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SURGICAL ENDOSCOPY
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Systems approach to reduce errors in surgery

J. Dankelman, C. A. Grimbergen

Man-Machine System Group, Department of Mechanical Engineering and Marine Technology, Delft University of Technology, Mekelweg 2, 2628 CD Delft, The Netherlands

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Abstract. Reducing the number of medical errors significantly is the challenge for the coming decade. In medicine and in surgery, in particular, errors are traditionally treated as being committed by individuals. To reduce human errors, two approaches can be used: the person approach and the systems approach. In the systems approach, the operator is not blamed, but the system is analyzed in order to find the causes of errors. Furthermore, defenses are built into the system so that errors will not result in an adverse outcome anymore. This article aims to provide insight into the systems approach.

The most common site for adverse events to occur in the hospital is the operating room (OR) [18]. The OR is a complex environment, with many people working together, involving a large variety of instruments and instrumentation, and patients have varying anatomy and pathology. In such a complex environment errors may easily occur. Another aspect is the tendency to switch from open to minimally invasive interventions, which is of benefit to the patient but makes the operation even more complex for the surgeon. Nonergonomic tools, limited freedom for manipulation, and the limited view of the operation field increase the chances of an unintended outcome [3, 6].

Traditionally, in medicine the emphasis is given to the perfection of diagnosis and treatment. Patients are dependent on their doctors and they (have to) view them as infallible performers. For a long time, errors in medicine were therefore hardly discussed. With the report, 'To Err Is Human, Building a Safer Health System' [16], the occurrence of errors in medicine became clear. This report gave high estimates of the number of injuries and casualties as a result of medical errors. Currently, patient safety and the role of human error in medicine are receiving much attention [20]. The book 'Human Error in Medicine' addressed aspects of medical care in which human error is associated with unanticipated adverse outcomes [4]. This publication, and many others, contributed to an increased openness on the role of human error in adverse outcomes. Despite this openness, the daily practice of surgery has not changed much, and therefore the problem has not been dealt with seriously.

Correspondence to: J. Dankelman

Person or systems approach to reduce human error

According to Reason [23], the human error problem can be viewed using two approaches: the person approach and the systems approach.

Person approach

In the person approach, the error is seen as the result of an individual failure. If an error occurs in surgery, traditionally the person who performed the error, usually the surgeon, is blamed. The approach assumes that the failure lies with people (e.g., ignorance and negligence). In the person approach, lawyers and judges play an important role.

The main disadvantage of the person approach is that it will not solve the problem. Pointing fingers at people who have performed an error will do nothing to prevent reoccurrence. The person approach neglects the fact that the vast majority of people working in health care are doing their best. The person approach has other negative consequences. Blaming the person will result in hiding of errors, and when errors are hidden it is not possible to learn from them. Furthermore, when blamed for an error, the surgeon may become very uncertain about his or her activities, and consequently his or her performance may decline.

Systems approach

In the systems approach, it is assumed that errors *will* occur and there is an accepted risk. It is known that even the best specialist will sometimes make errors in judgment or action. Causes of errors are searched for in the system, providing insight into the weak parts of the system and their consequences. The system is redesigned to absorb these errors using buffers, automation, checklists, and redundancy. Furthermore, procedures are standardized so that specific protocols and checklists can help to minimize the occurrence of human errors. The systems approach should be applied independently, meaning that the results of the investigations should not be provided to lawyers and judges.

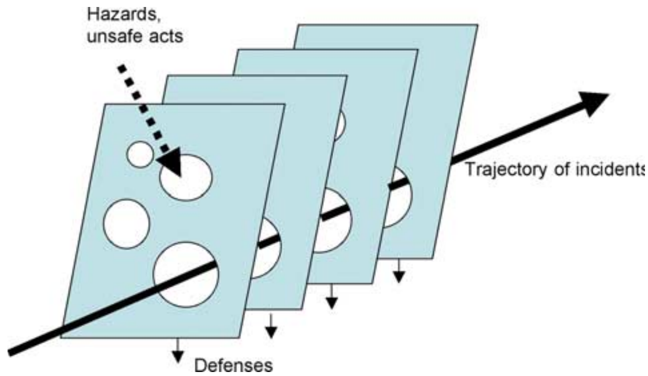

Fig. 1. Trajectory of incidents leading to an accident. Defenses in the system can reduce the occurrence of accidents.

Human error

In the past few years, studies have been reported in the field of human errors in medicine [4, 5, 7, 10, 11, 16–20, 23]. According to Reason [22], an error is "*a generic term to encompass all those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome, and when these failures cannot be attributed to the intervention of some change agency*." There are many definitions of different types of errors given in the literature [11, 22]. Only active and latent errors are discussed here. An active error is an operator error, committed by individuals. Examples of active errors are clipping of the wrong artery, cutting a nerve, and pushing a wrong button. Latent errors are errors in design, organization, training, or maintenance. Examples of latent errors are sleep deprivation [17], poorly designed tools, unclear protocol, and inadequate training.

