Delicate balance

Adaptive support to improve patient safety

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INTRODUCTION

Patient safety increasingly depends on health professionals' ability to deal with the technological, organisational and social complexity of their working environment.[1] The operating room (OR) is such a complex dynamic environment, not just because of the increasing use of technology, such as information technology (IT), monitoring and surgical devices to assist surgical procedures,[2 3] but also because of less obvious factors, such as an increasing number of comorbidities per patient[1] and the pressure to increase productivity and efficiency.[2 4] Although many efforts have been made over the years to improve patient safety in the OR, considerable avoidable harm to patients still occurs in the operative process.[2 4–7]

This paper starts from the assumption that supporting medical staff to deal with the increasing complexity of day-to-day OR practices will increase patient safety. This paper provides an overview of the current discussions on standardisation on the one hand, and flexibility on the other, as approaches to deal with complexity in the OR (section 2). We argue that a balance must be struck between standardisation and flexibility to ensure patient safety. More specifically, we propose to develop technological support systems based on an approach (section 3) in which standardisation and flexibility are reconciled to both reap the benefits of standardisation and maintain the ability to anticipate unexpected events. We call this *adaptive support*. Then we propose a stepwise approach to provide adaptive support (section 4) by: (1) ensuring high-level understanding of OR processes, (2) real-time recognition of the situation that is at hand, and (3) providing technological support accordingly. We describe how technology already provides some ways to make systems that adapt to day-to-day variability in the OR, but conclude that more work is needed to make adaptive support possible.

STANDARDISATION AND FLEXIBILITY: DIFFERENT APPROACHES TO IMPROVE PATIENT SAFETY

Many studies have recognised the tension between the complexity of medical practice and ensuring patient safety. This section depicts two common approaches to ensure patient safety with regard to the increasing complexity of medical practices; one intends to reduce complexity through standardisation, the other to embrace complexity by stimulating flexible policies, behaviour and technologies. Note that it is not merely complexity that poses a problem for patient safety. A process or situation can be complex in terms of factors and elements that feed into it, but still be perfectly manageable (for instance through automation). In our view, complexity poses problems once it leads to medical staff being presented with multiple options for action that are hard to oversee or prioritise because of their similar emergent character. Then, managing all the different elements of the complex system becomes a too demanding task.

The principle of standardisation

In the field of patient safety, systems thinking aims at improving patient safety by creating robust and reliable systems. This often implies a form of standardisation: an attempt to reduce variability and to make the system as a whole less complex. For instance, the introduction of standards and guidelines has remarkably benefited safety in anaesthesia.[5–7] The added value of standardising processes has also been recognised in clinical oncology in which time-outs, quality and safety checks were implemented strategically to increase the ability to detect and respond to failure, and thus reduce the propagation of errors.[3] Moreover, surgical checklists

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have been shown to decrease the amount of surgical complications and mortality[8 9] as well as the amount of incidents per procedure related to surgical equipment.[10] Guidelines on hand hygiene have also been introduced to reduce healthcare-associated infections.[11 12] Thus, a systems approach has definitely contributed to the provision of safe care.

Despite many benefits of standardisation, it may also result in unsafe practices due to a mismatch with existing working practices.[6] Disadvantages, such as the time-consuming aspect and the rigidity of the processes, have been recognised in previous studies.[10 13] These disadvantages can be well illustrated with the low rate of adherence of surgical checklists[14 15] and hand hygiene protocols.[12 16] They do not seem to be apt as patients sometimes arrive with several different checklists in the OR, which causes bureaucracy, time pressure, and leads to frustration of the OR team and thus devaluates the safety aspects of applying standardisation. Another example of rigid systems can be observed in OR scheduling. In general, average durations for each type of procedure are used to set up OR schedules. These schedules are often unreliable as they are not adaptable to unplanned changes in the progress of the procedures.[17 18] The consequence of employing rigid and time-consuming systems can be the proliferation of workarounds such as deviations, improvisation and shortcuts of these systems.[19] Workarounds can compromise safety as they may result in situations being less safe than without using the systems. Meticulous attention to the actual use of systems in situ is required to implement standardised processes while reducing the chance for workarounds.[20]

