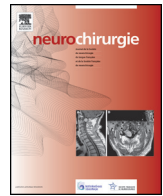




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Update

# A prospective video-based observational and analytical approach to evaluate management during brain tumour surgery at a university hospital



## Approche ergonomique pour l'analyse de la gestion des incidents au bloc opératoire

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### ABSTRACT

The operating room (OR) is a high-risk complex setting, where patient safety relies on the coordinated efforts of multiple team members. However, little attention has been paid to evaluating the strategies employed by OR practitioners to prevent and correct incidents that inevitably occur during surgery. Therefore, we were prompted to investigate human factor (HF) engineering methods that have been used in an innovative way in order to systematically observe and analyze the management of incidents in the neurosurgical OR of a French university hospital. A technical case report illustrates our approach that associates the following procedures: the recording of OR team member activities and behaviour by video cameras and direct observation of a HF researcher, with the description and the explicit demonstration of safety related procedures in self- and cross-confrontation interviews of OR team members. This technical report emphasizes complementary aspects of clinical performance related to safety skills. Moreover, individual and team performances rely on complementary abilities that associate practical knowledge, skills, and attitudes, which are engaged at various degrees to prevent and manage incidents. This report also enlightens new quality-improvement opportunities as well as further objectives for future studies.

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### R É S U M É

Le bloc opératoire est un environnement complexe, où la sécurité du patient repose sur les efforts coordonnés de tous les membres de l'équipe chirurgicale. Néanmoins, les stratégies déployées par ces professionnels pour prévenir et corriger les incidents, qui surviennent inévitablement, ont jusqu'à présent été peu étudiées. Nous décrivons une méthode ergonomique originale, utilisée pour observer et analyser la gestion des « erreurs » au bloc de neurochirurgie. Nous avons choisi, pour exemple illustratif, le cas d'une patiente de 70 ans, opérée d'une tumeur cérébrale. L'activité et les comportements des membres de l'équipe chirurgicale ont été observés par un chercheur en ergonomie, et enregistrés par des caméras vidéo HD. Les erreurs commises ont été recensées et catégorisées : 66 % étaient purement liées à la performance clinique ; 33 % impliquaient (au moins partiellement) la communication ou la gestion organisationnelle. Les actions associées à la sécurité du patient ont, par suite, été explicitées et analysées au cours d'entretiens personnalisés, au cours desquels les professionnels du bloc ont fait 86 références aux procédures en cours et à la check-list. Ils se sont appuyés sur des compétences complémentaires pour gérer les erreurs : les connaissances pratiques (citées 25 fois), les compétences techniques (citées 21 fois), le savoir être (cité 8 fois). Nous avons détaillé une méthode innovante d'analyse des erreurs au bloc opératoire ; les diverses compétences mises en œuvre dans la gestion de ces erreurs ont été explicitées

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Abbreviations: OR, operating room; ICU, intensive care unit; D2, two days after the operation.

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*Success is not final, failure is not fatal: it is the courage to continue that counts*

Sir Winston Churchill

## 1. Introduction

Previous epidemiological studies from several industrialized countries (e.g., US [1,2] and Western Europe [3–6]) have shown that:

- approximately 3% to 4% of hospitalized patients suffer a serious adverse event;
- surgical adverse events account for 48% of all adverse events;
- almost half to two-thirds of these adverse events are preventable.

Consequently, patient safety has received increased attention. It is now accepted that the operating room (OR) is an inherently high-risk environment and improving patient safety often involves the coordinated efforts of multiple members of the healthcare team. Nevertheless, little attention has been paid to these strategies adopted to manage risks among health professionals. In a prescient and seminal paper published in 1994, Leape [7] argued that if healthcare providers were to succeed in reducing errors in hospital care, they would need to fundamentally change the way they think about errors. The author subsequently stated that the solutions to the problem of medical error would not primarily lie within medicine, but in the discipline of human factors and ergonomics (HF&E). Indeed, HF&E is a multidisciplinary field incorporating contributions from psychology, engineering, industrial design, graphic design, statistics, operations research and anthropometry. In essence it is the study of designing equipment and devices that fit the human body and its cognitive abilities. HF&E provide prospective data in collective and qualitative analysis methods, which have been used in elite sports [8] and high-risk industries (e.g., commercial aviation, nuclear safety, aerospace) to study team performance. To obtain a better understanding of patient safety practice in the OR, we attempted to systematically describe the management of incidents by the OR team as observed in their natural setting, and then interpreted by these care providers (i.e. surgeons, anaesthesiologists, nurses) in a video-based self- and cross-confrontation interviews. Our aim was to perform a qualitative analysis of events/errors, in order to identify the root causes and understand how they may be harmful to the patient. In the present report, we describe the methodology developed for further prospective studies, providing one illustrated case.