It is known that latent conditions present in the system may easily lead to operator errors. As a result, it is difficult to classify a certain error. Classification can even be misleading. To indicate this problem, consider again the examples of active errors given previously. These active errors could also have occurred due to latent conditions. For example, it may be that clipping the wrong artery occurred because the operator was not well trained in anatomy, cutting a nerve could have occurred because the surgeon had to work all night, and pushing the wrong button could have happened because two buttons close to each other looked the same. Hence, errors that at first appeared to be active errors may have been caused by latent conditions. Finding and changing these latent conditions are the primary goals of the systems approach.

Culture change

Surgeons are very good at solving (unexpected) problems. Because no patient is the same, a good surgeon is very creative in solving clinical problems. The surgeon can also solve other problems not directly related to the patient's anatomy and/or pathology. For example, when a certain instrument is missing on an instrument net, the surgeon will try to do the task with a different instrument. When there is no image on the monitor during a minimally invasive procedure, the surgeon or other staff member will try to solve the problem quickly. In the past, we observed more than 200 operations, and it is our experience that during nearly every operation something happened that was not planned. Mostly, these were small incidents, such as no image on the monitor or a wrong, broken, or missing instrument, hardly affecting the outcome for the patient. These observations also show that surgeons and other staff members in the OR are used to small incidents. As a result, it is accepted that surgical procedures are not performed optimally. Although most of the incidents are easily solved, in cases of emergencies these incidents may contribute to a serious error, as illustrated by the Swiss cheese model of Reason (Fig. 1). To change attitudes regarding incidents, a safety culture should be created [24]. A safety culture is defined by the International Nuclear Safety Advisory Group [14] as an assembly of characteristics and attitudes in organizations and individuals that establishes that, as an overriding priority, nuclear plant (read medical) safety issues receive the attention warranted by their significance. This definition highlights some major points:

- Safety culture is about good safety attitudes in people, but it is also about good safety management established by organizations.
- Good safety culture means giving the highest priority to safety.
- Good safety culture implies a constant assessment of the safety significance of events and issues so that the appropriate level of attention can be given.To create a safety culture, everybody in the hospital should be involved. Hospital management should be especially proactive.

Collection of errors

To create a safety culture, there should be knowledge about all kinds of errors/problems that occur or may occur. To obtain this knowledge, data on errors (with or without adverse outcome) should be collected and analyzed. However, a reporting culture can only be achieved

Fig. 2. Onion model showing factors that need to be addressed in causal analysis of accidents.

when there is a just culture (not a blaming culture). In aviation, there is a black-box recording everything that occurs in an airplane. The same approach could be used in surgery. Surgical operations could be recorded so that adverse outcomes could be reconstructed and people could learn from the causes. Task analysis studies have shown that evaluation of recordings of surgical procedures can give insight on limitations and errors [2, 15]. In some trauma centers, recording of procedures already occurs [26].

Analysis of errors

A system can be viewed as a collection of components and the relations between them, whether the components are humans or not [19]. The areas that need to be addressed in causal analysis can be specified by considering the contributing causal factors as a series of layers represented by the onion model [9]. An adapted version of the onion model is given in Fig. 2. Accident investigation can be viewed as the process of peeling an onion, although the investigation usually proceeds from the middle outwards [9]. An alternative scheme, the artichoke model, is given by Bogner [5]. These models provide a useful metaphor for the accident causation process. It should be realized that each factor is related to the other factors. For example, limiting the number of working hours (national regulations, policy making, and organizational culture—outer system factor) may reduce the incidence of sleep deprivation and hence affect the inner system factors.

Systems approach to reduce errors

Only when the entire system is designed correctly will errors be minimized. The systems approach can be described as follows: Collect (possible) errors, analyze them to find (possible) causes in the system, and change the system such that these errors do not occur anymore or become of no consequence. Based on experience from other disciplines (e.g., industry and aviation) many suggestions for changing the surgical system can be given, including the following:

- The complexity should be reduced.
- Procedures should be standardized as much as possible.
- The information process should be optimized by using checklists and reminders.
- Equipment and instruments should be improved and standardized.
- Training should be adequate.

Reduce complexity

The OR is a very complex system. The system is composed of the operation team, the patient, equipment, and the interactions between them. For an error that must be prevented, there are many places to intervene [19]. Automation has often been introduced in other disciplines to reduce the role of human factors; however, increasing technology may make the situation even worse. Humans are much better at adapting to shortcomings in the systems than are computers, for example. Technological innovations can have many drawbacks, such as cost for maintenance and training, reliability problems, and incompatibility with existing equipment. The solution should be sought in simplification, which may result in a more reliable system. However, this is not an easy task.

