adjusted as the work unfolds. Such major changes either to the schedule or to the individual operation have significant consequences for the coordination of work at the ward, and hence involve both coordination and communication activities.

Qualitative Results

Except perhaps in the case of cancelled operations, the quantitative results presented above provide little insight into the reasons for, and the consequences of, these constant changes to the operation schedule. We therefore supplemented the quantitative analysis with a qualitative analysis aimed at investigating the reasons for changes in the operation schedules, the consequences of such changes, and the strategies used for coping with them.

The three charge nurses interviewed reported several reasons for changing the schedule. According to all three, the accommodation of acute patients was the prime reason for changing the plan:

Interviewer (I): *[W]hat are the typical reasons for changing the operation schedule in the course of the day?*

Charge Nurse 1 (C1): *Acute patients.*

Charge Nurse 2 (C2): *Someone not turning up, or a cancellation for one reason or another or other acute things or things to do with the anaesthetic.*

C1: *There can also be illness among the doctors.*

Charge Nurse 3 (C3): *There are more acute patients in the OR suite than the ones listed here [referring to the operation schedule].*

These statements correspond well with the quantitative data showing that the OR suite has to accommodate a number of acute patients. But the charge nurses also mentioned several other reasons for changes, such as patients not showing up, patients not being ready for surgery, illness among surgeons or other staff members, operations delayed due to complications, and incoming trauma patients. Various concerns about the patient and his or her physical or mental condition might also result in ad-hoc re-scheduling of operations. For example:

C2: *You often have to bear in mind that you need to remember this or that patient because there’s some particular thing...*

C1: *... it could be a patient with diabetes.*

C2: *But it doesn’t make that much difference that this or that patient has waited longest.*

C1: *Of course you try to take it into consideration if there are special handicaps or any special social issues..*

C2: *... but sometimes we don’t get all the information – or we haven’t read up on it – and then suddenly they tell us, like “she’s retarded” – there was actually a day when we had a retarded patient – and it would actually be very nice to know this in advance.*

C1: *... [For instance there was] this dementia patient that they couldn’t attach a drip to, and she couldn’t be lying there fasting a whole day without liquid... because then she’d ... Things like that. So – we might take them before they were scheduled, once we’d got that information...*

Thus although most changes to the schedule involve delaying or postponing operations, it seems that in some cases charge nurses move patients forward in the schedule due to patient-related concerns. The importance of taking the patient’s physical and mental condition into consideration is also underlined in the quantitative data, which show that 33% of all cancellations are due by the patient’s condition.

Asked about the consequences of changing the operation schedule, the charge nurses raised several issues. The main one concerned the cancellation of scheduled elective operations, which could actually mean that time was wasted:

C1: *If for instance there is an acute [patient] we need to admit, but we’re just not quite ready or there’s something missing ... Then waiting time arises and you can’t really do anything else... Well – only very minor things.*

C3: *And it can also mean having to cancel planned operations.*

The result for the patients is that they are kept waiting – sometimes for “a very long time”, which also means that they may be kept fasting for a long time. Illness among staff may also have serious consequences for the operation schedule:

C1: *It can also be because of illness amongst the [clinical] staff. There are days when so many are ill that we're forced to close one of the ORs. Or postpone the work there.*

From the staff's point of view, the main result is that they get reallocated to operations which they were not scheduled to perform. In extreme cases of emergency the staff may even have to perform tasks that they have not been trained to do:

C3: *... We've seen it happen that you have to say to some young doctor that they're needed on the floor [i.e. to assist] ... and then you're just standing there as an operating nurse telling him “you do this or that”, because of course they don't know the routine...*

C2: *... we've also had an orthopaedic surgeon acting as a scrub nurse during a [cesarean] section...*

C3: *sometimes you're forced to do that*

C2: *well – he was sitting in the coffee room anyway [and we said to him] “you might just go in and unpack this stuff”*

C3: *in such situations, nobody says no.*

The strategies for handling change range from rescheduling an operation to another point in the day (e.g. postponing it), moving it to another operating room, switching the order in which two patients are taken, and moving staff from one operating room to another. The charge nurses describe the work in general as akin to solving a puzzle;

C2: *Sometimes it's like having to put a lot pieces together – who can operate on this patient, who can operate on that patient – and then you have to, you know... Yes, it's a puzzle.*

The charge nurses reported in general that a lot of factors need to be taken into consideration when “solving the puzzle”: having the right staff present in the operating room; having the patient ready; having the right surgical equipment, medical records, and radiology images ready; and making sure that the operating room is equipped for the operation in question. In addition, the nurses emphasized the importance of providing a proper working environment for the surgical staff – for example, people need breaks in order to minimize the risk of adverse events.

