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Monitoring practice and alarm technology in anaesthesiology

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In this article we examine how one of the most pervasive technological implementations in the healthcare domain – the alarm system – is used in anaesthesiology as part of patient monitoring. The utility and appropriateness of alarms in healthcare domains have been widely addressed in the literature. However, we argue that we still know little about the practical use of alarm systems in actual healthcare practice. Studies rarely examine in detail the everyday monitoring practices during normal operations in the absence of, or before, problems become critical and alarming. They have mainly considered how medical professionals manage the interpretation of and response to alarms. Rather than examining how the anaesthesiologist identifies and responds to alarms and critical problems, in this article we focus on how the anaesthesiologist is actively and prospectively engaged in implementing a situated and emergent organization of patient monitoring, using a wide range of different technological and material resources.

Keywords

alarm technology, anaesthesiology, awareness, monitoring practice

Introduction

One of the most pervasive technological implementations in many healthcare settings is the alarm system. The utility and appropriateness of alarms in healthcare domains have been widely addressed in relation to the notion of monitoring and awareness in research fields such as human factors and ergonomics (cf. [1–3]). It is remarkable, however, given the proliferation of alarm systems in healthcare and the extent to which alarm technology is designed to support the practitioner, how little we know about its actual use in everyday healthcare practice. Many studies focus to a large extent on how medical professionals

manage the interpretation of and response to actual alarms. Studies do not examine in detail how alarm technology features within the mundane and everyday practice of skilled and competent practitioners; in particular, how practitioners orientate to alarms and critical problems during everyday normal operations, before problems become critical – save for a few exceptions [4, 5]. Less consideration is devoted to the detailed analysis of how practitioners themselves organize and configure their activities to avoid critical problems and alarms. There is an emerging body of studies concerned with tailoring practices and improvisational work [6, 7]. However, there is a tendency in this body of literature to favour the consideration of how improvisations and workarounds can be avoided by better technical design rather than examining how those tailoring and configuring practices should be supported as an integral and necessary part of the actual work.

In this article we consider a particular setting in which the conduct of patient monitoring builds on contingent forms of vigilance and attention to patient condition using a variety of technological support. The setting in question is the operating theatre and the examination focuses on the competence and working practices of the anaesthesiologist. Rather than examining how the anaesthesiologist identifies and responds to alarms and critical problems, we wish to focus on how the anaesthesiologist is actively and prospectively engaged in implementing a situated and emergent organization of patient monitoring. We will examine how the anaesthesiologist is engaged in a prospective reading of alarms and investigate the ways in which other more conventional technologies, such as paper records, feature as an integral part of their monitoring practice.

Before we present the setting and the analysis, it is worth mentioning that the issues and analysis of situated human conduct and practice discussed here have been influenced by a corpus of naturalistic workplace studies (cf. [8–12]) that have emerged through the pioneering work of Lucy Suchman [13]. One of the motivations for the present investigation is to show how seemingly individual cognitive activities are tied to the experience of particular cases and circumstances, a web of practical tasks and undertakings, the ongoing interaction with others in the setting, and the wide range of technological and material resources.

Anaesthesiology and patient monitoring

Anaesthesiology is the branch of medicine that is concerned with the management of anaesthetics to relieve pain and support the critical life functions of patients undergoing surgery. Available to the anaesthesiologist in the anaesthetic room and in the operating theatre is an anaesthetic machine. The anaesthetic machine has become increasingly complex and now incorporates components for delivering and controlling the anaesthetic gases, ventilating the patient, monitoring patient condition and managing medical data (see Figure 1). When the patient has been put into sleep and the body is no longer able to respond or function on its own, the anaesthetic machine and the monitoring devices support the anaesthesiologist in monitoring changes in bodily functions and protecting the patient against the surgical interventions. Importantly, as a substitute for direct contact with the patient, the anaesthetic machine provides visual, audible and tangible resources for managing the delivery and control of anaesthetics, and an invaluable support for detecting problems and critical events.