Standardization of procedures

Currently, comparable surgical procedures may be performed differently at different hospitals and even performed differently between two doctors working within one hospital. Because of this, detailed protocols on how a certain surgical procedure should be precisely performed do not exist. This causes limitations with regard to training of residents, and it also makes it difficult for the staff in the OR to develop a routine. Clear protocols for every procedure, starting with those procedures performed in peripheral hospitals, should be developed. In laparoscopic cholecystectomy, the guideline to dissect the triangle of Calot is an example of how a standardized protocol can help to reduce errors.

Checklists

Safety checks have been proven to be very effective in aviation and high-risk industries [12, 13]. Although the usefulness of checklists is clear, they are hardly used in medicine and surgery. Checklists could be developed to check availability and functioning of equipment in the OR before the operation starts. This is especially important during minimally invasive surgery because much equipment is used. In these procedures, often, something is not working well and small problems have to be solved during the operation. According to the Swiss cheese model, incidents may result in an accident; therefore, these incidents should be prevented and little disturbances should be solved. Preoperative checking using a checklist may be very helpful in this regard. Regarding anesthesia, the Food and Drug Administration has recommended the use of a checklist as a standardized approach to checking anesthetic equipment prior to use, and as a consequence the rate of equipment failure has been reduced from 14 to 4%.

Introducing an effective checklist is not a simple task. However, currently there are ongoing discussions about how a checklist should be used—either as a step-by-step "cookbook approach" or as a backup procedure [12]. Furthermore, when the number of items on a checklist is too high, items may be overlooked. The anesthesia checklist started in 1987 had 24 specific processes but was changed in 1993 to have 14 major processes. Finally, the items should be clear and have a unique interpretation.

Quality and standardization of instruments and equipment

Nondisposable instruments used during surgery are sterilized before transportation to the OR. Quality testing of instruments is hardly performed. Casseres et al. [8] showed that there were problems with light cables used during minimally invasive procedures, and Albayrak et al. [1] showed that many laparoscopic instruments had insulation failure. Therefore, tests should be developed to check the quality of the instruments prior to transportation to the OR. Quality testing becomes more effective when the applied instruments are standardized.

During minimally invasive surgery, the surgeon uses instruments with a lot of friction. Sjoerdsma et al. [24] showed that different laparoscopic graspers can have different mechanical configurations, leading to different force transmission characteristics. Since the appearance of the instruments may be similar, these differences may not be obvious to the surgeon. Manipulation of bowel may become especially dangerous. Standardization of instruments may solve this problem.

It is well-known that there is a lack of uniformity between equipment. In many hospitals, there are laparoscopy towers with equipment of different ages, from different companies, with different endoscopes. The layout and the control of the equipment are not standardized, causing disruption of tasks that, when standardized, could be performed routinely. Hence, standardization can help to reduce complexity.

Training

Training in minimally invasive surgery is difficult, which can partly be ascribed to the fact that much technology is involved. Currently, the main part of surgical training takes place in the OR, whereas outside the OR some basic skills are learned (e.g., in Pelvi trainers and virtual reality trainers). There is no emphasis on protocol knowledge; consequently the learning process in the OR is not very effective. Furthermore, although residents learn to use their instruments, they have not been taught to connect monitors, cables, etc. Young residents should be trained to check their instrumentation and equipment before the operation using checklists. Protocol knowledge and checklist use will help residents to learn more systematically what should be done and to quickly establish a routine in the sequence of actions that have to be performed. Finally, safety issues should become part of education. Residents should be trained to identify (their own) hazards and ask for help to find defenses so that the problems are structurally solved.

Threats

Although there is more openness about human errors in medicine and studies have started to collect data about errors, the following trends can be a threat to surgical safety:

- There is a tendency to decrease the duration of the stay in hospitals and, hence, to convert from long-stay treatment to one-day clinical treatment. This requires that the course of recovery can be predicted adequately in order to guarantee the patient's safety. It includes an increase in minimally invasive surgical techniques and the use of catheters in medical interventions.
- There is a tendency in many countries to restrict the use of animal experiments. This affects the training of residents and also has consequences with respect to the safety of introducing new medical treatments.
- Time for education and training of residents is decreasing in many countries. The working hours (presence) of residents are greatly reduced by new regulations. Hence, training should be made more efficient.
- To limit waiting lists and costs, the operating time should be kept as short as possible, placing pressure on reducing procedure time.

Conclusions

The systems approach is required to significantly reduce the number of human errors in surgery because insight on causes of errors is obtained. Systematic analysis of the causes of errors has a much larger effect than blaming the individual surgeon. To make surgery safer, the actions that have to be performed (protocol) and the instruments/instrumentation that are used should be carefully analyzed. Standardization and optimization of protocols and instruments should lead to reduced complexity and therefore reduce the chances of human errors. However, this does not mean that human errors will not occur. Defenses should be built into the system so that human errors do not lead to an adverse outcome for the patient. Although these aspects of the systems approach seem rather logical, in practice there are many impeding factors. First, the blaming culture should be rejected and the systems approach accepted.

The basis of the systems approach is well stated by Reason [23]: "*Fallibility is part of the human condition; We can't change the human condition, but we can change the conditions under which people work*."

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