## 2. Technical case illustration

### 2.1. Research setting

The present observational and analytical pilot research study was conducted in the OR of Toulouse university hospital in the department of neurosurgery, according to the principles of the declaration of Helsinki. Because it was an observational quality-improvement case study with no change in our current clinical practice, neither approval of the ethics committee nor informed consent was required according to French law. The experiment was reviewed by the Communication Board of our institution, then presented and clearly explained to the OR senior management and OR staff in advance. A representative sample of OR team members consented to participate to the study. All participants had been previously informed of the quality-improvement and educational purpose of the study, and gave their written informed consent to be filmed.

### 2.2. Operation profile

A routine elective case of brain tumour surgery was chosen for the following reasons: craniotomy for a brain tumour is a common neurosurgical procedure that is regularly performed in the department; it requires classic microsurgical technical skills [9]; its indications have been well defined in literature as well as its complications [10].

A 70-year-old woman was operated on for a right frontal meningioma of the skull convexity. Her basic preoperative complaint was headaches. The patient's ASA score was 2. The surgical team was composed of the following care providers: a staff surgeon, a chief resident surgeon, a resident surgeon, a staff anaesthesiologist, a resident anaesthesiologist, a scrub nurse, a circulating nurse, and an nurse anaesthetist. Staff doctors and nurses were all entirely familiar with the surgical procedure with the exception of one nurse, who was less trained in neurosurgery. All team members, except the residents, were permanent members of the neurosurgical department.

The anaesthesia was induced with sufentanyl and propofol. Curare was administered to facilitate the tracheal intubation. The patient received standard monitoring that included invasive and non-invasive arterial blood pressure, continuous electrocardiogram, pulse oximetry, oesophageal temperature, urine output, and end-tidal CO<sub>2</sub> as well as anaesthetic concentrations. The anaesthesia was maintained with a propofol infusion during the procedure that consisted of a right frontal craniotomy (performed by the chief resident) and extra-axial tumour resection (performed by the staff neurosurgeon).

After the operation, the patient was transferred to the neurosurgical ICU as standard procedure. Pathological report suggested a WHO-grade-2 atypical meningioma. A transient confusion was observed at D1 (one day after surgery), which was partly attributed to steroids and opioids. The patient was able to walk 2 days after the operation, and was rapidly discharged following a normal neurological examination. Postoperative CT revealed a parenchymal hypo-density at the surgical site, and a contralateral subdural collection. At D19, the patient was admitted for headaches and confusion and was operated on for a left sided subdural haematoma, which alleviated the symptoms.

### 2.3. Data collection and analysis

The study was performed according to the HF&E approach (Serious Game Research Network), and the researcher (JFC) trained to analyze professional behaviours of healthcare workers in the OR.

Firstly, the HF&E researcher prospectively collected observational data, which consisted of digital recordings obtained from 3 digital video cameras, placed to record team member behaviour and activities, supplemented with direct observations using ethnographic field note methods [11]. A working group composed of a staff neurosurgeon, a staff anaesthesiologist, and the HF&E researcher analyzed the video-recordings and field notes. They recorded a total of 18 failures, which were characterized according to a standardized terminology and classification schema [12], including their type and cause (Table 1). Major as well as minor incidents were analyzed (e.g., major incident that prolongs hospitalization, and/or leads to additional and not planned diagnostic procedure(s) or treatment(s); also the patient is often physically injured) [4].

Overall, 66% of these failures were basically related to clinical performance, whereas 33% involved communication or patient management, at least partially. Technical skills were the root cause of nearly 90% of the failures that occurred during the pre-intervention phase and 45% (4/9) of the failures during the intervention phase, whereas communication failures represented

