Organizational Change and Learning

Diffusing Aviation Innovations in a Hospital in the Netherlands

Dirk F. de Korne, M.Sc.; Jeroen D.H. van Wijngaarden, Ph.D.; U. Frans Hiddema, M.D.; Fred G. Bleeker, Peter J. Pronovost, M.D., Ph.D.; Niek S. Klazinga, M.D., Ph.D.

Article-at-a-Glance

Background: Many authors have advocated the diffusion of innovations from other high-risk industries into health care to improve safety. The aviation industry is comparable to health care because of its similarities in (a) the use of technology, (b) the requirement of highly specialized professional teams, and (c) the existence of risk and uncertainties. For almost 20 years, The Rotterdam Eye Hospital (Rotterdam, the Netherlands) has been engaged in diffusing several innovations adapted from aviation.

Methods: A case-study methodology was used to assess the application of innovations in the hospital, with a focus on the context and the detailed mechanism for each innovation. Data on hospital performance outcomes were abstracted from the hospital information data management system, quality and safety reports, and the incident reporting system. Information on the innovations was obtained from a document search; observations; and semistructured, face-to-face interviews.

Innovations: Aviation industry–based innovations diffused into patient care processes were as follows: patient planning and booking system, taxi service/valet parking, risk analysis (as applied to wrong-site surgery), time-out procedure (also for wrong-site surgery), Crew Resource Management training, and black box. Observations indicated that the innovations had a positive effect on quality and safety in the hospital: Waiting times were reduced, work processes became more standardized, the number of wrong-site surgeries decreased, and awareness of patient safety was heightened.

Conclusion: A near-20-year experience with aviation-based innovation suggests that hospitals start with relatively simple innovations and use a systematic approach toward the goal of improving safety.

Since the landmark *To Err Is Human* report,[1] many studies have shown that health care is often hazardous rather than beneficial to patients, with unnecessary morbidity and mortality.[2–4] However, similar contributing factors—complexity of the work processes, organizational characteristics, and professional autonomy[4–6]—can be found in other industries, some of which have found good approaches to mitigate the factors' effect on safety and quality. Nuclear production, for example, is widely recognized for its innovations in approaches to safety.[7]

Many authors have advocated the diffusion of innovations from other high-risk industries into health care to improve safety.[8–19]

According to Rogers, an innovation is "an idea, practice, or objective perceived as new by an individual, a group, or an organization," and diffusion is "the process in which an innovation is communicated, through certain channels over time, among the members of a social system."[20(p. 5)] As Greenhalgh et al. indicate, diffusion often is not a passive process but involves negotiating, influencing, and a staff that can enable change and "help it happen."[21] One example of an innovation diffused into health care is the investigative tool of root cause analysis, which emerged and spread through many industries, including nuclear power, aviation, and chemical plants.[12] Since 1995, The Joint Commission has required that it used to identify the causes of errors and incidents.[22] As another example, a children's hospital improved its intensive care unit handoff practice on the basis of the Ferrari's Formula 1™ races.[13]

The aviation industry is seen as comparable to health care because of its similarities in (a) the use of technology, (b) the requirement of highly specialized professional teams, and (c) the existence of risk and uncertainties.[6,8,15–19] It is the improvement in safety that the aviation industry has been able to achieve that has sparked special interest in health care. For example, between 1994 and 2006, the average rate of fatal accidents decreased from 0.05 to 0.022 per 100,000 departures, which led Pronovost et al. to conclude "health care's slow and disappointing efforts to improve safety contrast with the remarkable success of aviation safety."[23(p.480)] As in aviation, health care professionals have been urged to standardize work processes, employ checklists to ensure that patients receive evidence-based interventions consistently,[24,25] and use robust, scientific methods in collaborative efforts to identify and mitigate risks.[26,27] However, others have stressed the importance of learning from aviation's *safety culture* instead of just copying individual methods or models.[28–31]

Sorra and Nieva, for example, have defined a safety culture as follows:

> The product of the individual and group values, attitudes, perceptions, competencies and patterns of behavior that determine the commitment to, and the style and proficiency of an organization's health and safety management.[32]

On the basis of selected literature,[28–31] the following four dimensions appear to be relevant in determining a safety culture:

1. Mastery of risks (reporting errors, correction and analysis of errors, learning from [near] airplane crashes)
2. Social orientation (curtailing operator autonomy while preserving operator authority, increasing knowledge and skills in cockpit communication and helping)
3. Awareness of risks (anticipation of weather conditions, acceptance of human factors in safety)
4. Aversion to reporting errors (rigid focus on prevention, transparency with respect to errors, not covering up near misses during flights)

Comparing the safety culture in naval aviation and hospitals, Singer et al. showed that the safety culture was three times better on average among naval aviators than hospital personnel and that naval aviators perceived a culture that was up to seven times safer.[33] The authors contended that health care systems could benefit from adapting some of the structures, systems, and practices that have proven effective in aviation. Yet, little is known about how those practices are diffused in health care.

For almost 20 years, The Rotterdam Eye Hospital (Rotterdam, the Netherlands) has been engaged in diffusing several innovations from the aviation industry throughout the organization, as we describe in this article.

Methods

We used a case-study methodology to assess the application of innovations in the hospital, with a focus on the context and the detailed mechanism for each innovation.[34] We adapted the Greenhalgh et al. framework[21] to analyze the diffusion of innovations (Table 1, page 341). Data on hospital performance outcomes were abstracted from the hospital information data management system, quality and safety reports, and the incident reporting system (in which near-incidents [near misses or close calls] are also reported. We [D.F.K., F.G.B.] carried out a document search for senior and unit-level managers' correspondence (memos, letters, and e-mail), policy statements, and annual reports. We also conducted observations of the care practices, starting back in 1992 for the first innovation. In addition, in 2009, guided by a topic list based on the Greenhalgh et al. framework, we conducted 11 semistructured, face-to-face interviews with key participants from medical, nursing, and administrative staff, most of whom had worked in the hospital since even before the start of the innovations. We structured and analyzed content from the documents and the interviews according to tags drawn from the diffusion of innovations framework.

A Focus on Aviation

Setting

The Rotterdam Eye Hospital, founded in 1874, is the only eye hospital in the Netherlands (population, 16 million), providing secondary eye care for the region and tertiary eye care for the whole country. As a major referral center, on a yearly basis it handles approximately 140,000 outpatient visits and 14,000 surgery cases. Some 30 specialized ophthalmologists, 4 anesthesiologists, and 4 internists, not employed by the hospital, maintain their practices through a partnership within the hospital organization. The hospital, which has 400 employees and operates resident and fellow programs and a research institute, is a member of the American Association of Eye and Ear Centers of Excellence and the founding member of the European and World Association of Eye Hospitals.