The principle of flexibility

Several studies acknowledged the complexity of healthcare systems and the non-validity of simple cause and effect assumption.[7 21–23] Standards and guidelines are designed to match stable and predictable situations, which is not the actual situation in many healthcare settings.[7 22] As stated by Patterson,[21] 'imposing a simple standard on a complex process does not result in simplicity'. This has recently led to a new approach to safety called Safety-II, which claims, among others, that in complex healthcare systems, individual health professionals are often the ones ensuring safety by providing flexibility to the system. Through mindfully adapting to unexpected events, medical staff can balance the physical, social and technical demands they are confronted with in the OR.[7] Safety-II therefore encourages to study the functioning of systems under varying conditions in the operating room,[7 22] and particularly the role of the individual in dealing with unexpected events.[22 23]

The importance of individual and team capacity in patient safety is widely recognised.[24] Training of medical teams focused on communication, situational awareness, leadership and situation monitoring.[24] These aspects increase the ability of a team to function under varying conditions, and therefore match the Safety-II approach. An example to illustrate the key role of professionals in OR processes is OR scheduling. Despite research performed to improve OR scheduling,[25] the role of the OR scheduler in practice is still essential to deal with all the complexities of aligning the OR processes. One striking example of this is that even an OR manager game has been developed to give insights into the difficulties of this task.[26] Despite the extensive training of medical professionals, it is impossible to prepare for each possible unexpected event. Medical staff is trained for planned and acute emergency procedures, but sometimes things go wrong in busy OR departments. There is a limit to the ability of professionals to oversee all OR processes and possible course of actions.

The view emerges that standardisation targets elements of the system (such as procedures or protocols) to simplify OR processes. Flexibility, on the other hand, targets professionals in the sense that it gives them the opportunity to deal with the complexity of OR processes. There is a clear difference in mindset (reduce complexity vs embrace complexity) and in targets (systems vs professionals). In practice, a combination of both is needed; it is clear that some autonomy is needed for the professionals to manage complexity. At the same time, some form of standardisation is needed to ensure a constant level of quality and make OR practices more efficient and less demanding for medical staff.

STRIKING A BALANCE THROUGH ADAPTIVE SUPPORT

Knowing what level of standardisation or flexibility is desirable in a certain situation is key in adequately dealing with complexity. However, the two ways of dealing with complexity do not rule each other out. Therefore, it has been argued that a balance between, or rather an integration of, standardisation and flexibility is needed.[7 21] We propose *adaptive support* as a way to reconcile standardisation and flexibility, that is, standardisation that is adaptive to the particularities of a situation, while increasing the abilities of medical professionals to respond to varying and unexpected situations. Instead of creating rigid standardised systems in which professionals are forced to find 'workarounds', creating adaptive systems can incorporate standardisation in a flexible way. For example, adaptive checklists would entail a high level of standardisation and, at the same time, introduce flexibility by helping medical professionals make decisions on the ongoing procedure. Adaptive support could help professionals with monitoring processes, situation awareness and automating certain tasks. This provides support for professionals without the disadvantages of rigidity.

Support systems need to be well designed to respond to the situation at hand, and interaction with

the OR staff needs to be carefully studied. In order to do this, a high-level understanding of OR processes is required. This is obviously not an easy task considering the complexity of the environment. Insight into this complexity, which is essential to deeply understand the OR processes, is often lacking. Much of the friction and hazards that happen with systems based on standardised practices can be considered a knowledge problem. Such systems may not sufficiently take the particularities of the situations they were developed for into account. To develop adaptive support systems, we need first a high-level understanding about the range of possible OR processes, second, to be able to recognise the situation that is at hand, and third, to provide support accordingly.

THE WAY TO PROVIDE ADAPTIVE SUPPORT

The implementation of adaptive support is challenging at various levels; therefore, this section discusses a stepwise approach for how to achieve adaptive support. The approach is represented schematically in figure 1. For each step, we give practical examples of how technology may help achieve adaptive support. We also identify opportunities and challenges in doing this.