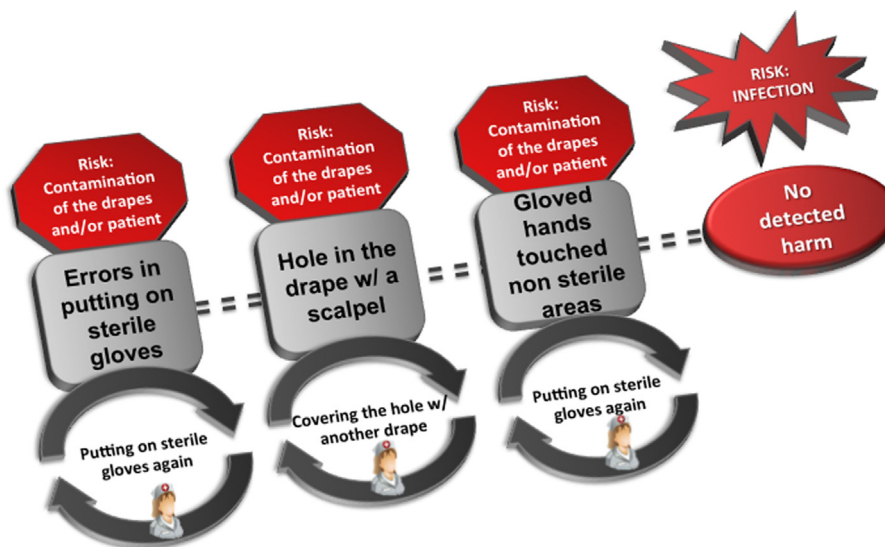
**Table 1**  
Incidents collected during the surgical procedure.  
*Incidents relevés au cours de l'intervention chirurgicale.*

| Meaning unit  | Subtype                                 | Type                                       | Cause   |
|---|---|--|---|
| Resident anesthetist induced anesthesia too fast  | Correct procedure incorrectly performed | Clinical performance                       | Human, practitioner, skill-based  |
| Nurse did not install the mute assistant correctly  | Correct procedure incorrectly performed | Clinical performance                       | Human, practitioner, skill-based  |
| Chief resident stapled the drapes, what the staff surgeon he assisted never does so                                   | Questionable interpretation             | Communication                              | Organizational, organizational culture, communication channels  |
| Chief resident did not install the sucker correctly   | Correct procedure incorrectly performed | Clinical performance                       | Human, practitioner, skill-based  |
| Nurse's gloved hand touched non-sterile areas (four times)  | Procedure contraindicated               | Clinical performance                       | Human, practitioner, skill-based  |
| Nurse made a hole in the drape with the scalpel   | Procedure contraindicated               | Clinical performance                       | Human, practitioner, skill-based  |
| The size of the craniotomy performed by the chief resident was inadequate   | Correct procedure incorrectly performed | Clinical performance<br>Patient management | Human, practitioner, skill-based,<br>organizational, organizational culture, chain of command   |
| Blood pressure (BP) monitoring did not function properly, since the position of the arterial catheter was not optimal | Correct procedure incorrectly performed | Clinical performance                       | Human, practitioner, skill-based  |
| Nurse did not install the cottonoids provider as expected by the surgeon  | Incomplete information                  | Communication                              | Organizational, organizational culture, communication channels  |
| Brain swelling occurred   | Correct procedure with complication     | Clinical performance<br>Communication      | Human, practitioner, skill-based<br>Organizational, organizational culture, communication channels<br>Transfer of knowledge<br>Supervision and training |
| Patient moved after resident anesthetist leaned on the operating table  | Procedure contraindicated               | Clinical performance                       | Human, practitioner, rule-based   |
| Surgeon turned his back to the scrub nurse  | Questionable interpretation             | Communication                              | Human, practitioner, unclassifiable   |
| Vascular clip felt when scrub nurse passed it to the surgeon  | Correct procedure incorrectly performed | Clinical performance                       | Human, practitioner, skill-based  |
| Skull screws and plates were unavailable for closure  | Incomplete information                  | Communication                              | Technical, facilities, materials availability   |
| The count of cottonoids was not performed   | Omission of essential procedure         | Clinical performance                       | Negligence  |

only 10% of failures during the pre-intervention phase but accounted for 55% of the failures during the intervention phase. Residents (both surgeon and anaesthetist) and the less trained nurse were involved in 100% of the skill-based failures. The staff surgeon as well as the staff anaesthetist and the chief resident were involved

in 100% of the failures related to patient management and lack of communication.

