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Managing unforeseen events in anesthesia: collective trade-off between "understanding" and "doing"

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Abstract. This study aims to describe how anesthesia teams handle unforeseen events that may affect the patients' health. More precisely, it investigates the mechanisms of decisions made by anesthesia teams to manage unthought-of situations, i.e. situations that have not been foreseen as "possible" ones before their occurrence. An empirical study, based on the analysis of simulated situations, was conducted in a pediatric anesthesia service of a university hospital in France. The results highlighted three ways of managing unthought-of situations (determined management, cautious management and overwhelmed management). They support the hypothesis of a collective cognitive trade-off, whereby teams would behave as virtual operators, with their own collective trade-off between "understanding" and "doing". The discussion of the results questions the assessment criteria, the safety perspectives we adopt and the possible ways to improve the management of unforeseen situations.

Keywords: patient safety, adaptive safety, simulation, team work, unexpectedness.

1. Introduction

During the past 20 years, anesthesia has become safer through important advances in pharmacology, improvements in monitoring techniques and professional commitment to safe practice standards. Although this medical specialty has to cope with a high level of uncertainty and variability related to the complexity and unpredictability of the human body, it is now considered as an ultra-safe system and a pioneer in the field of patient safety [2, 21, 44].

In order to understand how this system achieves high levels of safety despite the occurrence of disturbances, we conducted an empirical study in two French anesthesia services. The aim was to describe how anesthesia teams handle more or less predictable events that may affect the patients' health.

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2. Unforeseen events in anesthesia: "potential situations" and "unthought-of situations"

A first study was conducted to characterize the unforeseen disturbances that anesthesia teams are facing [8, 11]. Its goal was twofold: it was both to describe the variability of situations and their potential risks for patients and to decipher the "coping strategies" implemented by anesthetists to avoid the negative consequences of this variability. The results show two types of unforeseen situations endangering patients' lives:

- "potential situations". In this case, unexpectedness is not directly related to the event but to the time of occurrence of this event, that could not be determined with certainty by the practitioner before surgery.
- "unthought-of situations" for which anesthetists had not envisioned such a situation. The "unforeseen" dimension refers here to the nature of the event

and to the course of the situation itself which have not been considered by the anesthetists. The situation is not surprising because of its unexpected occurrence but because of its very nature, which has not been thought of.

These results show that the way anesthetists manage disruptions is not simply dependent on the nature of the disturbances themselves (often described by their frequences or their level of complexity), but mainly depends on the anticipation of these disruptions by operators who take care of the patient in context. In other words, having or not a priori planned and prepared the resources changes the management of disturbances. Thus, two perspectives have emerged to further investigate safety practices in anesthesia.

One possible avenue concerns the preoperative definition of an envelope of "potential situations" that could occur during the surgical intervention. In that case, the objective is to describe the way in which anesthetists anticipate "potential situations" and prepare themselves to manage them. This "anticipating factor" concerns the anesthetists' ability to "know what to expect", that is to imagine and prepare developments, threats, but also opportunities. This perspective has been developed in [10, 12].

A second avenue concerns the occurrence, during the surgical operation, of an "unthought-of situation", i.e. an event that was not envisaged before it occurrence. This second perspective aims to investigate the mechanisms of decisions made by anesthesia teams to immediately manage situations that have not been foreseen as "possible" ones. This is the subject of this paper.

3. Method

To understand how anesthesia teams manage "unthought-of situations", an empirical study was conducted in a pediatric anesthesia service of a university hospital in France. This study was based on the analysis of simulated situations.

3.1. Full-scale simulation

Our research was supported by a "high fidelity" simulator which recreates, in the form of a mannequin, the physiological and pharmacological reactions of 6-month-old infant (SimBaby^{TM}): breathing, vocalizations, palpable pulses, realistic airway that can be intubated, etc. This interactive mannequin reacts to the actions of participants thanks to a computer software programmed by the trainers [3, 29, 38].

This equipment was used to develop an experimental study. The advantage of such a study is twofold. First, it makes possible to observe the management of "unthought-of situations", situations that (thankfully) are avoided as much as possible in actual practice. On the other hand, the realization of an experimental study on simulator enables to conduct comparative analysis between teams on a single scenario and then to identify differences in how they manage critical events.