DISCUSSION

With the increased pressure on the modern healthcare system, there is a demand for more and more efficient use of operation capacity in order to reduce waiting lists and to meet the expectations of patients. From the patient's perspective one of the highest-ranking parameters for quality of treatment is that s/he actually undergoes a scheduled operation on the day it was planned. The cancellation of a scheduled operation is one of the most stressful things that can happen to a patient. Thus ensuring efficient execution of operations in a large hospital every single day undoubtedly requires ad-

equated planning, scheduling, and optimal use of scarce and costly resources. However, from our quantitative and qualitative study of operation schedules, and the way they unfold in practice, it is quite evident that such schedules are not enacted as planned, and substantial efforts have to be put into handling changes and mitigating their effects. In the following section we discuss these empirical results.

Optimizing Operation Schedules

In the surgical domain, the demand for increasing productivity is translated into a demand for creating optimal operation plans that maximize the efficient use of operating room time [7] “OR efficiency” in this context means that an OR is neither under-utilized (i.e., not fully used during its opening hours) nor over-utilized (i.e., used too much, meaning that staff have to work overtime). Research has shown that the productivity of a surgical service is determined almost exclusively by staffing decisions taken days or even months before the day of surgery, even though these involve only planning for *elective* surgeries [8]. Thus productivity is optimized through tight scheduling that reduces the exchange time between operations; through making schedules which plan for high utilization of critical resources such as ORs and surgeons; and through extending these “critical” resources to include nurses, operation technicians, and equipment in order to optimize the utilization of these resources as well.

However, our study showed that on average only 56% of the operations executed on any given day were scheduled at the beginning of the day, i.e., were elective operations. Thus the strategy of creating so-called “optimized” plans can only be sub-optimal since these encompass only a little more than half of the operations performed. Moreover, if the use of all resources was tightly planned, including use of nurses, equipment, and operation technicians, then it would be impossible to accommodate the acute operations – there would simply be no resources available to handle them.

Thus on the basis of our study we would argue that optimizing the way in which operation-performance is coordinated would help significantly to increase productivity in an OR suite that performs both acute and elective operations. Moreover, the strategy of increasing productivity through tighter scheduling of elective operations will only succeed if changes to the schedule are optimally coordinated and managed.

Plans, Contingencies, Articulation, and Coordination

Our quantitative and qualitative results unanimously show that operation schedules are subject to significant changes in the course of the day; 67% of all scheduled operations were changed more than plus/minus 30 minutes; 44% of all operation were acute and hence added to the program in an ad-hoc fashion; and the interviews gave an insight into the complex coordination tasks required from the charge nurses. The study thus provides ample evidence that it is impossible, both in practice and in theory, to anticipate and provide for every contingency that might arise in carrying out a series of tasks. This means that effort must be put into adequate articulation work to deal with the unanticipated contingen-

cies that arise. Articulation resolves these inconsistencies by packaging a compromise that ‘gets the job done’.

This articulation work of – or the work of “getting the job done” – is evident in many cases at the OR suite. One sees it, for example, in the charge nurses’ description of having to coordinate with and notify all the staff involved in case of change; in the fact that they sometimes need to “steal” and reallocate staff to different surgeries and operating rooms; in the fact that non-specialized staff sometimes take part in operations; and in the need constantly to negotiate with the staff on the wards concerning the priority of patients.

However, it is important to note that changes made during the day are made to the operations schedule in the PoCCS system: all admissions of acute patients, all rescheduling, all changes of location, etc., are entered and updated on the PoCCS system’s schedule. Thus a key part of the PoCCS system is the shared OR schedule, which can be viewed remotely on mobile devices and public displays inside the operating rooms and on the inpatient wards, recovery ward, etc. And once the schedule is updated, it becomes – for the time being – the governing plan, ordering all the work of the OR suite. In this sense the operation schedule works as a coordination mechanism [15] embedding a set of explicit conventions and prescribed procedures for the efficient mediation of changes to the schedule. In the case of the PoCCS system, the explicit conventions and prescribed procedures include using different color codes for elective versus acute patients; listing the order of patients vertically, and using standardized status indicators to show the status of a given operation. It is precisely because the schedule conveys information about the current and future development of the work in a systematic and standardized way that it works as an efficient coordination mechanism across the hospital.