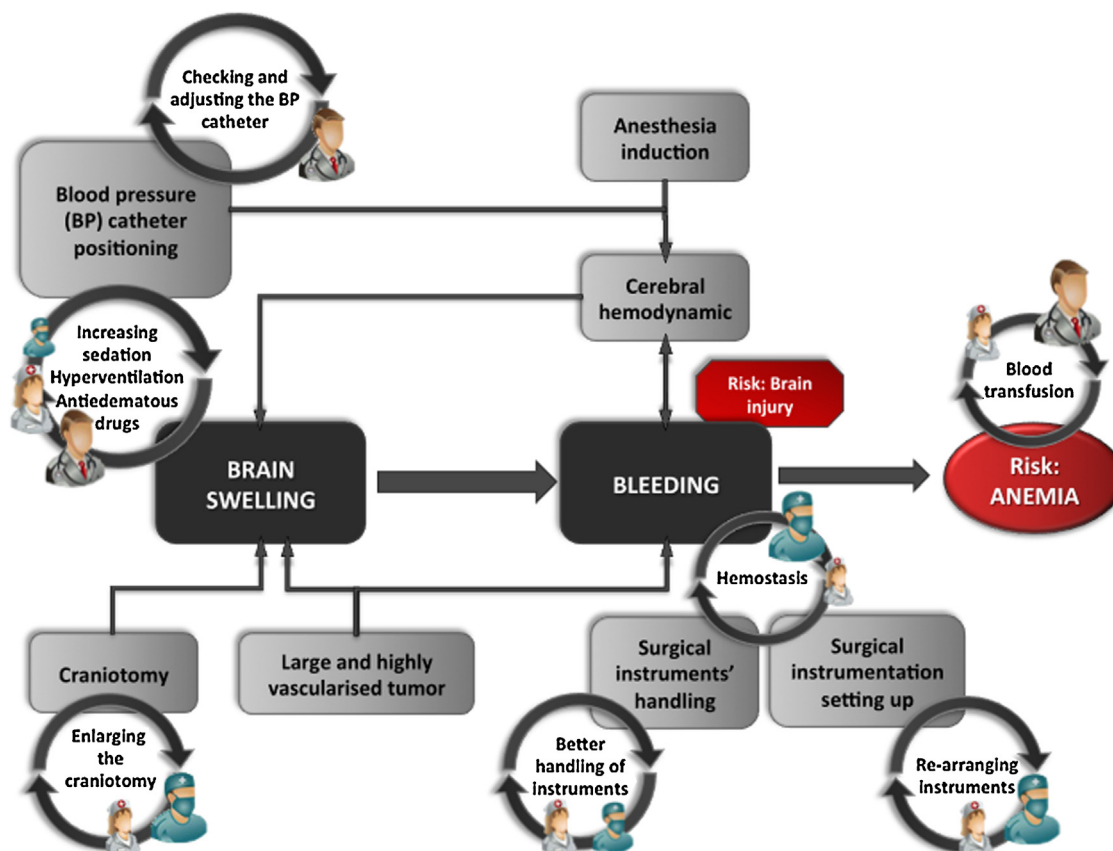
A framework was used to define the parameters of failures and to better understand their management by the team. Overall, all incidents but one (94%) were corrected or at least mitigated



**Fig. 1.** Incidents and corrections related to sterility maintenance.

*Schéma relatif aux erreurs liées au maintien de la stérilité.*

*Adapted from Chang et al., 2005 [12].*



**Fig. 2.** Incidents and corrections related to brain swelling. This diagram shows minor incidents or hazardous conditions that could have contributed to cause major incidents either directly or indirectly by interacting with their correction or mitigation (e.g. a large and highly vascularized tumour implies a risk of excess bleeding, also, to let vascular clips fall on the floor, when handing it to the surgeon who is performing the hemostasis, causes delay in actions, and can then indirectly contribute to bleeding): squares: causes or incidents/events; circles: actions engaged to mitigate events; roles of participants, the size of the circle is proportional to the engagement of the participant necessary to perform the action (e.g. surgeon accomplish the hemostasis, whereas anaesthetists process the transfusion); arrows represents interactions between causes and incidents/events or actions engaged to correct or mitigate incidents.

*Schéma relatif aux incidents en rapports avec l'œdème cérébral. Il montre le lien potentiel entre des circonstances particulières ou des incidents mineurs et des événements indésirables graves. Par exemple, une tumeur richement vascularisée implique un risque de saignement peropératoire ; par ailleurs, la perte de temps liée à un défaut de coordination dans le passage d'un clip nécessaire pour faire l'hémostase, peut aussi indirectement contribuer à une majoration du saignement : carrés : causes des incidents/événements ; cercles : actions engagées pour les corriger et acteurs impliqués ; la taille du cercle est proportionnelle au niveau d'engagement de l'acteur dans l'action considérée : par exemple, le chirurgien fait directement l'hémostase, tandis que l'anesthésiste transfuse). Les flèches représentent les interactions entre les causes des incidents/événements et les actions engagées pour les prévenir ou les corriger.*

Adapted from Chang et al., 2005 [12].

within a variable delay and with a variable participation of the team members. Failures related to maintaining sterility, which mainly involved the nurses, who always made correctable errors with no delay (Fig. 1). Failures related to the installation of the surgical setup were corrected with delay since it implied the cooperation of the more experienced staff surgeon and his appreciation of optimal setting partially related to his personal approach. The resident anaesthetist, who adjusted the position of the operating table, immediately corrected any error. More complex failures that are shown in Fig. 2 had been interacting and therefore contributed to two adverse events that took place in the postoperative course (i.e., the development of a symptomatic subdural haematoma that required a second operation, and anaemia that required blood transfusion). The counting of cottonoids that was not done was the sole non-corrected incident.