Getting Started

In the early 1990s, the hospital was at risk of being taken over by an academic hospital. The Dutch government allowed it to remain a stand-alone hospital only if it was able to achieve high production volumes, low costs, and a specific patient-centered approach. In 1992, the hospital was providing high-quality clinical care but had serious problems with patient logistics, as seen for example, in long wait times. The hospital decided to benchmark with aviation, given its accomplishments in handling more passengers, improving logistics and safety, and being service-oriented (as one senior manager described the industry). The fact that the same CEO and chief financial officer have been in place since the decision to benchmark was

Table 1. Analysis Framework for Diffusion of Innovations*

	System A (Airline)	System B (Hospital)	Feasibility of Changing Practice, Procedures, and Context of Hospital to Match Airline
The innovation	Salient features currently used in System A?	Salient features of innovation proposed for use in System B?	Could and should System B adopt the same innovation as is used by System A?
The resources	What resources were used in producing the outcomes (e.g., staff time, money, equipment, space)?	What resources in System B?	Does System B have the resources to emulate the practice of System A?
The people	What are the salient characteristics of the key actors in terms of expertise, experience, commitment?	What are the characteristics of the key actors in System B?	Insofar as there is a mismatch, would it be desirable or feasible to recruit different staff, invest in training, etc.?
Institutional factors	How much were the outcomes dependent on organizational/departmental structure, organizational cultures?	To what extent does the organizational structure and culture of System B determine practice?	Differences? Feasible or desirable to change the institutional structures and cultures in B?
Environmental factors	How much were the outcomes dependent on particular environmental factors (e.g., political, legislative)?	To what extent is the external environment of System B comparable to System A?	Differences? Change the external environment of System B?
Measures	What baseline, process, outcome, and other measures were used to evaluate success?	Does (or could) System B use the same measures?	Desirable or feasible for System B to change the way it measures and records practice?
Procedures	What was exactly done in System A that led to the outcomes reported?	Does (or could) System B do exactly the same?	Differences? Should System B change what it does?
Outcomes	What were the key outcomes, for whom, at what cost, and what are they attributable to?	What were the key outcomes in System B? Achieve for same actors as System A?	To what are the differences attributable? Desirable outcomes that System B is not achieving?

* Adapted from Greenhalgh T., et al.: *Diffusion of Innovations in Health Service Organisations: A Systematic Literature Review.* Malden, UK: Blackwell Publishing, 2005.

made has facilitated the continuity in policy. The CEO [U.F.H.]—a physician—played an important role in championing the program and in "selling it" to the medical staff. Many of the physicians seemed to find aviation to provide an acceptable model, which was useful in winning their involvement in quality and safety programs.

Innovations

For each of the six innovations, as shown in Figure 1 (page 342), we describe (a) the application, (b) the observed effects on quality and safety, and (c) the facilitators and barriers. Sidebars describing additional features and outcomes and other aspects of the innovations are available in the online article.

Innovation 1. Patient Planning and Booking System (1992)

Application. The purpose of the patient planning and booking (reservations) system, which was fully implemented by the end of 1992, was to reduce delay and to realize a more efficient system for patient logistics. The system was developed by careful study of the reservations system used by Royal Dutch Airlines (KLM). A KLM logistics expert worked in the hospital for more than a year to help implement a comparable system. The most important change was distinguishing central capacity management (master planning) from decentralized booking of individual patient visits. A central logistics department was introduced, which was responsible for master planning, including balancing office visits and surgeries—so physicians were no

Time Line of Six Innovations Adapted from Aviation at The Rotterdam Eye Hospital, 1992–2009

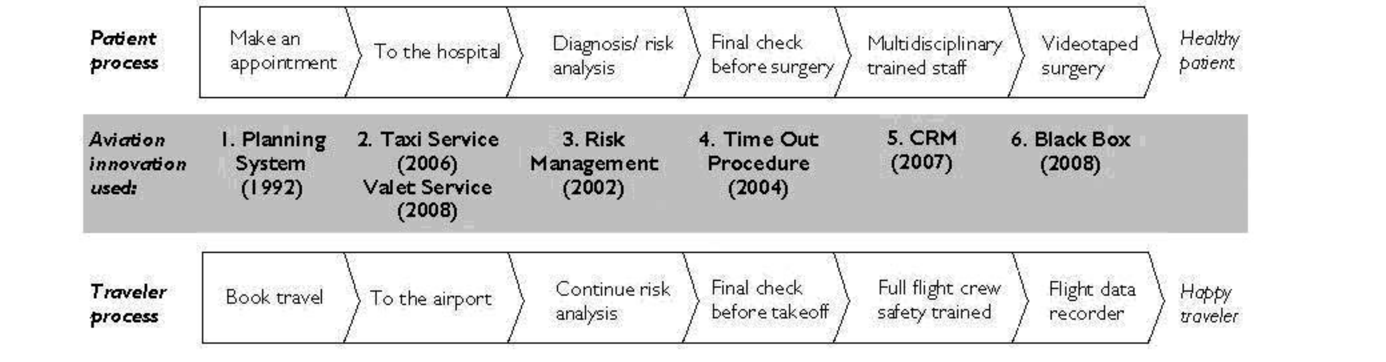


Figure 1. The six innovations adapted from aviation at The Rotterdam Eye Hospital are shown, with parallel patient and traveler processes. CRM, Crew Resource Management.

longer directly involved in planning and booking.

The planning and booking system remain operational, and software uses are being expanded to reduce manual labor.

Effects on Quality and Safety. The new planning system led to a reduction of waiting time from an average of 12 (in the early 1990s) to 4 weeks. The surgical productivity doubled, and the number of office visits increased from less than 100,000 to almost 140,000 patients per year, while the average capacity remained unchanged (Table 2, page 343). Because of increasing use of ambulatory surgery, the number of inpatient beds was reduced.

Facilitators and Barriers. Hospital staff were not able to diffuse the innovation by themselves. In 1992, aviation logistics experts introduced staff to the patient planning and booking system and trained them on an adaptation of the software. One of the challenges was that the information technology that supported the system in aviation was not available in the hospital. The hospital had to develop a Microsoft® Excel®-based system, which involved much manual work to operate, and the required software did not become available until 2008. In addition, at the start the hospital had little logistic expertise and therefore had to hire logistics experts and build their patient logistics department from scratch.

Although pilots are not involved in booking, physicians usually are, so introducing the system led to a loss of some autonomy for the physicians, who were no longer able to set their own schedules. The physicians' initial resistance lessened as they experienced the benefits of the innovation, which included far less administrative work—and more time for patient care, resulting in increased revenue. As one ophthalmologist remarked, "I am satisfied when I can spend my time on patient care instead of other burdens." Another ophthalmologist stated, "In this hospital, everything is organized around our specialty and therefore we can focus on quality and volume. In other hospitals, ophthalmologists are usually low on the totem pole when it comes to utilizing surgical rooms and technological resources." Thus, although the planning system was partly copied from aviation, the implementation process was not. The master planning system and the compartmentalized booking departments are still operational today.