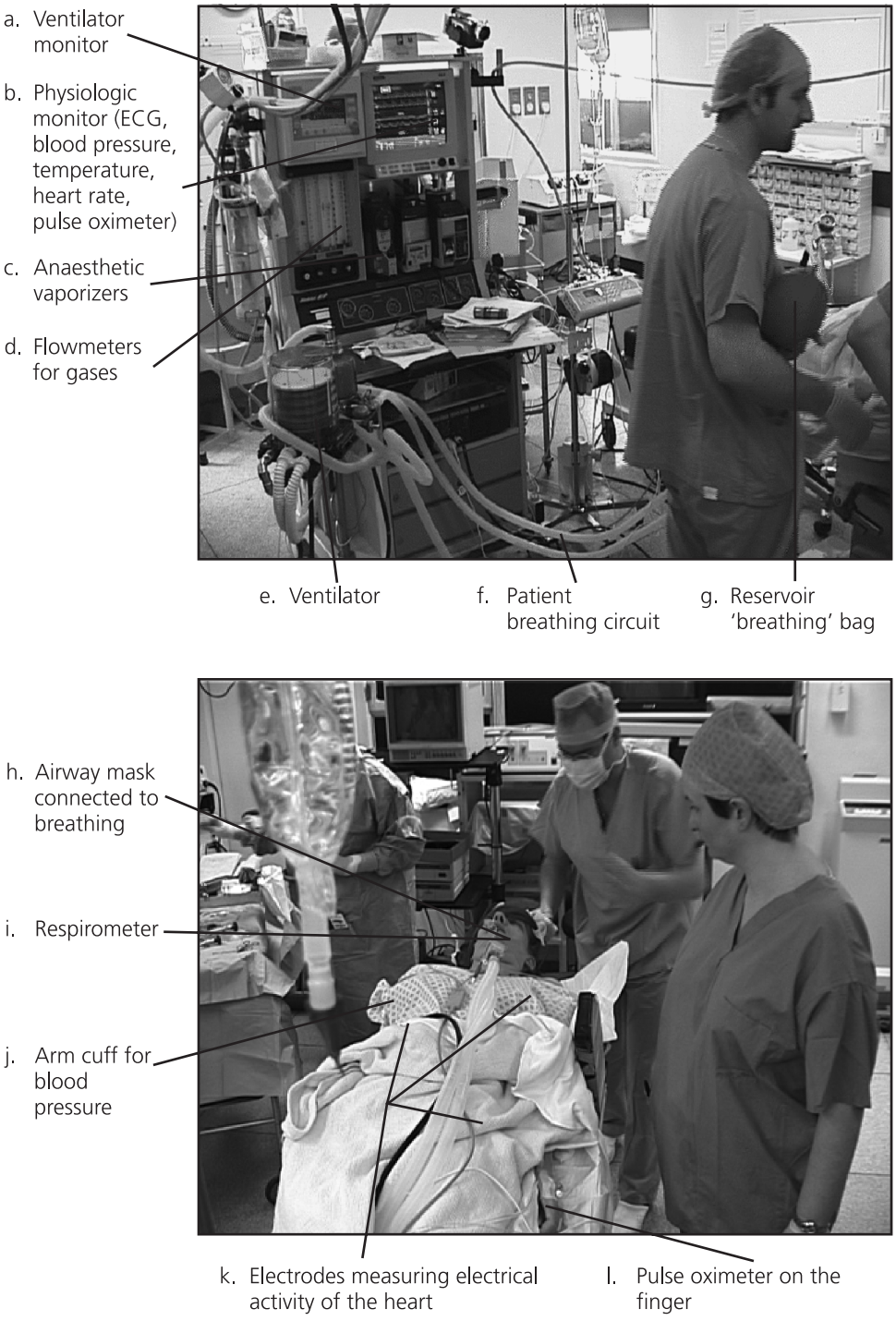


Figure 1 Anaesthetic machine

The monitor screens provide a range of indications of machine operations and patient condition. On the patient monitor the anaesthesiologist can observe the rhythm, rate and conduction of the electric forces of the heart translated into waveforms visually presented on the screen. Available are readings from the pulse oximeter, which presents the pulse rate and provides information about oxygen saturation, including other measures such as blood pressure, body temperature, urinary output and carbon dioxide. Sometimes when the indications observed on the monitor screens cause concern or appear unreliable – such as when the blood pressure is extremely low – the anaesthesiologist can rely on tactile resources. Occasionally, when possible, the anaesthesiologist can sense the pulse and the temperature by placing a hand on the patient's body; or can sense the pulse, the heartbeat and the ventilation through the tactile experience of holding and pressing the reservoir 'breathing' bag. Also, audible elements such as the rhythmic sound of heartbeat and the noise from the ventilator equipment, including the alarms and alerts for that matter, provide an alternative information resource when practical circumstances make it difficult to attend to the visual and tactile resources.

Available to the anaesthesiologist is a large amount of information that is important to the management of patient condition during the surgical operation. One might believe that the anaesthesiologist oversees all these indications and relies on the anaesthetic machine to provide the resources with which to detect events and respond to critical problems. However, in contrast to the conventional view on monitoring and awareness, the scope of monitoring and how the anaesthesiologist organizes monitoring depend on particular cases and practicalities at hand. Special to the trade of the anaesthesiologist, and the area of responsibilities, is the skill, competence, practical reasoning and routine practice of anticipating problems and implementing anaesthesia as appropriate within the developing course of a particular surgical operation. The anaesthesiologist creates and sustains an attention to the patient's condition that is closely tied to the organizational relevance of contributing to the smooth and unproblematic running of the surgical operation.

Organizing monitoring: regulating bleeding