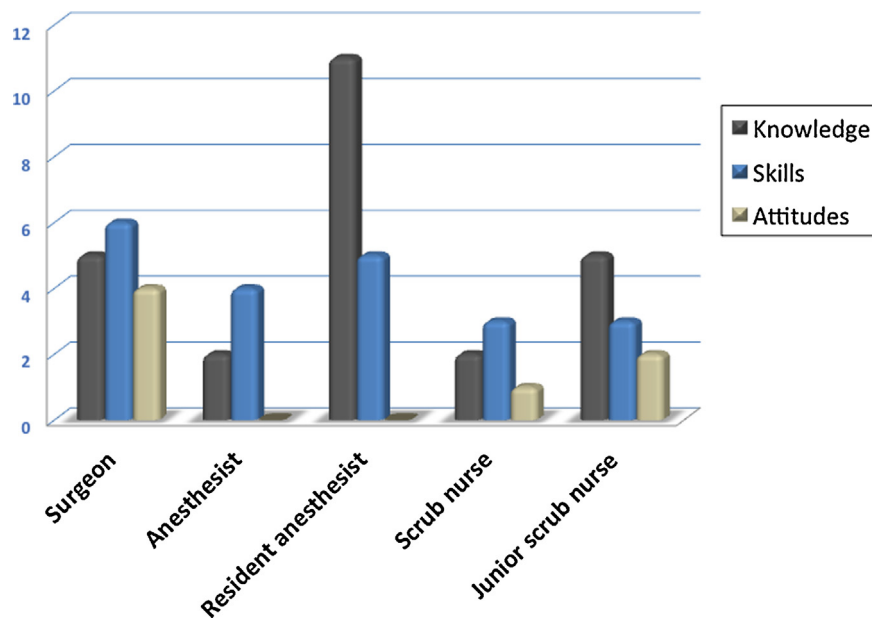
Secondly, the HF researcher conducted confrontation interviews [13], in which team members were presented with the OR video-recordings. The latter were asked not only to comment on what they saw but also to express, and clarify the reasons for their actions (i.e., self-confrontation) as well as those of other team members (i.e., cross-confrontation). Interviews were audio recorded. Because of time constraints the video-recordings were shortened to the

most informative sequences (i.e., < 20 min) by the aforementioned working group (i.e., staff neurosurgeon, staff anaesthesiologist, and HF&E researcher using Studio 12 [Pinacle software]), so that the self-confrontation interviews lasted no more than 60 minutes. These were transcribed *verbatim* by the interviewer and enabled the participants to confirm the validity of the transcription. All references to safety practice were noted. Qualitative analysis was made to understand the management of failures, and particularly ways of preventing and mitigating them effectively.

When they watched the videos and were confronted with their behaviour and activities, team members detected all incidents. The surgeon, the two anaesthetists and the two nurses respectively verbalized seven, 13 and 10 incidents they were directly involved in, while they verbalized six, eight and 12 incidents they were not directly involved in.

Describing their behaviours and activities, all team members spontaneously and regularly referred to the institutional procedures in use in the OR at the time of the operation: 22 references were noted for the surgeon, 19 for the two anaesthetists, and 45 for the two nurses. The World Health Organization surgical safety checklist [14] was the most cited procedure, followed by the one related the prevention of surgical site infections. Procedures were





**Fig. 3.** Profile of competencies engaged by operating room (OR) team members to manage incidents. Attitude refers to the behaviour aspects that allow team members to conduct themselves as care providers, and to master the attitudes, either personal or professional that could eventually enable them to practice professionally. Skills refer to the clinical and technical capacity that enable team members to act in the OR effectively. Knowledge refers to the professional knowledge that allows team members to think and act in a professional manner.