The experimental scenario is an emergency scenario due to an airway problem in the recovery room (extubation). In this scenario, designed by a senior anesthetist, the endotracheal tube, that ensures the artificial respiration of the patient, is moved "accidentally" by his father (actor). This blocks the flow of oxygen (O2) to the lungs. To solve the problem, the team must first remove the tube (recovery step) then intubate the child so to oxygenate him appropriately while ensuring protection of his airways (control step).

3.2. Participants

The simulated scenario was performed by six anesthesia teams. Because of constraints related to the use of the simulator and to the availability of physicians and nurses, these experimental sessions were conducted in the context of training sessions. Then, sampling was not fully controlled ; this generates some differences in the composition of teams (see Table 1). Anesthetists are senior residents (except one who is a young anesthetist, not a resident); nurses have different seniority in anesthesia.

Members of these teams may know each other but do not work together regularly. This reflects the usual composition of teams: in practice, teams are formed in a "more or less" opportunistic way, depending on the presence and availability of each, on the schedules of services, etc.

Table 1
Team composition

	Team 1	Team 2	Team 3	Team 4	Team 5	Team 6
Anesthetist in charge of the patient	1 anesthes-tist resident	1 anesthes-tist resident	1 anesthes-tist resident	1 anes-thestist resi-dent	1 anesthes-tist resident	1 anesthes-tist
Staff of the recovery room	2 nurses	2 nurses	2 nurses	1 nurse	2 nurses	1 nurse and 1 resident

3.3. Data analysis

Data were collected through video recordings. The analysis focused on the teams' behavior (observations of the patient's evolution and of the nurses and anesthetists's actions) and on the verbal communications exchanged within teams.

3.3.1. Analysis of the behavior of the teams

The analysis of the behavior aims to describe and compare the actions performed by each of the six teams to solve the problem and manage the risks to the patient. Systematic observations are based on the collection of 4 categories of observable events:

1. The "state of ventilation" describes the changing ways to ventilate the child (manual ventilation, automatic ventilation, natural ventilation, extubation, etc.). As the problem addressed in the scenario concerns the ventilation, this category can account for the progress of the critical situation, since its occurrence (extubation by the father) until its resolution. In particular, this category of observable events can identify the two stages in the resolution of the problem: the recovery step and the control step (see § 3.1).

2. The "composition of the team" reflects the changing composition of the team by mentioning the successive arrivals of new participants (not actors) and by indicating their function (anesthetists or nurses).

3. The "calls for help" indicate any requests for reinforcements made by the teams. A call in reinforcement corresponds to an explicit request for assistance in order to strengthen the anesthesia team facing the emergency.

4. The "saturation" is the numerical measure of the percentage of oxygen in the patient's blood. This value is recorded from the real-time monitoring of the child throughout the care. It allows one to account for changes in the health of the patient and therefore to describe the dynamic process that the team must control.

3.3.2. Analysis of the verbal communications

In addition to behavior analysis, verbal communications exchanged during the simulation sessions were transcribed from videos and analyzed. During transcription, the dynamic evolution of speech was taken into account through a timed record every 30 seconds. Transcribed communications were then categorized.

The coding scheme is based on a functional typology that accounts for different levels of representation of the situation by operators according to the aims they pursue (from a "concrete" level about objects handled, to more "abstract" levels concerning concepts, models and knowledge). The functional typology is also in line with the time scale: it takes into account the temporal variables and actions vis-à-vis the changing dynamics of the situation (since the local management of the situation in the short term, to the management of data external to the process, the consequences of which are evaluated in the longer term). This coding scheme distinguishes four exclusive classes:

1. Action-oriented communications concern the implementation of actions in progress, the establishment and adjustment of the local and temporary configuration of the system. They generally aim at carrying out an "operational synchronization", that is, at facilitating interference between operators in achieving the task in the short term (almost immediately), by dividing subtasks and resources between partners and by ensuring the rhythm of operations to be performed [15]. Example: "Go ahead", "Wait", "Give me the mask", "Where is the stethoscope?"