Step 1: Generating a high-level understanding of OR processes

In order to gain insight into OR processes, information needs to be systematically *recorded in the OR*. Various solutions to gather data intraoperatively are available, such as audio and video recording, or using endoscopic images and vital parameters of the patient.[27–29] Additionally, the usage of instruments and devices can be monitored[29–32] and data can be retrieved from electronic health records and OR scheduling systems. These studies revealed many opportunities of (automated) data recording, but are not performed on a large scale (yet). In order to record and store these many data sources, a robust and integrated IT infrastructure is required. A recent study showed the potential of IT infrastructures for a structured recording of intraoperative data and expressed a wish for further integration of data acquisition technologies.[31]

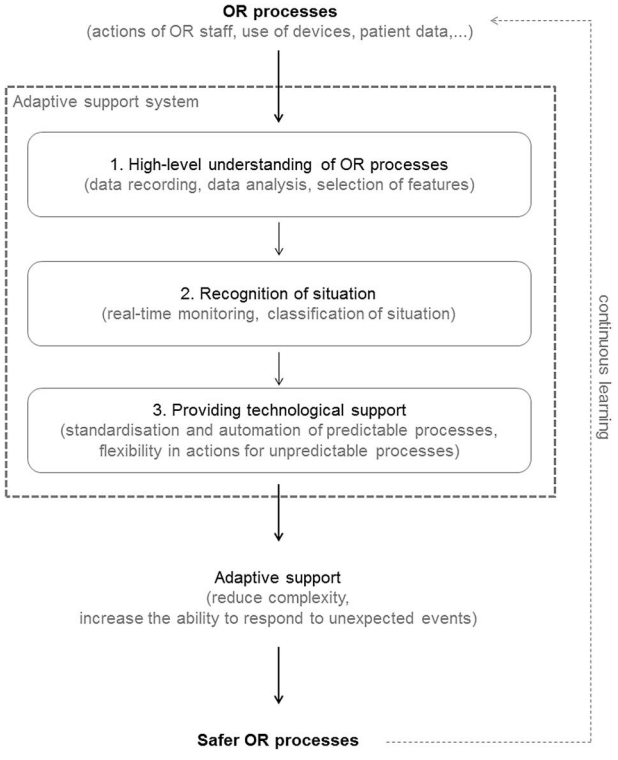

Figure 1 Schematic representation of adaptive support. OR, operating room.

Next, we can start to study the complexity of OR processes and achieve a *high-level understanding of OR processes through data analysis*. There are several data analysis tools available that can help assess and predict the variability medical staff is confronted with.[33] Various studies worked on the modelling of surgical procedures to analyse and evaluate procedures.[34–38] For example, there are seemingly unpredictable events, such as surgical procedure durations, that turn out to be predictable once sufficient data are gathered.[17 18] Another example is the unexpected difference among surgeons in handling surgical devices during relatively standardised procedures.[39] Data analysis can bring interesting insights into OR processes and help recognise hazardous situations. However, much of the data analysis still requires manual steps, such as the identification of use of instrument from endoscopic images[29 40 41] and interpretation and coding of text in electronic health records, which is time-consuming.

Through a high-level understanding, we can *select relevant features* that influence the variability and predictability of OR processes. These features allow to distinguish differences in progression of procedures, which is essential in providing adaptive support. Note, however, that the choice of data that have been recorded influences the selection of features to monitor for adaptive support purposes. There is a risk that too much attention is paid to specific features as opposed to others that may be overlooked by the initial choice of data gathering. This reflects the limitations of patterns/models that are constructed through data analysis.

Step 2: Real-time recognition of the situation

In order to make adaptive systems, OR processes need to be recognised automatically. *Real-time monitoring* of the identified relevant features is needed to *classify the situation* at hand. The information and models that are developed in step 1 will feed into this classification process. The accuracy of the real-time recognition is dependent on the data gathered previously. Although it is not an easy task to automatically perform, various studies have presented promising results on real-time recognition of the surgical

process.[29 41–43] They monitored specific activities, such as equipment usage and different states of the patients. Recognition of the situation at hand is necessary, as well as the predictability of the remainder of the situation matters. There may be situations that are complex but still present recognisable patterns, and therefore become predictable. On the other hand, there are situations that are inherently unpredictable. Once the situation is recognised, systems can be adapted accordingly.