*Profil des compétences mises en œuvre par les professionnels du bloc pour gérer les erreurs ou incidents. Attitude renvoie aux aspects comportementaux qui permettent aux membres de l'équipe de se conduire en tant que prestataires de soins, et de maîtriser les attitudes, qu'elles soient personnelles ou professionnelles, qui leur permettent d'agir professionnellement. Skill renvoie aux capacités cliniques et techniques qui permettent aux membres de l'équipe d'agir efficacement dans le bloc opératoire. Knowledge renvoie à la connaissance professionnelle qui permet aux membres de l'équipe de penser et d'agir de manière professionnelle.*

evoked to prevent failures. For example, a nurse said: “it is an institutional protocol, we catheterize all patients before operations of over two hours’ duration” or “all nurses are using two pairs of gloves, which is a recommendation from the Local Nosocomial Infections Surveillance Committee”. The anaesthesiologists also evoked procedures in the correction or mitigation of all but one of the incidents they were involved in.

Commenting on incidents’ correction and mitigation, the surgeon, the anaesthetists, and the nurses, evoked variable contributions of knowledge, skills and attitudes, which are summarized in Fig. 3. Knowledge was the most quoted competence mobilized to manage incidents, followed by skills and attitudes. Nevertheless, the staff neurosurgeon, the resident anaesthetist, and the more experienced scrub nurse ranked skills first. Half of the references to attitudes came from one team member, the surgeon.

### 3. Discussion

In this prospective video-based observational approach, the ways incidents were detected and then corrected or mitigated, emphasized two complementary aspects of clinical performance. The first aspect is associated with an individual practitioner, which corresponds to the non-interdependent components of an individual’s performance and mainly includes practical knowledge and skill in performing specific procedures. The second aspect is then the interdependent aspects of performance, or the components of OR team members’ tasks that require joint action to be completed. Specific competencies that underlie a practitioner’s ability to function as an effective team member mainly rely on behavioural and communication skills [15]. Our video-based self-confrontation approach permitted to explicitly identify these aspects of professional competencies, thus constituting the bases for their learning and integration.

#### 3.1. Individual practitioner task work

Failures in clinical performance occurred because some practitioners had a lack of knowledge and technical skills. More precisely, it appeared that it was rather a question of applying knowledge to real-world situations and using personal knowledge rather than a default of core knowledge. The residents and the less-experienced nurse were consistently involved in quite a number of minor incidents with a skill-based cause during the operation, none of which really compromised the safety of the patient or the final outcome of the surgery. In addition, the profile of competencies mobilized to correct or mitigate incidents was determined by the experience of the practitioner: the staff practitioners put skills first and knowledge second, whereas the trainees put knowledge first and skills second. The development of expertise depends on accurate and detailed assessment and feedback. A direct observation of trainees by the faculty is critical in university hospitals for teaching and assessing clinical and communication skills. In this regard, the 2008 Institute of medicine report recommends greater supervision in medical education to improve patient safety and education [16,17]. Many tools are available for the direct observation of clinical skills of surgical trainees [18] or junior OR nurses [19] even though the validity of evidence and the descriptions of educational outcomes are scarce [20]. Future studies are then required to prospectively evaluate these tools; one is ongoing in our academic institution.

#### 3.2. Teamwork

Effective and efficient performance of complex, interdependent tasks necessitates that practitioners be not only highly competent in their technical skills, but it also needs proficient team members. Indeed, merely perfecting the technical work of individual doctors and nurses is definitely insufficient to prevent most medical errors [21,22]. Our case illustration has demonstrated that major incidents are often associated with complex causality and thus what is

strictly required in an OR is anticipation, communication and close cooperation of all team members in their detection, correction and mitigation (i.e., not only between surgeons and anaesthetists but also between doctors and nurses). Competent patient care increasingly requires practitioners to consider the importance of each profession where those representatives whose skills and expertise help to optimize health outcomes. This is well illustrated in our case by the following correlating statements: “she (the staff anaesthetist.) is changing the parameters of the ventilator to go for hyperventilation, thus reducing brain bulging and helping me” (the staff surgeon); and, “all these procedures make his (the staff surgeon) surgery more difficult, we have to help him the best as we can to reduce the swelling” (the staff anaesthetist).

In regards to safety procedures, our data support the idea that using briefing and checklists in the operating room improves team performance. Indeed, all team members continuously referred to the surgical safety checklist when the HF researcher interviewed them about patient safety measures. This procedure, which has been integrated in our practice for nearly 3 years, then gave the impression of being effective in improving patient safety. Such interpretation might be extended to other procedures that had also been cited (e.g., the surgical site infection survey launched by the Local Nosocomial Infections Surveillance Committee).