One of the immediate concerns in many of the typical cases in the hospital where this study was undertaken is to produce a relatively low and stable blood pressure over a longer time. The reason is that variable blood pressure levels may cause bleeding and in middle ear operations, for example, bleeding can disrupt and make the surgical procedures difficult. For the anaesthesiologist, the concerns are to provide good opportunities for the surgeon under safe conditions for the patient: low blood pressure reduces bleeding but increases the risk of problems for the patient during and after the operation (see [14] for more discussion about the coordination of blood pressure).

One of the ways in which the anaesthesiologist can produce a fall in blood pressure is to adjust the level of anaesthetic gas and administer drug injections. Achieving a constant low blood pressure is very difficult and relies upon knowledge about the properties and influences of drugs and gases. The anaesthesiologist pays particular attention to the emerging effects of drug actions as the results of adjustments may not always show immediately and sometimes there is a risk of causing lower or higher blood pressure than intended.

Another complication is that an individual drug or agent, or a combination, may cause unwanted effects. For example, lowering the blood pressure by increasing gas flow may have a negative influence on the heart. In such cases, special attention is directed to the visual and audible indication of the heartbeat. On the other hand, when decreasing the level of anaesthetic gas administered, which subsequently causes higher blood pressure, the anaesthesiologist has to pay attention to the level of pain relievers and make sure the patient is properly asleep. As we can start to recognize, the work of patient monitoring is very much about continuous vigilance of the progress of surgery and its effects on the patient's body, and intervention so as to compensate for those effects and maintain equilibrium. Interventions are not, however, called for as in the sense of an alarm, at least not during normal operations, but are called for from within the work of actively having done the regulation and adjustment of the blood pressure. The anaesthesiologist knows what to look for, and when, and what to do in order to avoid potential problems becoming critical. Monitoring practice relies upon the skilled competence and reasoning of the anaesthesiologist, embodied in the emerging organization of actually doing the fine adjustments.