Step 3: Providing technological support

At this stage, the question arises how to proceed once a situation is automatically recognised. We propose that technological support should depend on the predictability of the progression of the processes. The balance between standardisation and flexibility relies on the classification of the situation, that is, how much is known about the next steps in the OR processes?

On one side of the spectrum we find *predictable processes*, for which tasks can be fully automated or standardised. For example, OR devices can be configured automatically according to the type and stage of procedures.[44] Other examples are track and trace systems that automate the search for the location of assets in the hospitals[45] or the check for correct maintenance dates of OR devices.[46] Such processes, which do not require interventions by medical professionals, can be automated but should still be transparent, as we believe it is important to still provide information on the automated task to the OR staff. Processes that do require interventions by medical professionals, such as checklists, can be adapted to the specific situation and thereby provide standardisation that takes the situation into account.

Some processes are *not completely predictable*, but still occur within a certain range of reliability. In such processes, for example, the planning of procedures and patient flow, technology can support information availability and exchange between medical staff. For example, patients can be tracked in order to streamline the patient flow to reduce intermittent communication between the nursing department and OR.[47] Another example is a system supporting updates from estimated surgical procedure duration by the anaesthesia staff in the OR.[17] In these cases, gaining information about patients is automated, but the decision on how to proceed remains with the medical staff. At the other end of the spectrum, there are unpredictable processes, for example, when an OR device is unexpectedly malfunctioning, or unexpected complications occur during surgery. It is important that *unpredictable situations* do not become the object of rigid standardisation, as this will most likely have adverse effects. However, some form of support is still possible, for example, by supporting easy exchange and centralising information about unexpected events, such as malfunctions of devices.[46] Moreover, systems can be used to increase situation awareness, to support staff in dealing with information overload and keep track of the different processes under stressful conditions. For example, a task information system could be used that is personalised for the different OR staff members[48] or other systems that provide essential information on the activity of the OR staff, the anatomical structures and technical equipment.[49] The feedback that these systems provide to medical staff will help them to be aware of the situation and make intelligent adjustments of their working processes to the demands of the situation.

Outcome for the OR staff

The outcome of this approach is a technological system that takes the complexity of day-to-day OR practices into account. The automation or standardisation of predictable OR processes *reduces complexity* for health professionals, by taking over processes or providing support to the professionals, and thereby reducing their workload. Providing information about unpredictable OR processes increases situation awareness and leaves flexibility for actions of medical professionals. Thereby, it increases *the ability of professionals to respond to unpredictable events*. Adaptive support systems help in the recognition of the predictability of situations. This helps professionals to decide what processes need more attention at that moment, for example, in the case of hazardous situations, and ensures that the system allows them to operate flexibly when needed.

Adaptive support is a dynamic process that facilitates *continuous learning*. Adaptive support systems provide information about the current situation at hand, as well as enable a high-level understanding of the complexity of OR processes, which may lead to the identification of unnecessary standardisation, redundancies that can be reduced, and steps that are essential in providing safe care.[50] Integrating adaptive support systems in the OR may lead to a redesign of work processes and new interactions between technology and OR staff, which will provide input for new cycles of adaptive support. It is essential that medical teams are actively involved in this learning and (re) design process.[51] Systematic evaluation of processes in structured non-hierarchical and blame-free team meetings would benefit outcome of care. This will encourage the OR staff to adopt the adaptive systems as well as to jointly take responsibility for patient safety.

CONCLUSION

Adaptive support systems can help ensure patient safety and team performance in the OR by enabling learning about the complexity of OR practices. By gaining knowledge through data gathering and analysis of OR practices, support systems can recognise situations in real time. This allows systems to provide support that is adapted to the day-to-day variability in the OR, by

automating and standardising processes where possible, and providing information and flexibility to professionals when needed. However, much work is needed to meet the challenges and grasp the opportunities in building adaptive support systems. In particular, the development of technologies for real-time recognition and real-time adaptable technological support systems will be key to achieve adaptive support.

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