Innovation 2. Taxi Service (2006)/Valet Parking (2008)

Application. Because of the hospital's inner-city location and the fact that more than 50% of the patients commuted from the surrounding counties, parking problems were endemic. Patients often were late for appointments, stressed, and dissatisfied with the overall travel experience. The hospital, inspired by airport shuttles, implemented a taxi service to bring patients to the hospital. In collaboration with a health travel provider, the hospital began a cataract taxi service ("cat cab") in 2006. The service was cancelled the following year, however, because of lack of financing. The hospital then contracted with a private valet parking service in 2008, which remains in operation and almost breaks even now.

Effects on Quality and Safety. The taxi delivery can be viewed as addressing service and quality. Cataract surgery is usually performed under local anesthesia, so that a low stress level for patients is important. No evidence exists, however, that the taxi service or valet parking led to a reduction in patients' preoperative anxiety. Patients were satisfied with the taxi service concept, even when paying out of pocket. A satisfaction survey

Table 2. Quality and Safety Statistics, The Rotterdam Eye Hospital, 1992–2009

Year	Surgeries	Initial Office Visits	Total Office Visits	Faculty	Residents	Full-Time Support Staff	Beds	Wrong-Site Sentinel Events	Reported Near-* Wrong-Site Incidents
1992	6,734	46,864	97,010	23	14	207	65	4	1
1994	7,340	49,208	101,861	24	14	204	61	5	2
1996	8,515	51,557	106,723	23	14	206	50	6	1
1998	9,537	56,507	116,969	24	11	205	28	5	0
2000	9,701	58,982	118,197	22	9	200	13	6	1
2001	9,955	58,104	123,352	23	10	208	11	8	1
2002	10,328	59,469	124,998	27	13	200	9	6	2
2003	10,428	58,379	123,748	25	14	207	9	3	5
2004	11,199	58,394	119,143	26	16	213	9	0	4
2005	11,864	62,008	141,433	26	18	259	9	1	5
2006	12,692	64,698	139,981	27	20	285	8	0	7
2007	12,610	65,343	137,525	27	20	268	8	0	3
2008	13,338	66,315	136,754	29	21	282	7	1	8
2009	13,242	64,532	134,163	29	19	273	7	1	9

* Near-, near miss or close call.

showed that for 114 patients, 91% found it more convenient than public transportation, and 87% agreed that they arrived more relaxed in the hospital. Valet parking, common in the United States, has since been used by an increasing number of patients at the hospital, the first in the Netherlands to provide such a service.

Facilitators and Barriers. The hospital administration was able to diffuse the service themselves by contracting with external parties. It sought a less expensive alternative to taxi service, however, after the health insurers were no longer willing to reimburse the costs. The hospital co-financed valet parking by asking for a small contribution from patients and drawing on innovation funds.

Innovation 3. Risk Analysis (2004)

Application. Wrong-site surgery, one of the worst types of patient harm that can occur in any hospital,[35] was occurring an average of five to six times a year at the hospital (Table 2). To eliminate adverse events, especially wrong-site surgeries, the hospital introduced Toyota Production System (TPS) Lean Six Sigma risk management, a methodology broadly applied in aviation and other industries.[36] Multidisciplinary risk management teams of physicians, residents, nurses, administrators, and quality executives (five to eight participants each) pursued risk analysis, in which they analyzed critical processes in the hospital and used the methodology to identify risks and propose improvements. Risk management experts were hired to assist in five training sessions for each team to train the staff in using the methodology. On the aviation safety experts' advice, the methodology was adapted to the hospital setting, given its less intense focus on safety. For example, the time frame for conducting root cause analyses was shortened.

When reporting incidents and near-incidents, health care professionals are asked to assess risks on the basis of estimated frequencies and severity. Beginning in 2006, the hospital began using the risk-analysis method in developing clinical pathways, and since 2009 it has applied the method to its safety reporting management system.

In 2009, a digital safety-reporting management system was introduced, and three safety committees (surgery, outpatient, facilities and administration) each performs one risk analysis per quarter. Incident reporters are asked to estimate the risk based on frequency and severity for every incident or near-incident. Starting in 2010, internal quality audits have focused on processes instead of on individual departments.

Effects on Quality and Safety. The risk-analysis method helped to identify critical gaps in various processes and stimulated the introduction of checks during patient intake and screening in the wards and recovery rooms. The majority of the identified risks were related to human factors, such as ophthalmologists' late arrival and their and other staff members' illegible handwriting and communication failures. The actions reduced but not eliminate wrong-site surgeries (Table 2).

Facilitators and Barriers. There was no "risk management culture" in the hospital, according to the aviation safety experts, because when protocols are set in place professionals are not held accountable and do not feel obliged to follow them.

Also, the experts felt that the full range of factors contributing to wrong-site surgery may not be fully understood and that staff might not always comply with intraoperative interventions to prevent wrong-site surgery.

Yet the process-based approach for risk management was received with enthusiasm by the medical staff and other staff, primarily because it was practical and directly related to everyday routines and largely perceived as effective. As one ophthalmologic resident stated, "It is really useful to visualize your work from a bird's-eye perspective and to see what kind of things people are doing before and after you."

One of the experts stated, "When I compare the situation in the operating room to the cockpit, it seems as if I go back 30 years in aviation history." Physicians, for example, have much more leeway in terms of using guidelines and procedures than pilots. The hospital also lacks the aviation industry's strict system of registration and accountability for cases in which checks are not performed.

Innovation 4. Time-Out Procedure (2004)

Application. Continuing the attempt to eliminate wrong-site surgeries, in 2004 the hospital introduced another innovation from aviation, a "time-out" procedure. Immediately before surgery and with all members of the surgical team present, a final check is conducted using a standardized (open) questionnaire to ensure that the surgery being performed is on the right patient and on the intended side.[37] The time-out procedure includes a check of the required materials (for example, intraocular [implant] lens, donor cornea) and the patient's health status with respect to the planned surgical procedure, comparable with aviation's flight plan before takeoff. The procedure is in addition to the normal preparatory checks and is documented in an anesthesia data system.