Given the delicate nature of organizing monitoring, the anaesthesiologist utilizes a range of technological resources. For example, the ways in which blood pressure is measured and presented provide certain practical resources. One feature of the anaesthetic machine is an automatic blood pressure instrument that can be set to measure and present the blood pressure reading on a regular basis (usually every 1–3 minutes). When a new blood pressure reading is available, the anaesthetic machine activates a single sound alert and presents an update of the reading on the monitor. Rather than constantly looking at the monitor, the anaesthesiologist can wait for the audible indication. Related to this function is a graphical progress bar that indicates remaining time before next update; thus, it is a known and regular waiting time. Let us consider a brief example.

We enter the action in the operating theatre. The anaesthesiologist has been sitting down for a while after having managed to produce a relatively stable blood pressure. The anaesthesiologist turns to the anaesthetic machine, glances (see Figure 2a) at the monitor and notices that the progress bar indicates an upcoming update. She sits up in the chair and a few seconds later the audible indication of the reading activates. The anaesthesiologist turns more directly towards the monitor and inspects the visual presentation of the blood pressure reading on the monitor screen (2b). Apparently, this particular reading does not seem to cause any concern as she immediately turns away from the anaesthetic machine (2c).

Repeated observations of this occurrence show that the blood pressure alert is not only a prompt supporting the anaesthesiologist in remembering to examine the blood pressure, but also an opportunity for overseeing all other indications and possible complications on a regular basis. Moreover, the progress bar saves the anaesthesiologist from unnecessary inspections as the timing of the next reading is revealed. In other words, the technology supports a way of engaging actively and prospectively in monitoring the patient without demanding constant attention.

This observation becomes even more interesting when considering how this practice is related to the making of notes in anaesthetic records. Despite the availability of automatic record-keeping facilities, anaesthesiologists most of the time make their own notes in

a b c

Figure 2

paper records. These paper records contain information about drugs administered and other readings such as oxygen saturation, airway pressure, and temperature. Another feature of the records is a blood pressure and pulse chart (see Figure 3). These notes provide an account of the context of the readings registered in the automatic machine records. On an everyday basis, the plots provide a resource for anaesthesiologists to illustrate and organize the maintenance of a stable blood pressure and to detect problems. Interestingly, one of the features of this approach and the availability of regular blood pressure readings is that it opens an opportunity to make regular notes in the anaesthetic records.

Another related point is that regular note taking is an opportunity and an encouragement to make the necessary adjustments to the anaesthetic. Consider the following brief example. The anaesthesiologist has just received an update of the blood pressure reading and is about to make a note in the record (see Figure 4a). As is often the case, the anaesthesiologist stands up and makes a few adjustments (4b), checks the patient manually (4c), and then prints the notes in the records (4d). In our material we can see how the anaesthesiologist often checks the patients and makes notes of other readings before notes are made. For the anaesthesiologist, note taking is an opportunity to evaluate and decide what changes are necessary to regulate the condition and maintain a constant and low blood pressure in order to avoid critical problems.

These brief fragments begin to reveal some of the ways in which the anaesthesiologist orients to the task of patient monitoring. We can also see how particular tools and technologies feature in its accomplishment. It is interesting to recognize how the visual and audible indication of the blood pressure reading provides a practical resource for the anaesthesiologist to attend vigilantly to the patient's condition during the long hours in the operating theatre. Moreover, as we have seen, the regular note taking in the conventional paper records is nicely made to coexist with the functions of the monitoring equipment and the features of the display interface. The practical use of tools and technologies is intimately