2. Informative communications are intended solely to share information on the evolving situation in real time: they do not have immediate consequences in terms of actions. These verbalizations are used to maintain and "update" the "common frame of reference", that is to say, to build a shared representation

of the situation within the team [23, 24]. These communications address then both the dynamic evolution of the process to manage (control and supervision of the patient and his environment) and the activity of the team itself (control and supervision of the team members' activities). Example: "How is the saturation? "; "The tension is not so bad"; "Have you prepared drugs or not? "; " I set the oxygen to 15 ".

3. Understanding-oriented communications aim to collect "initial" or "complementary" data regarding the ongoing process and to link them to the current data in order to build a more elaborate, more coherent and deeper representation of situation. The objective is here to establish the logic underpinning the evolving process and to identify the problem's causes. Thus, the influence of these data on the course of action takes place in the long term, following the reasoning carried out by team members on the basis of their general knowledge. Example: "What happened in the operating room?"; "He bled a lot? They told you or not?"; "I thought that the ventilator was not working... but now I feel that there are leaks"

3. Agreement-oriented communications allow operators to ensure that their knowledge and skills are compatible with those of their partners, and in case of conflict, they allow them to develop a shared perspective and/or a procedure for action. Examples: "We should normally observe a reflux, right ? We do not care?"; "It worked well before, so we will not turn it off to turn it on !"

4. Results: three ways of managing unthought-of situations

The results highlighted three ways of managing unthought-of situations: determined management, cautious management and overwhelmed management.

"Determined management" (2 teams) is characterized by a rapid succession of steps to recover the situation (oxygenate the patient) and to control long term risk (reintubate the patient), thereby saving the patient's life: these two steps are carried out with an interval of less than 2 minutes. In such cases, we note that anesthetists made the first valid diagnosis to explain the problem and that the teams did not call for help. Analyses of verbal exchanges show that the communications aimed at understanding the problem were mainly grouped within a short period, located when the anesthetist arrived to handle the situation.

"'Cautious management" (3 teams) also ensures the success of the mission. However, in this case, two distinct steps are observed. Initially, the situation is recovered (manual oxygenation). Then, in a second step (at least 5 minutes later), the patient is reintubated so as to avoid long term risks. During this interval of time between the two steps, the child is in a stable state: his saturation has regained a constant high level, which means he is no longer in immediate danger. In this case, we see that the problem is already partially solved by nurses when the anesthetist handled the situation. Problem understanding communications are also mainly gathered on a short period, but this time they do not occur when the anesthetist arrives, but later, once the situation is recovered and before the patient is reintubated (that means between the two resolution steps). Finally, we note that two of the three teams that have handled the situation in a "cautious way" have made "calls for help" to get the backing of senior anesthetists.

"Overwhelmed management" (1 team) is characterized by a very long time before the recovery of the situation, which leads to the failure of the takeover: the life of the patient is saved in the simulation but would not have been saved in reality. Here, the first step in recovering the problem occurs only 9 minutes 30 after the arrival of the anesthetist. The team then formulated several calls for help. We observe in this case that when the anesthetist arrived to handle the child, the diagnosis is far from being resolved. However undrstanding-oriented communications do not occur within a specific period, but are dispersed throughout the management of the situation.

5. Interpretation

The different ways of managing unthought-of situations by teams are not related to the nature of the risk for the patient (which is identical for all teams). It is related to the way in which teams manage their cognitive resources (which differs from one team to another). When the management is "determined", the problem is understood collectively, as soon as the anesthetist comes into the room, through a short period mainly devoted to verbal exchanges aimed at understanding the situation. The diagnosis is then made quickly by the physician. Thereafter, the subsequent course of the situation confirms this shared understanding of the problem. The team maintains control on the situation, without the need to set aside misunderstood details. We can hypothesize that this

control without misunderstanding explains the absence of "call for help".

In the "cautious management", the anesthetist arrives when the etiological diagnosis has already been made by the nurse (at least partially). The anesthetist trusts this "sufficiently consistent" understanding and follows his teammates to recover the situation quickly, at the cost of a limited shared-understanding of the problem. These incomplete interpretations may explain the frequent calls for help expressed by these teams. Subsequently, the delay before full recovery is not a loss of time but a necessity to develop a coherent and shared understanding within the team. In other words, the fact of "taking time" once the child is out of immediate danger is a cautious attitude vis-à-vis the management of the team's cognitive resources. Meanwhile, many communications are exchanged in order to collectively describe in detail the problem.