Continuous Planning

It is interesting to observe that the hospital operates with a strict division between the “planning” phase and the “execution” phase. Our study suggests, however, that this division may be rather artificial. If one looks at it from another angle, one could say that planning continues throughout the day, but that the activities and priorities involved in planning change.

Prior to the day of execution, the planning of elective operations is carried out on the basis of best-case scenarios (e.g. all patients will turn up and there will be no illness amongst staff) and strict rules are often enforced by the booking systems (e.g. rules that match the diagnosis to the surgeon with the right skills and the right equipment). An open question when making plans is how much space to reserve for unforeseen events. In Horsens Hospital one of the operation rooms is reserved for unplanned activities and in general no operations are pre-scheduled for the evening or night, even though staff are available to man an operating room during these hours. Despite this rather large “slack” in planning, which would appear to leave plenty of room for acute patients, 57 % of the elective operations are moved back or forward by more than an hour.

On the day of execution, the operation schedule is no longer optimized for utilization but for performance. At their conference each morning the clinicians discuss the program of the day. From this moment on, all clinicians act according to this program and a change in the program can no longer be made without involving all the people affected by it. Thus on the day itself planning activities are focused less on achieving an optimal situation than on coordinating and communicating in order to solve a puzzle involving unforeseen constraints and events.

This continuous adjustment of the operation schedule is the responsibility of the charge nurse. But it is not something she does alone; the ongoing adjustment is a collaborative activity involving most of the actors associated with the operating ward:

I: *So how many people do you reckon you have to talk to do coordinate such a change [an acute patient]?*

C1: *You could say you have to talk to all groups... Because we need to talk to the anaesthesia group, maybe the sterile department, maybe the service department...*

C2: *[...] the inpatient ward [...]*

C1: *[...] the surgeons [...]*

C2: *[...] the operation technicians*

C1: *[...] yes, the technician if he’s needed to help with handling [the patient] [...]*

I: *So there’s actually no one you don’t need to talk to?*

C1: *No [laughs]*

In order to handle contingent events that may occur, the charge nurses seem to constantly develop “what-if” scenarios; as one of the nurses explained, they constantly come up with ideas for alternative plans:

C2: *You don’t always have enough staff to handle an extra operating room and then you have a plan in the back of your mind. What if that happens, who could you take out of an ongoing operation. These kinds of things are already planned in the back of your mind.*

But in general the charge nurses agreed that unforeseen changes were part of the reality of an acute OR suite. It is not possible to plan for most acute operations, operations that take longer, operations being cancelled due to the patient’s condition, etc.

C3: *[Taking about unforeseen events] But – it’s something you can’t really do anything about – I think. I mean you can’t plan your way out of it...*

Articulating Continuous Planning

Because the plan is unstable and subject to ongoing adjustment, keeping everybody informed becomes essential:

I: *Is there anything particular you have to remember to do or say when the plan is changed?*

C1: *Inform the people in the operating room*

C1: *Yes — that’s probably the most important thing*

C2: *And the anaesthesia coordinator [...]*

In general the clinicians plan their own activities according to the most recent plan. This helps them anticipate the role(s) they will have to play on the day. Thus changes and reallocations become stressful factors in the work environment. For the charge nurse, an important way of reducing the overall stress level is to keep people constantly informed, as quickly as possible, about any changes made to the schedule.

C1: *[Talking about stressful situations for operating teams] If you [i.e. the operating nurse] have just prepared for a patient and you suddenly get another order. Then you have to remove all the instruments and find new ones. And it's not only that — you also have to mentally adjust to a completely new type of surgery.*

Thus an important job for the charge nurse is to keep everyone informed as soon as possible of any changes to the plan. The sooner the people involved know about a change the less stressful that change will be.

Whereas the responsibility for planning ahead is assigned to specific secretaries on the basis of available personnel and resources, the authority to change the plan while it is being executed is belongs to the charge nurses. But the charge nurses have to carry out this task in close collaboration with all the actors involved; the task is therefore challenging in terms of both cooperation and communication.