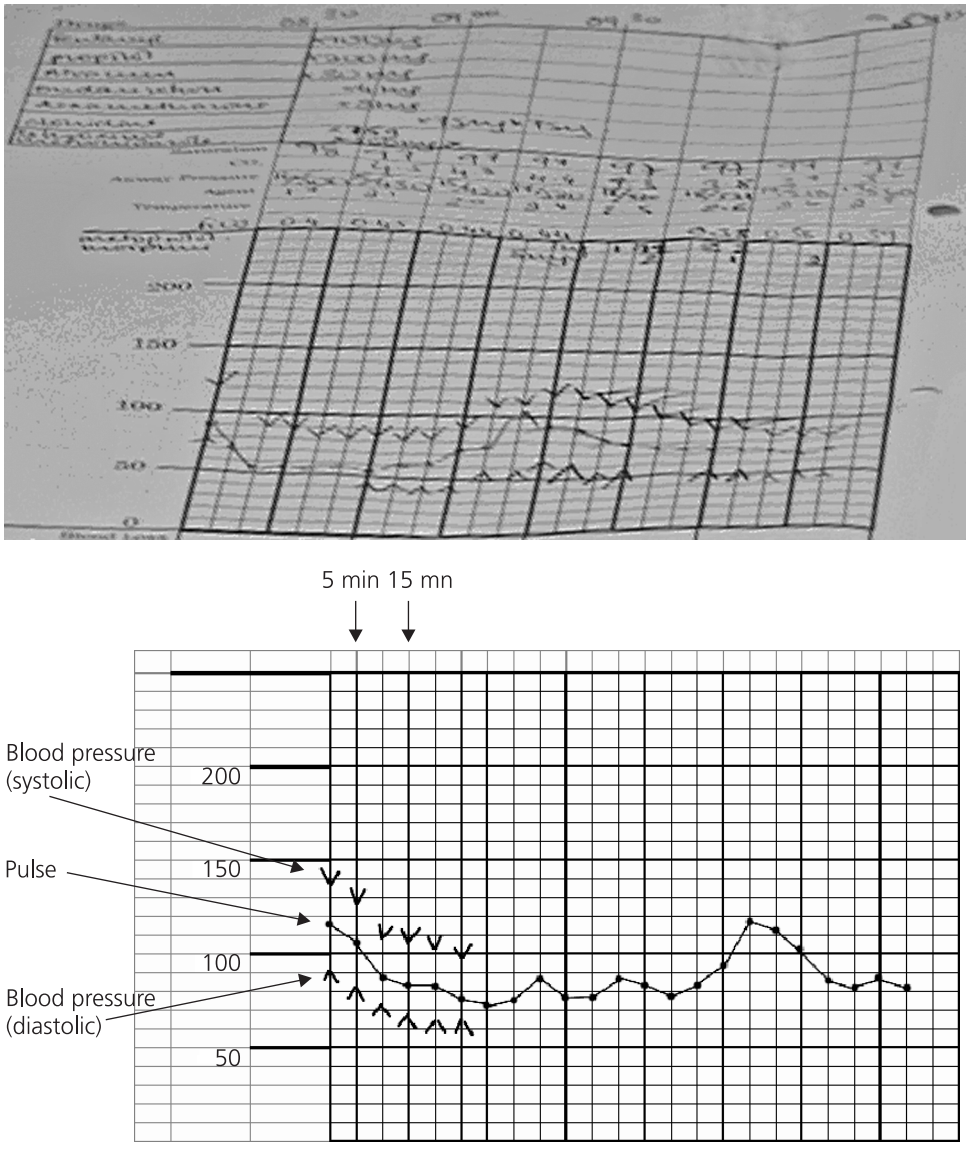
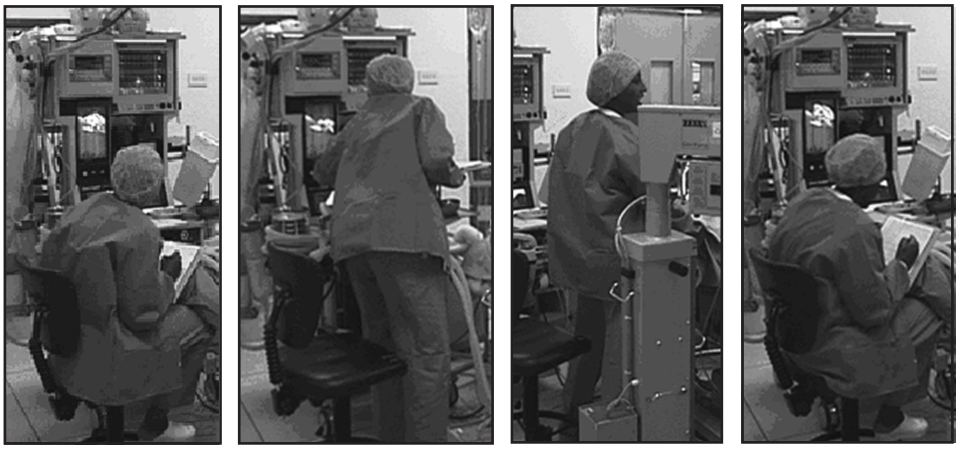