Without this understanding, the patient is exposed to another danger: that of loss of control on the possible evolution of the patient's health, related to accumulation of incomplete or inaccurate interpretations of the event. This trade-off between managing the immediate risk for the patient and managing the available cognitive resources to cope with potential future risks in the longer term is the result of an extremely subtle compromise. And it is the inability to resolve this trade-off between "understanding" and "doing" within the team, which leads to the loss of control of the process [1, 25]. This is what we observed in the "overwhelmed" management: whatever the possible causes of this failure, the fact is that it is correlated with a lack of management of cognitive resources within the team. In particular there is no period dedicated to the understanding of the problem: communications to build a deeper representation of the problem are miscellaneous and dispersed throughout the care.

These results support the hypothesis of a collective cognitive trade-off, whereby teams would behave as virtual operators, with their own collective trade-off between "understanding" and "doing" [31-33].

6. Discussion

6.1. Better way(s) to manage unthought-of situations: two views on safety

It seems obvious that the management called "overwhelmed" is not satisfactory in terms of system safety: such care does not guarantee the survival of the patient. And the team does not control the situation for a very long time (about 9 minutes 30).

Managements characterized as "determined" and "cautious" have, for their part, saved the child. However, they do not necessarily correspond to the idea that one may have about an optimal risk management for the patient. The question raised is then: what is "an optimal management" of unexpected risky situations? In other words, can we identify *a priori* the characteristics of a good management of unthought-of events? To answer this question, two views are possible.

6.1.1. Safety

The first view is that of the traditional approach (called a safety 1). According to this approach, an optimal risk management is a management where "nothing goes wrong " or "can go wrong" [26, 27]. It is then necessary to find the causes of "what goes wrong" in order to prevent it from happening. Studies and research are intended to identify these causes and to clarify their contribution to adverse events. Typical causes (like errors, long delays, no call for help, lack of leadership, etc.) have been identified, especially in anesthesia risk management [28, 43]. These causes must be eliminated or weakened. And the performance of risks management can be assessed by counting these causes.

Under this approach, the "determined" management is the most compliant with safety 1 criteria: these teams quickly mastered the situation through a fast reintubation and without a period of "latency", they are controlled by an anesthetist "leader" who verbalizes the etiological diagnosis shortly after his arrival. One can simply blame these two teams for not having called for a senior in reinforcement, as it is advised to do in critical situations. Conversely, "cautious" management does not comply with safety 1 criteria: long lead times before the action of reintubation are observed, communications to analyze and understand the process are more numerous and longer and this can be interpreted as a waste of time, the anesthetist communicates the diagnosis very late, etc. However, the good point in most of these "cautious teams" is that they call for reinforcements. Thus, under this approach (safety 1), a "determined" management is a safer management of unforeseen situations. All teams should therefore strive for such management.

6.1.2. Safety 2

The second view (safety 2) assumes that "things that go right" and "things that go wrong" occur for the same reasons [27]. Indeed, in the real world complexity, individuals and organizations must always adjust their performance to the current conditions. As resources (in particular time) are finite, it is inevitable that such adjustments are approximate and that imperfections and defaults may occur [1, 14, 17, 35, 39]. As a consequence, there are no special causes or 'mechanisms' for things that go wrong and other causes or 'mechanisms' for things that go right : the both happen for the same reasons.

Thus, in this perspective, the shortcomings and imperfections identified are not simply regarded as potential causes of accidents. They are above all the results of the trade-of made by the teams to adapt their actions to the characteristics of situations and to keep sufficient control on the process, including the long term control. For example, "calling for help" is certainly favorable to the immediate management of the problem. But "calling for help" is also costly vis-à-vis the organizational constraints [8]. Calling for reinforcements systematically, even if it is not "really necessary" may even be harmful in the long term (for the risk management of future patients or for patients from other services). Similarly "taking time" once the process is partially mastered certainly increases the short-term risks for the patient (because it increases the risk of spasms). But "taking time" is also a way to build a deeper shared representation, in favor of a sustainable control of the patient-process: if a new unexpected event happens, the team will be better able to cope.