Effects on Quality and Safety. Time-out was introduced after the occurrence of a number of (near-) wrong-site surgeries despite safety checks earlier in the process. Since its introduction in 2004, the number of wrong-site surgeries has dramatically decreased, while more near-incidents were reported (Table 2). One ophthalmologist stated, "The simplicity of the protocol, the involvement of staff during implementation, and the fast, clear results were eye-opening. It should be a rule always and everywhere to start surgery with a time-out." The time-out procedure, however, was not used during all surgeries. For the wrong-site incidents that occurred in 2005, 2008, and 2009, analysis revealed that the time-out procedure was not performed or not performed correctly.

Facilitators and Barriers. The hospital was able to diffuse this innovation without the help of aviation safety experts. In the aviation version of the time-out procedure, the entire flight crew follows the final checklist with all relevant parameters immediately before departure. Each team member is asked certain questions to ensure total participation and dissemination of relevant information. The hospital copied the concept but used its own content, drawing on the Universal Protocol for Preventing Wrong Site, Wrong Procedure, Wrong Person Surgery.™[35]

Representatives from the medical staff were involved in both the design and implementation of the time-out procedure. Yet, again because physicians traditionally have more autonomy, the safety procedure was not used regularly. Although most of the physicians followed the procedure without fail, others did not use the procedure at the outset, while others used it only when not pressed for time. The hierarchy in health care, which is stronger than in aviation and other industries, led us to assign responsibility for the procedure to the ophthalmologists, but the same hierarchy discouraged others from confronting ophthalmologists who did not carry out the procedure. For the medical and surgery staff, using checklists was first primarily viewed as a time-consuming activity without clear benefit. Yet, ophthalmologists' compliance improved when it became known that no wrong-site surgeries had occurred when the procedure was used and after the hospital received recognition in 2004 in the form of the Golden Helix Award.[38] One ophthalmologist commented, "The fact that we were used as an example has greatly encouraged me to take the time-out seriously." As stated, the goal of ophthalmologists' 100% compliance remains unmet. For example, registration as documented in the anesthesia data management system showed a noncompliance of 2%, while the surgical department expected underreporting and nonreporting of incorrectly or incompletely conducted time-out procedures. Greater understanding of staff's perception of and barriers to complying with time-out may improve compliance and facilitate the design of more effective and efficient procedures.

Innovation 5. Crew Resource Management (2007)

Application. To improve teamwork, safety awareness, and compliance with the time-out procedure, the hospital diffused a fifth innovation from aviation, Crew Resource Management (CRM), a safety training program that is mandatory for airline pilots worldwide. Five aviation safety experts with experience in training flight crews led hospital staff in adapting CRM training as used in aviation to the medical context and, in pairs, taught the program to multidisciplinary medical teams. The four-hour sessions were as follows (see Sidebar 5 in online article):

1. Session 1 consisted of a presentation and discussion of the context of patient safety (human factors) and the consequences and necessary tools of teamwork (communication).

2. Session 2 elaborated on the theory and practice of the core notions of situational awareness for risk situations and decision making, with discussion of causes and appropriate reactions to faults and (un)acceptable risks.

3. Session 3 addressed personality and (non)functional behavior in relation to patient safety. Leadership and the importance of accountability were important themes. Participants were asked to openly discuss their personal experiences with safety issues.

4. Session 4 took place in a Boeing 737-800 flight simulator, an environment in which the trainees had to use their newly learned skills without being able to fall back on their professional technical skills. The simulator was also used as an incentive for physicians to become involved in the training.

The training was mandatory for everyone but physicians, 70% of whom participated; starting in 2009, participation was made mandatory for all residents, nurses, managers, and ophthalmologists physicians (as agreed by management and medical staff). The hospital provides CRM training for current and new staff on an ongoing basis, and since 2009, it has extended the training to outpatient-clinic teams. Efforts are being made to investigate the effect of the training in terms of incident reporting and patient outcomes and to use feedback from staff to develop training that best meets their needs.

Effects on Quality and Safety. There is no evidence that ophthalmologists' compliance with the time-out procedure has improved since the CRM training was provided. Yet, positive feedback on the training has been provided. For example, one of the ophthalmologists stated, "Yesterday I had to perform a complex lamellar keratoplasty surgery. I have the different stages of the surgery written down and always study it beforehand. I often thought about taking these notes with me, but I was afraid of losing face—I am an experienced surgeon and I should be able to do this! The safety training showed me the importance of showing your doubts and vulnerabilities. Ever since, I have taken my notes with me. It feels like a victory."

Facilitators and Barriers. As stated, in contrast to the mandatory participation in the training program in aviation, the hospital's management was not initially able to require ophthalmologists to participate. The aviation safety experts who provided the training were viewed as credible by the participants, given the comparability between aviation and health care—and the cockpit and the operating room—as well as the fact that they did not occupy positions in medical hierarchy. One nurse commented, "You take him seriously because he's an expert from aviation, and he therefore is also able to approach all the participants in the training—doctors and nurses—as if they were on the same level."

Innovation 6. Black Box (2008)

Application. To stimulate further the use of safety management principles, the hospital introduced a sixth innovation inspired by aviation's "black box," which by recording all flight crew activities is used to determine the cause(s) of an accident. In adopting the innovation, the hospital recorded surgical team activities. The aviation safety experts videotaped several ophthalmologic surgeries, which were provided to give the team feedback on the application of the safety procedures that were taught during CRM. Adherence to protocols for the production, use, and distribution of the images (which are not part of the medical record) was documented.

Effects on Quality and Safety. The video recordings revealed team-specific differences in performing the time-out procedure and in use of the safety communication rules agreed on during the CRM training; they also showed that the absence of team members at the preoperative briefing resulted in less structure and some communication lapses during the surgery. As one of the aviation safety experts, who had provided CRM training, said, "It is a new and inspiring experience for ophthalmologists to see their own performance . . . within their environment. It confirms the notion that surgery is a team activity." Video images showed the importance of teamwork; it is difficult to deny teamwork failures when they are clearly shown on tape.

Facilitators and Barriers. While the black box used for recording in-flight images and voices is automated, because of financial constraints the hospital used the somewhat more intrusive handheld videorecorder. The medical staff were initially hesitant to participate, fearing that recorded unexpected outcomes could be used against them. Only ophthalmologists who participated in the CRM program, who knew and trusted the aviation safety experts, consented to have their surgeries vidorecorded, and only if the images were used solely for their own training. The ophthalmologist-in-chief, who declared his willingness two months into the program to make the recordings available to all the hospital's attendings, residents, and nurses, along with attracting media attention (http://nos.nl/video/32459-chirurgen-gaan-samenwerken-met-piloten.html) stimulated others to get involved in the program. The hospital is seeking funding to develop a continuous, automated videorecording system for all surgeries and is expecting a decision soon on whether the Health Care Inspectorate (IGZ;

http://www.igz.nl/ english/) will develop legislation concerning the production and use of such recordings.