Figure 3 Notes in anaesthetic records

connected to the practicalities of the tasks at hand and the demands of particular cases. Thus, rather than simply passively monitor or respond to a large and complex amount of data presented and indicated, the anaesthesiologist is actively organizing the medical evaluation and regulation. The anaesthesiologist selects a set of monitoring devices in a way that enables him or her to detect and treat likely problems and events. Moreover, the anaesthesiologist deploys an organization of the monitoring task in a way that will preserve the safety of the patient and the contingent practical concerns of the surgical activity.



a b c d

Figure 4

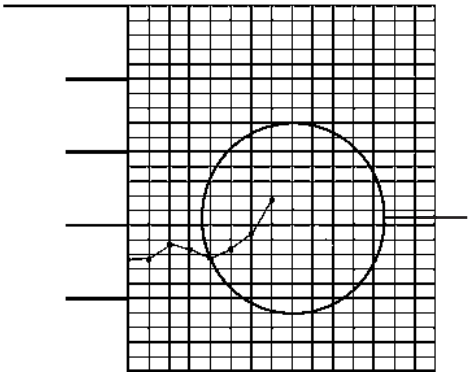
Observing surgical conduct: prospective orientation

The organization of patient monitoring is firmly embedded in an understanding of the progress of the surgical operation. Observations of surgical conduct may reveal potential problems and upcoming complications. For example, during the surgical operation the patient may respond negatively to the stress of surgery because some interventions may stimulate the body and produce unwanted effects on blood pressure, heart rhythm and other bodily functions. By observing and inspecting an incision and following the result of an intervention, the anaesthesiologist can make the necessary preparations for potential problems and implement timely responses: the anaesthesiologist is prospectively orientated. Consider the following example.

The surgeon is currently making an incision in the head scalp. This is a procedure that is particularly painful for the patient. For the previous 10 minutes, the senior consultant anaesthesiologist, Mary, has noticed an increasing blood pressure and heart rate. She has made continuous notes in the anaesthetic record, which show how the blood pressure has quickly gone from 79/46 to 116/64 (see Figure 5). However, Mary has also paid attention to the fact that the surgeon is currently making an incision, which provides an explanation for the increasing blood pressure. Since the anaesthesiologist knows that pain influences blood pressure, she has given the appropriate drugs to relieve pain and stabilize the blood pressure.