### 3.3. Lessons from incidents

Expert clinicians learn to work confidently yet safely, by anticipating and negotiating the hazards of their work. For instance, Morineau et al., [23] observed that experts cope with task demands by monitoring conflicts between the surgical intervention and the biological laws governing the patient's body. Long et al., [24], who studied the key skills and attributes of the safe and effective clinician by interviewing clinical staff, have highlighted vigilance and anticipation as key components of professional competency. Anticipation involves thinking ahead and envisioning possible problems and hazards. For example, as he expected potential brain swelling in a suspected atypical meningioma, the staff surgeon judged necessary to enlarge the craniotomy formerly performed by the chief resident. Similarly, vigilance involves observing all preliminary signs of a potential incident and consequently engaging an action to prevent or mitigate it. For example, during her interview the more experienced nurse mentioned that the amount of liquid in the surgical aspiration collector had warned her of the risk of transfusion. She then immediately transmitted this to the circulating nurse so that she could be ready to rapidly engage the associated procedure if required by the anaesthetists. Again, the junior nurse did not perceive these set of actions when interviewed.

Juniors learn safety skills by trial and error, or by observing experts recover from dangerous situations. In healthcare unlike many other high-risk industries, these skills are seldom explicitly identified or formally trained [25]. Direct video-based observation followed by self- and cross-confrontation interviews provide objective data for self-evaluation, correction, and feedbacks from staff clinicians. Furthermore, the identification of incidents and discussion about them help to identify simple or even more complex system issues and can prevent similar ones from resulting in actual adverse patient outcomes for the patient in the future. Moreover, our method also provides opportunities to implement other approaches to error analysis (e.g., root cause analysis [22], which has its foundations in industrial psychology and HF engineering, is widely applied to investigate major industrial accidents).

### 3.4. Key ethical principles

We believe this video-based observational analytical approach to incident management offers enormous potential for the

understanding and improvement of the quality and safety of surgery; nevertheless, it raises a number of ethical concerns. These have been pointed out and addressed by Vincent et al., [25], and could be summarized as follows: fear of a blame, or a disciplinary action, and fear of promoting litigation. This is the reason why some obligatory principles must be respected. They consist of providing clear information, respecting the decision of team members to participate or not, respect the quality-improvement and educational objectives, preserving anonymity, and deleting data after accomplishment of the objectives. Collaborating with HF engineering professionals is also of paramount importance in developing the utilization of the technique.

## 4. Conclusions and perspectives

Our preliminary experience integrating this video-based observational and analytical approach in our OR safety program has been positive and productive. It helped us to obtain a better understanding of how incidents become apparent and why decisions and actions of the individuals as well as whether or not the entire team make sense in the context. Self-confrontation interviews promoted self-improvement among team members. Cross-confrontation interviews gave practitioners the opportunity to recognize the contribution of each profession to patient care. It encouraged communication and respect within the team, but also enlightened new considerations that would entail change and further objectives for our future work.

### Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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### References

- [1] Brennan TA, Leape LL, Laird NM, Hebert L, Localio AR, Lawthers AG, et al. Incidence of adverse events and negligence in hospitalized patients. Results of the Harvard Medical Practice Study I. *N Engl J Med* 1991;324:370–6.
- [2] Leape LL, Brennan TA, Laird N, Lawthers AG, Localio AR, Barnes BA, et al. The nature of adverse events in hospitalized patients. Results of the Harvard Medical Practice Study II. *N Engl J Med* 1991;324:377–84.
- [3] de Vries EN, Ramrattan MA, Smorenburg SM, et al. The incidence and nature of in hospital adverse events: a systematic review. *Qual Saf Health Care* 2008;17:216–23.
- [4] Michel P, Lathelize M, Bru-Sonnet R, Domecq S, Kret M, Quenon JL. Enquête nationale sur les événements indésirables graves liés aux soins 2009 (ENEIS2): description des résultats 2009. Rapport final à la DREES. Bordeaux: Ministère du Travail, de l'Emploi et de la Santé; 2011 (<http://www.drees.sante.gouv.fr/les-evenements-indesirables-graves-associes-aux-soins-observees-dans-les-etablissements-de-sante-7390.html>) [Accessed 14 July 2012] (French).
- [5] Thomas EJ, Brennan T. Errors and adverse events in medicine: an overview. In: Vincent CA, editor. *Clinical risk management. Enhancing patient safety*. London: BMJ Publications; 2001. p. 31–44.
- [6] Vincent C, Neale G, Woloshynowych M. Adverse events in British hospitals: preliminary retrospective record review. *BMJ* 2001;322:517–9.
- [7] Leape LL. Error in medicine. *JAMA* 1994;272:1851–7.
- [8] Hollnagel E, Woods DD, Leveson N. *Resilience engineering. Concepts and precepts*. Hampshire, England: Ashgate; 2006.
- [9] Hernesniemi J, Niemelä M, Karatas A, Kivipelto L, Ishii K, Rinne J, et al. Some collected principles of microneurosurgery: simple and fast, while preserving normal anatomy: a review. *Surg Neurol* 2005;64:195–200.