Discussion

None of the six innovations from the aviation industry that have been diffused in patient care processes at The Rotterdam Eye Hospital since 1992 could be exactly replicated—all needed to be adapted for use in health care. The taxi service and the black box concept were inspired by the aviation industry, but their deployment and purpose were altered. The remaining innovations used the same principles for similar purposes, but with different content.

Observations indicated that the innovations had a positive effect on quality and safety in the hospital: waiting times were reduced, work processes became more standardized, the number of wrong-site surgeries decreased, and awareness of patient safety was heightened. In general, the health care professionals at the hospital were interested in participating in the innovations, especially when aviation safety experts were directly involved in implementing them. There were also indications that they talked more openly about their safety concerns and the risks and ways to counteract them. Yet, in the absence of validated measures and an experimental design, the article is limited to a description of the innovations and lacks systematic evidence for their effectiveness.

Together, the six innovations addressed the four dimensions of safety culture previously cited—mastery of risks, social orientation, awareness of risks, and aversion to reporting errors.[29–31] The interviews showed that the ophthalmologists and other hospital staff became increasingly aware of safety issues because of the interventions. Innovation 3 (risk-analysis method) and Innovation 4 (time-out procedure), which were used to prevent, correct, and analyze errors, particularly addressed the mastery of risks within (surgical) processes. For both innovations, the multidisciplinary approach was experienced as a change from a functionally oriented culture. As Tal and Lichtenfeld have recently shown, health care's learning from aviation is primarily not about borrowing methods but rather is about changing professional and organizational culture.[39]

Innovation 5 (CRM training) and Innovation 6 (black box) seemed to promote social (team) orientation and risk awareness and to discourage aversion to reporting. Feedback based on videorecording, as described in Innovation 6, appeared to address all four safety-culture dimensions. The efforts to overcome staff's hesitation to participate in videorecording reflect the importance of trust in the process of a culture change. Yet, data regarding the effects of the innovations on safety culture are not available; only in 2007, after the first four innovations had already been implemented, was a hospitalwide survey, the Error Culture Questionnaire,[28] distributed. The survey was again recently distributed; results are pending.

The study also showed that a number of barriers have to be overcome for successful diffusion of innovations from aviation or indeed other industries. Health care financial resources are often limited or earmarked for specific purposes. Many of the innovations required new sources of funding, for example, for hiring senior people from aviation to serve as experts, often for extended periods. It is unclear how such infrastructure investments should be financed in health care. Because aviation is also a much more forward-looking industry when it comes to the use of information technology, virtually any innovations are likely to operate less efficiently in health care.

As stated, professional autonomy is more deeply entrenched in health care (physicians) than in aviation (pilots), so it is all the more important that physician "champions" are actively involved in diffusing the innovation.[40] In aviation, safety has been high on the agenda for decades, and a coherent safety system evolved in the form of a structured and supporting culture in which there are few degrees of freedom in following safety guidelines, regulations, and procedures. The issue of the relationship between physicians' sense of professionalism and a safety culture is outside the scope of this article, but attempts to diffuse innovations from aviation or another industry into health care may be more likely to contribute to a safety culture when a series of innovations are pursued, as was the case at The Rotterdam Eye Hospital. In addition, the fact that the hospital has had almost all the same board members since 1992 has consolidated the hospital's long-term commitment to these innovations. However, we believe that the findings are relevant to other hospitals, which as reflected in many of the facilitators and barriers associated with the innovations, share the high risks, limited resources, and highly educated professionals found in health care.

Conclusion

On the basis of a near-20-year experience with aviation-based innovation, we recommend that hospitals start with relatively simple innovations and use a systematic approach toward the goal of improving safety. Budgeting adequate resources for implementation of innovation may itself require innovation. J

This article was adapted from a paper, "Flying with Doctors: Experiences with the Application of Six Techniques from Aviation Industry in the Rotterdam Eye Hospital," presented at the Healthcare Systems Ergonomics and Patient Safety Conference, Jun. 25, 2008, Strasbourg, France. http://www.heps2008.org/abstract/data/pdf/dekorne.pdf (last accessed Jun. 21, 2010).

Dirk F. de Korne, M.Sc., is Research Fellow, Rotterdam Ophthalmic Institute, Rotterdam Eye Hospital, and Institute of Health Policy & Management, Erasmus University, Rotterdam, the Netherlands. **Jeroen D.H. van Wijngaarden, Ph.D.,** is Assistant Professor, Institute of Health Policy & Management, Erasmus University. **U. Frans Hiddema, M.D.,** is Chief Executive Officer, Rotterdam Eye Hospital. **Fred G. Bleeker** is Aviation Safety Consultant, QST Safe Skies, Almere, the Netherlands. **Peter J. Pronovost, M.D., Ph.D.,** is Professor, Department of Anesthesiology and Critical Care Medicine, Quality and Safety Research Group, and Departments of Surgery and Health Policy and Management, The Johns Hopkins University, Baltimore, and a member of *The Joint Commission Journal on Quality and Patient Safety*'s Editorial Advisory Board. **Niek S. Klazinga, M.D., Ph.D.,** is Professor, Department of Social Medicine, Academic Medical Center, University of Amsterdam, the Netherlands. Please address correspondence to Dirk de Korne, D.deKorne@oogziekenhuis.nl.

Online-Only Content

See the online version of this article for

Sidebar 1. Patient Planning and Booking System (1992)
Sidebar 2. Taxi Service (2006)/Valet Parking (2008)
Sidebar 3. Risk Management (2002)
Sidebar 4. Time-Out Protocol (2004)
Sidebar 5. Crew Resource Management (2007)
Sidebar 6. Black Box (2008)