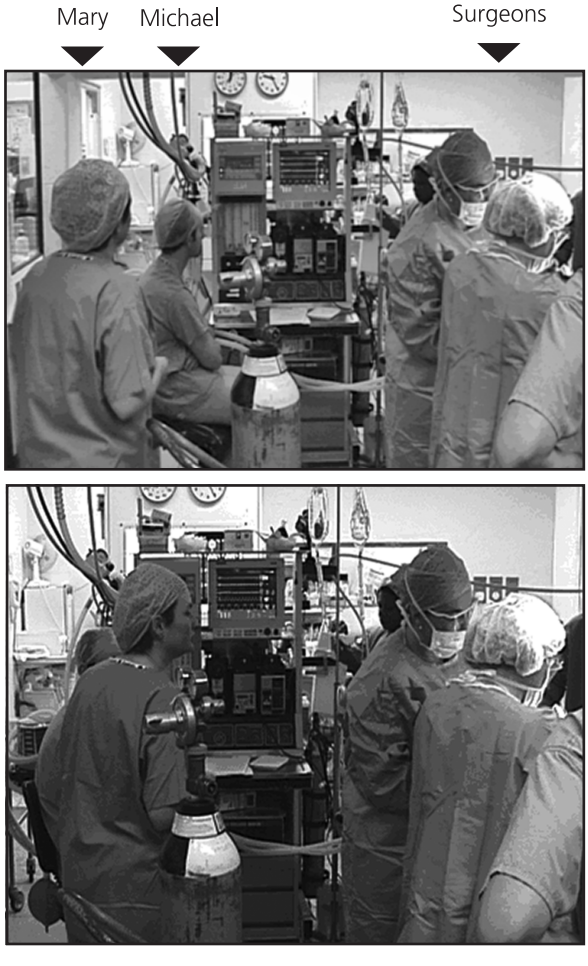
When we observe the action in the operating theatre a few minutes later, a senior registrar, Michael, has just joined Mary. At this point, Mary leaves the room to fetch some materials. When she returns a moment later she notices Michael staring at the monitor screen and appearing to have noticed the current problem (see Figure 6a). Mary turns around towards the scene of the surgical operation (6b). Michael looks at Mary and when she turns towards him again he asks her, 'What's going on?' (6c).

Michael's question to Mary seems curious in that one would expect him to know what is going on just by looking at the monitor screens and reading the notes in the anaesthetic



Time	Pulse	Blood press.
9.11	72	79/56
9.13	80	91/47
9.16	69	98/51
9.18	91	101/58
9.22	92	104/54
9.24	100	108/58
9.27	100	116/64

Figure 5 Increasing pulse and blood pressure



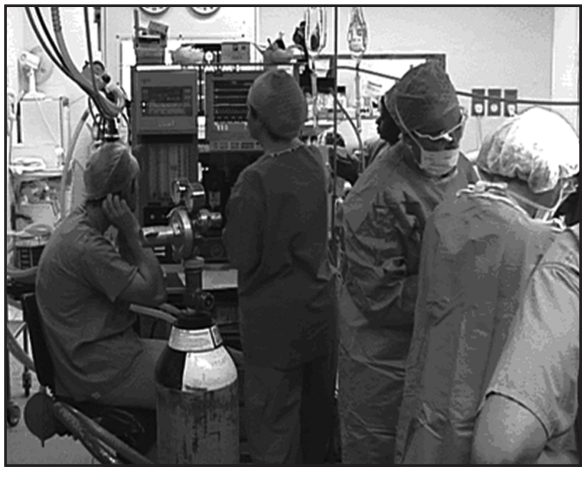
(*Figure 6 continued*)

(*Figure 6 continued*)

c

Michael: What's going on

Mary: Ahmm (—) I have given some (_____) =



d

Mary: = but I think this is pain

(1.0)

Mary: We just have to wait and see

Figure 6

records. But it is a reasonable question as he has just joined the operation and has not seen what has just happened or has been done recently. Even though we are not able to recover exactly what is being said next, it is possible to hear how Mary tells Michael that she has given the patient a drug: 'I have given some ….' She then gets Michael to see the fact that the current problem has to do with the previous incision procedure that has been under way for the past 15 minutes. She steps forward and points at the indication of the blood pressure on the monitor screen (see 6d) and tells Michael, 'I think this is pain' and 'We just have to wait and see.' Interestingly, asking what is going on is not only a question about the current status, but appears to be an invitation to give an account of what has already happened and what to do next; at least, that is what Mary seems to understand as a relevant response given the current circumstance. Mary's account enables Michael to see and understand the current situation retrospectively.

This brief encounter between the anaesthesiologists shows some of the ways in which patient monitoring is organized in orientation to the emerging circumstances and implications of the surgical operation. The orientation is not only to the specifics of this particular case but also to the ways in which this case, here and now, develops over time. Based on this understanding, the anaesthesiologist puts in place an organization of necessary actions and a utilization of particular technological resources. As we have seen in the previous example, one of the anaesthesiologists has been immersed in the management of this process, the other has not. That 'This is pain', and that 'Wait and see' is what should be done next, are not possible to understand without having actually been immersed in the continual process of organizing the activity and doing the work. It is the moment-by-moment use of medical data, computer functions, paper documents, and the contingent configurations of routine procedures and practices, worked into the task at hand, which make up the accomplishment of patient monitoring. The anaesthesiologist's primary skill and responsibility are not to be ready to handle emergencies but to read alarms prospectively and avoid critical events emerging and happening.