Negotiation Continuous Planning

The operation schedule also acts as a contract between the various actors involved in the work of the surgical departments. Thus any change to the schedule involves a modification to this contract, with the result that patients may have to wait, staff may have to work longer, or operations may have to be cancelled. One of the charge nurses' roles is thus constantly to renegotiate this contract. In the following excerpt the charge nurse discusses how the nurses on the inpatient ward often represent the views of the patient.

I: *Do you sometimes have to negotiate with people when you announce a change ... do the staff on the inpatients ward sometimes complain and argue: "You really can't move Mrs. Jensen", or ...?*

C3: *Yes, ...*

C3: *... they represent the patient's view*

C2: *.. and obviously, if you have to wait [...]*

C1: *.. and it's alright [to disagree]*

C2: *... it clearly isn't satisfactory ... and sometimes one of the patients does complain about it. And that's understandable, but we can't do magic here.*

Solving the "scheduling puzzle" involves a great many constraints and concerns and the patient's view is merely one of them. Thus only if the staff on the inpatient ward comes up with especially good arguments will their view be taken into consideration. As we saw above, such arguments often relate to the patient's condition.

The PoCCS system plays a key role in the way changes are negotiated. One problem, especially during the evening

and night, is to explain to the staff on the inpatient wards why their acute patient may have to wait several hours while patients from other departments are being operated. The PoCCS system makes clear which acute patients from the various departments have been given priority. Although this lays the charge nurses open to argument concerning their choices, the nurses in general felt that the system allowed for more sensible discussion.

C2: *They [the staff on the inpatient ward] are able to follow the work [in the PoCCS system] and see that we are currently operating on this patient. And they can see how things are lined up. But still sometimes — not as often as before [the PoCCS system was introduced] — they call and say: "My patient was booked for 2 pm. and it's 4 pm now . — why does my patient have to wait?". Then we say: "Take a look; you can see we are currently working with this patient", "Yes", [...]*

I: *So the job involves both coordinating and communicating*
C2:: *Yes.*

THE DESIGN OF COORDINATION TECHNOLOGY

Technology plays a key role in planning, coordinating, and executing operations in the OR suite at Horsens Hospital. The PoCCS system provides the clinicians with a common shared artifact where up-to-date information can be monitored. This eliminates the need explicitly to contact and disturb a clinician in order to obtain relevant information. The PoCCS system works across physical, temporal, and organizational boundaries, facilitating a shared overview and making it possible to trace communications through the messaging system. As such the system is used extensively, as the following statement makes clear:

C3: *And then in the medical department we get a lot of telephone calls — it would be very nice if... Will they ever be included in it [i.e., the PoCCS system]? Because they can't see anything... they can't follow what's happening. Because that's the thing ... it's very frustrating to be constantly rung up.*

Since the PoCCS system is intended solely for the surgical departments, the medical departments do not have it installed. Yet inpatients in the medical wards may also need to undergo surgery. The above statement by the charge nurse indicates that the PoCCS system has become an integral part of the coordination work inside and around the OR suite, and it becomes quite "frustrating" when other parts of the hospitals do not use it.

The PoCCS system is thus designed to provide distributed social awareness and evidently does this very well. However, it provides less support for what we have called "continuous planning". Adjusting the plan is still a largely manual process in which the charge nurse needs constantly to "plan ahead" and figure out various alternative scenarios if acute patients are to be incorporated into the schedule. And once this alternative plan has been created, she needs manually to go to the interactive whiteboard and move operations around between different rooms, reallocate surgeons

and nurses, update relevant information, add new acute operations, and manually start notifying the staff involved using either the text messaging system or the telephone. Thus accommodating a change to the schedule involves a lot of both mental and manual work for the charge nurse.

One implication of this study is thus that the PoCCS should be extended further to support “continuous planning”, in particular the handling of acute operations, the re-scheduling of existing operations, and the efficient notification and communication of these changes to the staff involved.

Handling Acute Operations

A key requirement in supporting continuous planning is to support the handling of the large percentage of unforeseen, acute operations (44% in this study). Acute operations are fundamentally different from elective ones, being by nature unpredictable. Thus it is not always possible to use the booking system to handle acute operations because the system requires the user to enter information on the ID and name of the patient, the operation to be performed, the staff required, the OR, and the equipment needed. But since in many acute cases none of this information is known – including even the ID of the patient – it may be impossible to “book” an acute patient. Although the PoCCS system is somewhat more flexible in this respect, allowing information to be added as it is elicited, the system offers only limited support for handling acute operations.