References

1. Institute of Medicine: *To Err Is Human: Building A Safer Health System.* Washington, DC: National Academy Press, 1999.
2. Classen D.C., et al.: Adverse drug events among hospitalized Medicare patients: Epidemiology and national estimates from a new approach to surveillance. *Jt Comm J Qual Patient Saf* 36:12–21, Jan. 2010.
3. Haynes A.B., et al.: A surgical safety checklist to reduce morbidity and mortality in a global population. *N Engl J Med* 360:491–499, Jan. 29, 2009.
4. Leape L., et al.: Transforming healthcare: A safety imperative. *Qual Saf Health Care* 18:424–428, Dec. 2009.
5. Hudson P.: Applying the lessons of high risk industries to health care. *Qual Saf Health Care* 12(suppl. 1):i7–i12, Dec. 2003.
6. Sexton J.B., et al.: Error, stress and teamwork in medicine and aviation: Cross sectional surveys. *BMJ* 320:745–749, Mar. 18, 2000.
7. Flin R., et al.: *Safety at the Sharp End: A Guide to Non-Technical Skills.* Aldershot, UK: Ashgate Publishing, 2008.
8. Wilf-Miron R., et al.: From aviation to medicine: Applying concepts of aviation safety to risk management in ambulatory care. *Qual Saf Health Care* 12:35–39, Feb. 2003.
9. Flin R., Yule S.: Leadership for safety: Industrial experience. *Qual Saf Health Care* 13(suppl. 2):ii45–ii51, Dec. 2004.
10. van der Schaaf T.W.: Medical applications of industrial safety science. *Qual Saf Health Care* 11:205–206, Sep. 2002.
11. Roberts K.H., Tadmor C.T.: Lessons learned from non-medical industries: The tragedy of the USS Greeneville. *Qual Saf Health Care* 11:355–357, Dec. 2002.
12. Carroll J.S., et al.: Lessons learned from non-medical industries: Root cause analysis as culture change at a chemical plant. *Qual Saf Health Care* 11:266–269, Sep. 2002.
13. Sower V.E., et al.: *Benchmarking for Hospitals: Achieving Best-in-Class Performance Without Having to Reinvent the Wheel.* Milwaukee: ASQ Quality Press, 2008.
14. Shaw J., Calder K.: Aviation is not the only industry: Health care could look wider for lessons on patient safety. *Qual Saf Health Care* 17:314, Oct. 2008.
15. Powell S.M.: My copilot is a nurse: Using crew resource management in the OR. *AORN J* 83:179–180, Jan. 2006.
16. Singh H., et al.: Understanding diagnostic errors in medicine: A lesson from aviation. *Qual Saf Health Care* 15:159–164, Jun. 2006.
17. Dunn E.J., et al.: Medical Team Training: Applying crew resource management in the Veterans Health Administration. *Jt Comm J Qual Patient Saf* 33:317–325, Jun. 2007.
18. Kao L.S., Thomas E.J.: Navigating towards improved surgical safety using aviation based strategies. *J Surg Res* 145:327–335, Apr. 2008. Epub May 2, 2007.
19. Pronovost P.J., et al.: Reducing health care hazards: Lessons from the Commercial Aviation Safety Team. *Health Aff (Millwood)* 28:w479–w489, May–Jun. 2009.
20. Rogers E.M.: *Diffusion of Innovations*, 4th ed. New York City: Free Press, 1995.
21. Greenhalgh T., et al.: *Diffusion of Innovations in Health Service Organisations: A Systematic Literature Review.* Malden, UK: Blackwell Publishing, 2005.
22. The Joint Commission: *Sentinel Event Policy and Procedures.* Updated Jul. 2007. http://www.jointcommission.org/SentinelEvents/PolicyandProcedures/se_pp.htm (last accessed Jun. 18, 2010).
23. Pronovost P.J., et al.: Reducing health care hazards: Lessons from the Commercial Aviation Safety Team. *Health Aff (Millwood)* 28:w480, May–Jun. 2009.
24. Pronovost P.J., et al.: An intervention to decrease catheter-related bloodstream infections in the ICU. *N Engl J Med* 355:2725–2732, Dec. 28, 2006.
25. Pronovost P.J., et al.: Sustaining reductions in catheter-related bloodstream infections in Michigan intensive care units: Observational study. *BMJ* 340:462, Feb. 27, 2010. Epub Feb. 4, 2010. Rutherford W.: Aviation safety: A model for health care? *Qual Saf Health Care* 12:162–163, Jun. 2003.
27. Flin R., et al.: Measuring safety climate in health care. *Qual Saf Health Care* 15:109–115, Apr. 2006.
28. Van Dyck C.: *Putting Errors to Good Use: Error Management Culture in Organizations.* Unpublished doctoral dissertation, Free University of Amsterdam, Amsterdam, 2000.
29. Hoffman D.A., et al.: An investigation of the relationship between safety climate and medication errors as well as other nurse and patient outcomes. *Personnel Psychology* 59:847–869, Winter 2006.
30. Bogner M.: *Human Error in Medicine.* Hillsdale, NJ: Lawrence Erlbaum Associates, 1994.
31. Nance J.: *Why Hospitals Should Fly: The Ultimate Flight Plan to Patient Safety and Quality Care.* Bozeman M.T.; Second River Health Care Press, 2008.
32. Sorra J.S., Nieva V.F.: *Hospital Survey on Patient Safety Culture.* Agency for Healthcare Research and Quality: Publication No. 04-0041, Sep. 2004. http://www.ahrq.gov/qual/patientsafetyculture/hospsurvindex.htm (last accessed Jun. 21, 2010).
33. Singer S.J., et al.: Comparing safety climate in naval aviation and hospitals: Implications for improving patient safety. *Health Care Manage Rev* 35:134–146, Apr. 2010.
34. Yin R.K.: *Case Study Research: Design and Methods.* London: Sage, 2003.
35. The Joint Commission: *Universal Protocol.* http://www.jointcommission.org/PatientSafety/UniversalProtocol/ (last accessed Jun. 18, 2010).
36. Rampersad H.K., et al.: *TPS-Lean Six Sigma: Linking Human Capital to Lean Six Sigma.* Schiedman, The Netherlands: Scriptum Management, 2003.
37. Roos W.D.M.H.: The time-out procedure. In van Everdingen J.J.E., et al. (eds.): *Patient Safety Toolbox: Instruments for Improving Safety in Health Care Organizations.* Houten, The Netherlands: Bohn Stafleu van Loghum, 2006, pp. 311–314.
38. Rotterdam Eye Hospital: News Release: *Rotterdam Eye Hospital Wins Golden Helix Quality Award with Time-Out Protocol.* Oct. 18, 2004.
39. Tal Y., Lichtenfeld I.: *Transferring the Aviation Risk Management Model (ARMM) into an Ambulatory Healthcare Organization.* Tilburg, The Netherlands: Tilburg University Press, 2010.
40. Aagaard E.M., et al.: Physician champions are key to improving antibiotic prescribing quality. *Jt Comm J Qual Patient Saf* 36:109–116, Mar. 2010.

Online-Only Content

Sidebar 1. Patient Planning and Booking System (1992)

Features

■ Implementation of a department for patient logistics and a central scheduling system for office visits and surgery

■ Training of department staff by aviation logistic experts in using central master planning and booking software. Time for both surgery and office visits for all procedures and ophthalmologists was strictly blocked one year ahead in two blocks per day (master planning). For less predictable and more complicated retina and orbital surgery, whole days were blocked.

■ Booking staff working at the department level were responsible for booking patients in the agreed time slots. The slots were opened gradually, e.g., 20% of the capacity was available 5 months before surgery, 60% 2 months before, and 100% 2 weeks before. This system allowed for scheduling of medically urgent cases.