Conclusion

When examining work situations involving a monitoring function, there is a tendency to make a sharp separation between two modes of work: the everyday uneventfulness, when nothing happens; and the dramatical events, when critical problems call for attention and immediate action. This is an outside view. We would argue that such a view might lead to the idea that we only need the work practitioner to discover emergencies and intervene when problems become critical. It is also a view on technology that runs the risk of directing our analytical attention to issues of how practitioners use alarm technology and the ways in which they manage the interpretation and response to alarms. In this article we have taken an inside and detailed view on monitoring practice and the use of technology in anaesthesiology. Our observations reveal that the anaesthesiologist in the course of doing the work does not – and would not – make a distinction between the unexpected and the uneventful. We have shown that the work of patient monitoring is not primarily about correcting mistakes or responding to critical events but depends largely on the practical reasoning and competent ways of organizing attention, avoiding problems and preparing for the unexpected using an array of technological resources. The anaesthesiologist is actively and prospectively engaged in reading and avoiding problems by implementing a situated and emergent organization of patient monitoring, using a wide range of technological and material resources.

These observations are interesting with regard to technology and system design. Operating theatres provide an excellent example of a working environment that has been subject to considerable technological developments. Automated record-keeping systems and advanced alarm technology are now commonplace in the operating theatre. However, it is interesting to notice how conventional technologies such as paper documents continue to be a critical resource for the management of patient monitoring. As we have seen in the cases observed, monitoring practice in anaesthesiology builds on an interrelationship between the attention to patient data and the updating of the records. Making notes in

paper records provides a resource for organizing contingent attention to medical data such as blood pressure. Moreover, the multimedia system has functions that can be set to prompt the anaesthesiologist on a regular basis to check a range of other readings and make the necessary adjustments before the notes are made in the records. These observations indicate that the anaesthesiologist has to remain central to the operations of the equipment; the anaesthesiologist must not only identify and determine the relevance of events but remain in control of building an organization of anaesthesiological attention with regard to the particulars of the case at hand and the ongoing surgical activity. The general recommendation to designers of systems and technology for monitoring practice in healthcare settings is to recognize the practitioner's competence and reasoning that constitute the accomplishment of patient monitoring – a recognition that speaks for the relevance of flexible support for accomplishing the ongoing organization of patient monitoring. The anaesthesiologist combines a wide range of different technological resources that provide the kind of flexibility and focused support that enable the anaesthesiologist to stay informed and vigilant – both in times of uneventfulness and within the course of emerging problems and critical events. One could, for example, consider how new systems would be able to support the practices of making notes as a resource for monitoring, including allowing computers to support the reading and writing of the records during the course of the surgical operation.

There is one more general issue with regard to the place of technology in future practices of patient monitoring. There is a danger in believing that automation technology and alarm systems could remove the professionals from the actual monitoring process and only call for human attention and intervention when problems occur. However, there is an increasing recognition that we cannot conceive the performance of mundane and routine operations as replaceable in the sense that we only need the professional labour to intervene when problems become critical. It is not simply that we run the risk of underestimating the specific skills and knowledge involved in patient monitoring. It is rather that we may fail to recognize that not allowing the competent practitioner somehow to be involved in the situated and emergent regulation of patient condition makes it difficult for him or her, and in particular for collaborating others, to step in and take responsibility for responding to critical problems and events. We are not saying that less effort should go into the design of alarm technology, but we are arguing that studies of technologies in practice can guide designers and managers to understand how monitoring technologies can become more supportive of the work that actually goes on in the medical setting.

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