Then, according to Safety 2, the performance of risks management can not be assessed by counting causes as imperfections or shortcomings. The performance lies in the ability of teams to make trade-off decisions, by adjusting themselves to the characteristics of situations (that is to say not only to patient characteristics but also to the characteristics of the team). This means being able to accept defects and approximations in order to keep control on the situation, even in the long term.

This time, the "optimal risk management" does not correspond to the management in keeping with the safety 1 criteria (speed, call for help, leadership, etc.). The "optimal management" is here the one that allows the system to achieve its goals (preserve the patient's health) while remaining within "acceptable" safety margins (and not "ideal" or "perfect" boundaries). So, in this view, the "determined" and "cautious" managements are both effective: in these five teams, the act of recovery is carried out within 2 minutes after the arrival of the anesthetist. This ensures a quickly restoration of the child's health. And, in parallel, these five teams develop a shared representation that permits them to maintain control and to handle potential new contingencies.

6.2. How to improve the management of unthought-of situation?

With a "safety 1" perspective, improving risk management relies on a normative approach (or a rule-based approach [20]), which consists essentially in dictating rules of conduct. These recommendations guide in particular operators on how they should communicate and mobilize resources to deal with such emergencies (material, human, organizational). These include, for example, stipulating the teams to "call for help" in case of emergency.

With a "safety 2" view, the improvement of risk management is based on an adaptive approach (adaptive safety), which is helping operators to make the best trade-of decisions given the complexity of real situations. For example, this is to assist teams in assessing their own mastery of the situation, so that they call for help if (and only if) the situation escape beyond their control.

Our view is that these two approaches (normative and adaptive) are not basically incompatible. To improve the management of unexpected situations, one can certainly encourage operators to adopt behaviors identified *a priori* as safe one (eg "it is recommended to call for help"); while recognizing that it is unrealistic to attempt to prescribe the right decisions to take in each situation ("In such a case, such a team should call for help"). Then, the recommendations should not focus on the decisions in themselves, but should focus on:

- the conditions that enable one to make the appropriate decisions, by ensuring that the organization is really favorable to their implementation. For our example, these means recognizing and facilitating the unofficial organizational strategies that underlie the mutual-aid networks [7, 9].
- the conditions for learning to make good decisions. This means facilitating the development of the teams' skills on their own skills and resources and on their management (meta-knowledge). It may be, in our example, to conduct training based on real cases "of

calls for help", provided that these training are favorable to reflective practice [34, 41, 42].

6.3. Limitations and perspectives of the study

These results have limitations that require further work. First, these studies are not conducted in real situations, but in simulated ones. The development of current technology orients research and training to the idea that it is possible to faithfully reproduce the work situations. According to this view (called “figurative view”), simulations are designed as “exact copies” of reference situations and the simulated situations are perceived as “mirrors of reality”. However, we cannot forget that the simulations are specific situations which will never replace reality: "doing as if” is not "doing"[18]. The large literature on the use of such simulators discusses the validity of the results they provide[6, 13, 30, 36, 40]. This literature argues the need to overcome “figurative” approaches: the key is not to try to faithfully reproduce reality but rather to identify the conditions of the context to translate in the simulated situation according to the objectives of the research [4, 5, 36, 37]. One may regret that the simulation sessions we observed were designed from this figurative approach.

Moreover, these results are part of a clinical perspective since they come from in-depth study of some singular cases [30]. One of the criticisms often addressed to this approach is that it does not support the generalization of results[16, 19]. But dealing with singular cases, in practice as in research, does not mean that generalization is impossible. To achieve such a repetition of cases, it is necessary to use a trick: the use of colleagues’work [19]. In other words, the different interventions and research conducted may constitute “a collective practice of replication, even if they are not made on a rational planning but rather developed throughout the circumstances" [22]. Further researches are then necessary to extend data collection to other hospitals (and, more generally, to other work situations) in order to assess the validity of this model.

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