■ In 1992, the central planning department introduced overbooking as a method for capacity management at the clinics. The decentralized bookers were allowed to book a few patients extra per clinic to anticipate possible no-shows. Also, a flexible number of available ophthalmic residents were used for capacity management.

■ Physicians had to give notice of elective absence at least 3 months before date.

Outcomes

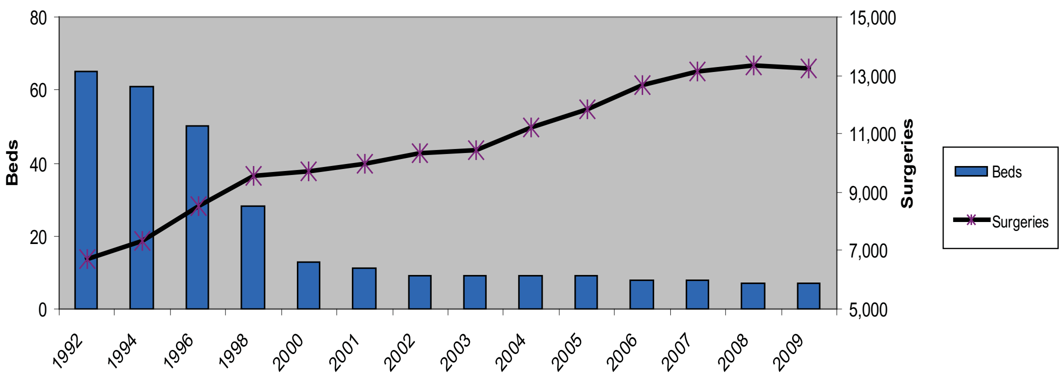
■ The surgical productivity doubled, and the number of office visits increased from 97,010 to 134,163 patients per year, while the average capacity remained almost unchanged.

■ The waiting times were reduced from more than 12 weeks in the early 1990s (as reported by two staff persons interviewed) to 2 weeks in 2009. However, the hospital did not systematically measure and report wait times in the 1990s. The available data show an average waiting time of 13.8 weeks in 2000 and 4.7 weeks in 2009 (ambulatory surgery, 6.6 weeks; inpatient surgery, 2.9 weeks).

■ Because of increases in ambulatory surgery, the number of inpatient beds was reduced from 65 beds in 1992 to 7 beds in 2009.

■ The increasing number of patients resulted in an increase of revenues for both ophthalmologists and the hospital.

Developments in Number of Surgeries and Clinical Beds



Data source: Hospital Management Information System / Annual Reports. Surgeries include all inpatient and outpatient ophthalmic surgical procedures. The hospital had 120 licensed beds until 1999 and 100 licensed beds from 2000 through 2009.

Sidebar 2. Taxi Service (2006)/Valet Parking (2008)

Features

■ Taxi service (in 2006) for cataract patients was provided by an external company in close cooperation with the surgical department.

■ Valet service (in 2008) for all patients and visitors was provided by an external company, in close cooperation with the front desk of the hospital.

Outcomes

A survey done in 2006 showed that patients appreciated the taxi service; 91% of 114 respondents, given the survey after cataract surgery, agreed that this service was more convenient than public transport.

Online-Only Content

Sidebar 3. Risk Management (2002)

Features

■ For each multidisciplinary risk management team, five one-hour sessions were organized in which critical processes were analyzed using Toyota Production System Lean Six Sigma management techniques. First, process flow charts were created and examined to identify failures, their root causes and relationships with other process steps, and possible consequences. Second, risk factors (R) were identified, using the product of frequency (F) and the severity (S) for every possibly weak process step. Finally, improvement methods were determined, using the R-value for prioritizing; responsibilities were indicated; and the results were reported and evaluated.

Examples of Determined Risks and Actions Perioperative Process of Eye Surgery

Subprocess	Failure	Root Causes	Consequence	F	S	R	Improvement Action
Diagnosis and completion of surgery form	Not readable	Bad handwriting	Misinterpretation OD/OS (left or right eye)	2	7	14	None
Preoperative check of anesthesiologist, retro bulbar injection or total anesthesia	Incorrect or insufficient preoperative report	Communication errors (language/ rational level/patient pre assumed surgery at other eye)	Stop of procedure, consult ophthalmologist or: wrong eye is injected	2	9	18	1. Responsibilities are documented. 2. Focus on (corrective) behavior. 3. In case of confusion, always stop procedure.
Ophthalmologist checks presurgical plan and wraps up the eye	Reading failure/ communication error	1. Communication obstacle (language/ rational level/ patient hypothesized other eye) 2. Slovenliness 3. Only medical chart is screened	Stop of procedure or: wrong eye is wrapped up	2	10	20	1. Instruct on responsibilities and necessary complete check. 2. Focus on behavior. 3. Discuss outcomes of risk analysis with whole medical staff. 4. Medical chart is checked again at surgery by surgeon. 5. Surgical nurse puts chart in front of surgeon.
Surgery on eye	Surgery on wrong eye	Multiple (see causes mentioned)	Wrong-site surgery	2	10	20	See actions mentioned before.

R (risk) = Frequency (F) x Severity (S). F and S are each rated on a 0–10 scale (F: 0 = Impossible, 10 = For sure; S: 0 = No problem, 10 = Catastrophic). The minimum estimated risk value of 15 was agreed as starting point for improvement actions.

Outcomes

■ Wrong-site surgery was identified as one of the most important risks; therefore, critical checks were introduced into the preoperative process. However, elimination of wrong-site surgeries (the primary goal) was not achieved.

■ The majority of determined risks were related to human factors—errors, nonpunctuality, unclear written reporting, and communication failures between co-workers and with patients.

Online-Only Content

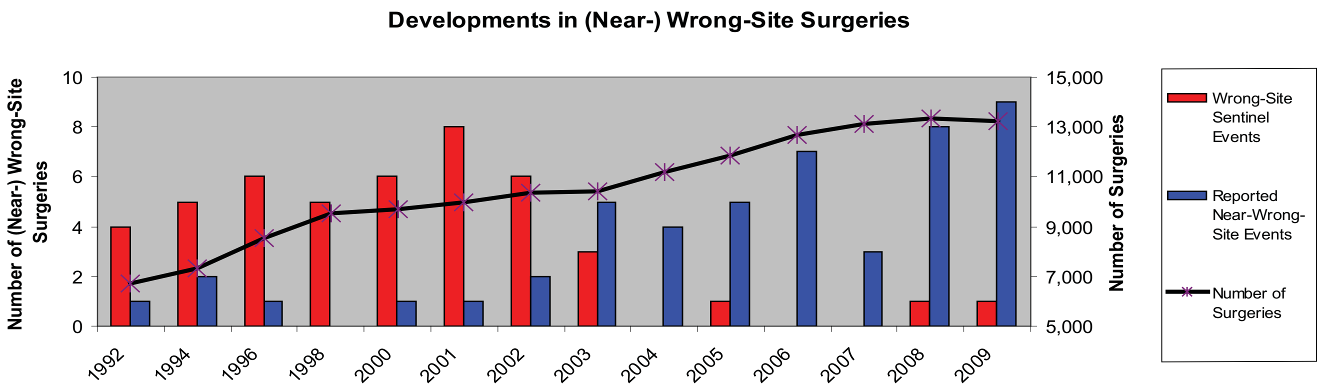
Sidebar 4. Time-Out Protocol (2004)