- [10] Sawaya R, Hammoud M, Schoppa D, Hess K, Wu S, Shi WM, et al. Neurosurgical outcomes in a modern series of 400 craniotomies for treatment of parenchymal tumors. *Neurosurgery* 1998;42:1044–55.
- [11] Hammersly M, Atkinson P. *Ethnography: principles in practice*. 2 London: Routledge; 1995.
- [12] Chang A, Schyve PM, Croteau RJ, O'Leary DS, Loeb JM. The JCAHO patient safety event taxonomy: a standardized terminology and classification schema for near misses and adverse events. *Int J Qual Health Care* 2005;17:95–105.
- [13] Mollo V, Falzon P. Auto- and allo-confrontation as tools for reflective activities. *Appl Ergon* 2004;35:531–40.
- [14] Haynes AB, Weiser TG, Berry WR, Lipsitz SR, Breizat AH, Dellinger EP, et al. A surgical safety checklist to reduce morbidity and mortality in a global population. *N Engl J Med* 2009;360:491–9.
- [15] Helmreich RL, Schaefer HG. Team performance in the operating room. In: Bogner M, editor. *Human error in medicine*. New Jersey: LEA; 1994. p. 225–53.
- [16] Eden J, Wheatley B, McNeil B, Sox H. Institute of medicine. *Knowing what works in healthcare: a roadmap for the nation*. Washington, DC: National Academies Press; 2008 ([http://www.nap.edu/catalog.php?record\\_id=12038](http://www.nap.edu/catalog.php?record_id=12038)) [Accessed 14 July 2012].
- [17] Ulmer C, Wolman DM, Johns MME. Committee on optimizing graduate medical trainee (resident) hours and work schedule to improve patient safety. *Resident duty hours: enhancing sleep, supervision and safety*. Washington, DC: National Academy Press; 2008 (<http://psnet.ahrq.gov/resource.aspx?resourceID=8815>) [Accessed 14 July 2012].
- [18] Beard JD, Marriott J, Purdie H, Crossley J. Assessing the surgical skills of trainees in the operating theatre: a prospective observational study of the methodology. *Health Technol Assess* 2011;15:113–28 (<http://www.hta.ac.uk/fullmono/mon1501.pdf>) [Accessed 14 July 2012].
- [19] Sevdalis N, Undre S, Henry J, Sydney E, Koutantji M, Darzi A, et al. Development, initial reliability and validity testing of an observational tool for assessing technical skills of operating room nurses. *Int J Nurs Stud* 2009;46:1187–93.
- [20] Kogan JR, Holmboe ES, Hauer KE. Tools for direct observation and assessment of clinical skills of medical trainees: a systematic review. *JAMA* 2009;302:1316–26.
- [21] Leonard M, Graham S, Bonacum D. The human factor: the critical importance of effective teamwork and communication in providing safe care. *Qual Saf Health Care* 2004;13(Suppl. 1):i85–90.
- [22] Shojania KG, Duncan BW, McDonald KM, et al. Making healthcare safer: a critical analysis of patient safety practices. Evidence Report/Technology Assessment No.43 (prepared by the university of California at San Francisco – Stanford Evidence-based Practice Center under contract No.290-97-0013), AHRQ Publication No. 01-E058. Rockville, MD: Agency for Healthcare Research and Quality; 2001 (<http://www.ahrq.gov/clinic/ptsafety/>) [Accessed 14 July 2012].
- [23] Morineau T, Morandi X, Le Moëllic N, Diabira S, Riffaud L, Haegelen C, et al. Decision making during preoperative surgical planning. *Hum Factors* 2009;51:67–77.
- [24] Long S, Arora S, Moorthy K, Sevdalis N, Vincent C. Qualities and attributes of a safe practitioner: identification of safety skills in healthcare. *BMJ Qual Saf* 2011;20:483–90.
- [25] Vincent C, Moorthy K, Sarker SK, Chang A, Darzi AW. Systems approaches to surgical quality and safety: from concept to measurement. *Ann Surg* 2004;239:475–82.