There are several ways to improve the PoCCS system. First, acute patients often enter the hospital via the emergency department (ED), but there is currently no connection to the PoCCS system from the ED. In order to create early awareness of incoming acute patients, the PoCCS system should be able to start visualizing them as soon as possible, perhaps even before they arrive at the ED. Further, much better support could be provided for gradually filling in relevant information and adding staff and other resources as the case evolves.

Rescheduling Operations

Accommodating acute operations into the schedule involves extensively rescheduling. Although the PoCCS system allows the charge nurse to reschedule operations, both time-wise and between operating rooms, it provides very little support for handling the cascading consequences of rescheduling an operation. For example, if an acute operation needs to be accommodated in the program, rescheduling all the elective operation for that day is a tedious manual task. And the decision as to where and when to place the acute operation often depends on the consequences of any given decision for the entire schedule – consequences which may be hard to grasp without actually doing the rescheduling. And if the choice made turns out to be a bad one, there is no support for “undoing” the rescheduling.

An important aspect of a system that aims to support continuous rescheduling would thus be that it would allow the user to try out various new scenarios involving different schedules. The charge nurse could enter a simulation mode to try

out different options in theory; only once a workable new schedule had been created would this become the official plan. At any point the charge nurse should be able to revert to the original schedule.

The creation of such rescheduling scenarios could be guided by real-time data about the ongoing work at the OR suite combined with the various constraints that need to be upheld. For example, the PoCCS system might list potential surgeons for an operation based on their current availability and location, and simplify scheduling by ruling out any double booking of resources such as surgeons, nurses, and ORs.

Notification and Communication

Once the schedule has been changed, these changes need to be articulated and the relevant staff need to be notified. Currently, notification is done manually by the charge nurse who sends messages to the relevant people and places (e.g. the ORs involved). An important aspect of supporting continuous planning is to help the charge nurse and other clinicians to communicate efficiently. Support for semi-automatic notification can be added to the PoCCS system. For example, once a new schedule has been designed and is being made official, the system may help the charge nurse to notify the staff involved. Automatic notification concerning changes to the schedule should, however, be designed with caution in order not to generate too many irrelevant and potentially annoying notifications. Thus it is important that the design would allow the charge nurse to be able to select which notifications to send, and to whom; how the notifications are delivered; and provide mechanisms for receivers to set up preferences as to which notifications they want to receive.

CONCLUSION

While it is hardly a surprise for the CSCW community that plans in a collaborative workplace should be regarded more as a resource than as a determining factor, few studies have provided quantitative insight into the extent of this phenomenon. On the basis of log data from a Peri-operative Coordination and Communication System (PoCCS), which supports the execution of operations in an OR suite, we have been able to investigate to what extent the “plan” deviates from the actual work done “by the end of the day”. Our findings include the following:

- Only 56% of all operations are planned ahead. The remaining 44% are acute and thus scheduled *ad-hoc*.
- 8 % of all operations are cancelled.
- 31% of all operations are shortened or prolonged more than 30 minutes.
- 67% of all planned (“elective”) operations are substantially changed.

In total these figures imply that on average only 18% of any given operation schedule is enacted as planned. This quantitative analysis was followed by a qualitative analysis investigating the reasons for changes to the plan, the consequences

of such changes, and the strategies used to cope with them. These qualitative studies confirmed the quantitative results in highlighting incoming acute patients as a primary source of change, but also pointed to several other factors, including the condition of the patient and illness among staff. As far as consequences were concerned, the changes involved a lot of rescheduling (referred to as “solving a puzzle”), articulation and negotiation with the involved parties.

A common theme in the study was that planning evolves as plans and execution are entangled in a complex coordination puzzle. We have called this phenomena “continuous planning”. Whereas effective booking is the main tool in planning for optimal resource utilization, planning while executing requires coordination, communication and articulation work. On the basis of our quantitative and qualitative data, we have shown how continuous planning takes place around an operation suite, and we have highlighted some of the coordination, communication and articulation strategies the coordinators embrace to solve the planning challenge.

Finally, we argue that while the hospital’s PoCCS system supports workplace awareness, coordination, and communication, it fails to provide adequate support for continuous planning, which could help the charge nurse to be more efficient in handling the constant rescheduling of operations.

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