Features

- Immediately before surgery and with all members of the surgical team present, a final check is conducted using a standardized (open) questionnaire to ensure that the surgery is being performed on the right patient and on the intended side.
- The time-out procedure includes a check of the required materials (e.g., intraocular [implant] lens, donor cornea, and so on) and the patient's health status with respect to the planned surgical procedure.
- The procedure was an addition to the normal preparatory checks (e.g., time-out with anesthetic team before delivery of anesthesia) and is documented in an anesthesia data system.

Outcomes

- Wrong-site surgeries have decreased from an average of five a year before 2004 to zero in 2004, 2006, and 2007, while the number of surgeries has increased.
- In 2005, 2008, and 2009 one wrong-site incident a year has occurred.
- More identified near incidents were reported.



Online-Only Content

Sidebar 5. Crew Resource Management (2007)

Features

■ All multidisciplinary surgical teams (ophthalmologists, anesthesiologists, residents, [surgical] nurses, management) were trained (with 10–15 participating in one training program) in Crew Resource Management (CRM).
■ The program consisted of four sessions of four hours each, led by an aviation safety expert.
■ The first three sessions were classroom-based, interactive, and focused on the organization, the team, and the individual, respectively. The fourth session took place in a flight simulator (see table, below).

Training Program for Crew Resource Management

Session	Content
Session 1: Organization	Introduction to CRM Statistics and examples of human factor failures Primary causes of incidents Recognizing errors using human factors theory and SHEL-Model (software, hardware, environment, lifeware)* Threat and error management Swiss cheese model and actions to reduce the likelihood of error† Information processing Situational awareness in decision making (part 1)
Session 2: Team	Situational awareness in decision making (part 2) Effective communication and coordination CRM loop: inquiry → advocacy → conflict resolution → decision making Leadership and teamwork Situational leadership Relation- and task-focused Feedback: push and pull styles Push and pull styles of communication for leaders Team exercises Personality and behavior (part 1)
Session 3: Individual	Personality and behavior (part 2) Hazardous attitudes How to beat hazardous attitudes Personality Feedback: theory and exercises
Session 4: Flight Simulator	Relation and application of lessons learned, in an external, exciting environment without the usual roles and hierarchy Use of a Boeing 737-800 flight simulator: "Pilots Get Food Poisoning": Ophthalmologists and nurses have to prepare for landing, cooperate, and practice tools learned.

* Edwards E.: Man and machine: Systems for safety. In *Proceeding of British Airline Pilots Associations Technical Symposium.* London: British Airline Pilots Associations, 1972, pp. 21–36.

† Reason J.: *Managing the Risks of Organizational Accidents*. Burlington, VT: Ashgate Publishing Limited, 1997.

Outcomes

■ Participants indicated that the training promoted their risk awareness, teamwork, and cooperation.
■ In addition to the time-out procedure, a (de)briefing was implemented.
■ A "safety eye" (right) was developed as a tool to determine risks and to stimulate professionals to "speak up" during surgery. One nurse stated, "We sometimes just say to each other, 'almost yellow,' to signal that we have to change the current direction."

Source: Rotterdam Eye Hospital.

SAFETY EYE©

Online-Only Content

Sidebar 6. Black Box (2008)

Tool

- For every quarter since 2008, a full day of surgery has been videotaped with a handheld videorecorder.
- The tapes are analyzed by an aviation expert, and the most useful parts were used in a feedback session for the surgical team. All feedback is given by the aviation expert, who does not fingerpoint but provides examples of aviation practices.
- If the surgical team consented, a selection of the video images and the related feedback was provided with others during a medical staff meeting (see table below).

Outcomes

- The video recordings have revealed team-specific differences in performing the time-out procedure and in use of the safety communication rules agreed on during the CRM training; they have also showed that the absence of team members at the preoperative briefing results in less structure and some communication lapses during surgery.

Examples of Video Observations and Feedback to Multidisciplinary Team

Item	Observation	Feedback
Mental preparation	Before the patient was on the operating table, it was not yet agreed who (attending or resident) was supposed to perform the surgery.	The performing surgeon is not able to prepare mentally and obtain situational awareness.
Briefing	After the patient arrived in the operating room, a resident and student received a medical-technical explanation about the procedure. There was no talk about who would be performing what actions or potential problems. As it turned out, the resident was asked to jump in during the surgery and was not prepared to do so.	A "captain" needs to have the situational awareness regarding the competences of his colleague performing the operation. To prevent such errors, he or she briefs him before as to what to expect, so the situational awareness of the "copilot" is updated. The copilot can ask questions or make things clear to the whole team.
Projection	The ophthalmologists discussed the surgery schedule for the day and indicated that the first surgery in the afternoon was expected to take 2.5 hours. He asked the team to plan their lunch time accordingly.	This is a good example of correct projection of tasks and managing of resources.
Time-Out	The time-out was performed, but there was no check against the information in the medical chart.	How can we ensure that the time-out procedure is performed in a standardized manner?
New Tip	Halfway during surgery, a scalpel with new tip was on the surgery table. The surgeons did not know why.	The fact that surgeons did not know about the new tip can be observed as a "threat" from the organization. Are the communication procedures from the organization to surgeons sufficient, and did the team take responsibility and sufficient measures to prevent errors from such threats?
Communication	The surgeon asks for an intraocular lens (IOL) , and the circulating nurse gets one. Before putting it on the surgery table, she says "20" but did not receive a response from the surgeon. After a while, the surgeon asks to see the chart to check the IOL power.	When the IOL is unpacked, it was shown to be the wrong one. Why not close the communication loop before unpacking the IOL or implement a check moment before?
Communication	Frequently, a task or some material is required, but is not repeated in a standardized manner to confirm that it is understood.	Communication possibilities at the surgery are limited (e.g., covered face, working hands, not looking at each other), which every team member should be aware of and try to compensate for. Closing the communication loop during handovers (repeating an assignment, saying "check" or "yes") seems to be useful.
Assertiveness	As the ophthalmologist prepared to wash the eye, the circulating nurse asks if the right method and material were used.	The circulating nurse's assertiveness was perfect, as was the reaction of the ophthalmologist.