Abstract: Whilst anesthetic incidents due to problems with the delivery of medical gases to a surgical unit are exceptional, their consequences are potentially drastic. With the growing of modern hospitals, every anesthetist may one day find himself confronted with such events, which are new to him, partly because they are infrequent, but mainly because they are due to causes outside his immediate environment. A simple mistake in the labelling and identification of medical gas lines resulted in a cross-connection of the oxygen and air, causing perioperative hypoxemia following the administration of a mixture poor in oxygen. The questions of training, responsibility and procedures in regard to these types of incidents are discussed below.

Key words: Anesthesia; anesthetics; inhalation / administration & dosage; gas delivery; inhalation / poisoning; equipment failure; intraoperative complications.

Introduction

Safety in anesthesia has made great strides over the past twenty years with the advent of reliable monitoring instruments and the use of high-tech equipment compliant with rigorous European standards. The many advances made have extended surgical possibilities, notably operations on increasingly fragile patients, on the one hand; and proportionally have meant fewer anesthetic incidents, and a definite decrease in peri-operative mortality (3, 8).

The operating room environment is a place in which the anesthetist feels very much at ease, thanks to first-class training including automatic control systems, strict procedures and decision trees. He is perfectly equipped to deal with the majority of incidents that might occur during an operation. However, a malfunction occurring in or external to his immediate environment places him in very rarely encountered situation. His clinical judgment and experience in such cases are both vital assets in identifying and understanding the precise nature of the incident and sometimes lead him to question the relevance of the data from his monitoring instruments: artefacts or effective reflections of a reality whose origin is so improbable he scarcely suspects it?

Case Report

The increase in hospital activities was followed by an increase in hospital area, with the creation of five additional operating rooms in a whole new wing of the surgical unit. The old surgical unit, which is still in use with four remaining rooms, is connected to the new area by a recovery room common to both entities. For a while, each wing of the operating theatre was supplied in medical gas by its own gas supply centre, the old one and a modern one. A few months after the inauguration of the new wing of the surgical unit, the connection of the supply of medical fluids from the new, modern gas supply centre to the old surgical unit was completed, bypassing definitively the old supply centre.

The head of the anesthetics department was informed several days beforehand of the work to be carried out to enable him to arrange the timetable best suited to surgical activities, because while the works were going on, the supply of medical fluids to the old surgical unit had to be interrupted in order to enable the old installations and pipes to be connected to the supply system and pressure reducing unit and also the emergency rack in the new surgical unit. In anticipation of the construction of the new surgical unit, the four new oxygen, 5-bar compressed air, nitrous oxide and carbon dioxide lines had been installed between the two wings, and the ends of these lines had already been fitted with valves close to the old supply plants.

Thus the work consisted in connecting the new valve connections to the old lines and then closing
The patient's hypoxemia with a 21% FiO2 level did not reverse the engineering work done the previous evening. The tube and immediately a link was established with ventilation from the respirator on the endotracheal oxygen. Saturation increased to 94% with manual mivacurium 13 mg, the patient rapidly presented progressive desaturation to a saturation level of 93%. The anesthetist thus immediately stopped the procedure, even before being informed that a similar incident had just occurred in the first operating room.

As soon as the work started, the duty anesthetist realised that the oxygen supply to the recovery room was not getting through. He immediately contacted the technical manager assisting with the works, who in turn found that the supply to the recovery room was not reliant on the new block, contrary to what he had thought. The patients were safely evacuated from the recovery room to a preparation room in the new surgical unit, where there was no gas supply problem. After about 90 minutes' work, the head of the anesthetics department was informed that the supply had been reconnected to the old block, that the line had been bled and the pressures checked. Accordingly, permission was given to use the old block again should a night-time emergency arise and for the operations scheduled for the next morning.

In practice, no emergency work was required during the night, and two operating schedules were arranged for the following day in two of the four rooms in the old surgical unit.

In the first operating room, an ASA I female patient aged 23 was given a general anesthetic for laparoscopic tubal ligation. Following the usual monitoring – ECG, NIBP, oxygen saturation and peripheral venous access – the oxygen mask was placed over the patient’s face and standard anesthesia was induced intravenously with 4 ml of 2% lidocaine, sufentanil 75 mg, propofol 310 mg and mivacurium 13 mg. The patient gradually presented hypoxemia with an oxygen saturation level of 87%. She was immediately intubated and it soon became clear that she was not receiving any pure oxygen. Saturation increased to 94% with manual ventilation from the respirator on the endotracheal tube and immediately a link was established with the engineering work done the previous evening. The patient’s hypoxemia with a 21% FiO2 level displayed by the gas analyzer in both the respirator (Excel 210 S.E. Ohmeda 7100 Smart Vent) and the Datex AS3 monitor, and the engineering work done the previous evening pointed to a technical error in the gas supply, despite the entirely normal pressure gauges for the oxygen, nitrous oxide and compressed air in the respirator. The portable oxygen bottle was brought in immediately, and the patient was transferred directly to the new surgical unit where the scheduled operation was performed with no further complications and no repercussions.

At the same time, three operating rooms away, a six-year-old child was anesthetised for a circumcision. The anesthetic method consisted of inhalatory induction with a Mapelson D circuit connected directly to the fresh gas outlet (thus short-circuiting the respirator’s gas analyzer). With this method, for children of this age the anesthetist usually administers a mixture of 50% oxygen and 50% nitrous oxide before adding increasing doses of halogenated agents.

After taking a few deep breaths of the 50% oxygen and nitrous oxide mixture, the young patient rapidly presented progressive desaturation to a saturation level of 93%. The anesthetist thus immediately stopped the procedure, even before being informed that a similar incident had just occurred in the first operating room.

**Discussion**

The reports of cases concerning problems with the delivery of medical gases are rare, anecdotal and somewhat old, especially during the period in which monitoring devices were still not standard or available in every operating room. More recently, a Japanese case report presented an incident in the ceiling column of a new operating room which occurred six months after the inauguration of two new operating rooms. The defective column of a protoxide pipe had gradually closed the O2 delivery pipe valve. The anesthetist had observed that no O2 was being delivered to the respirator when checking his equipment prior to the arrival of any patient (11). And cases of hypoxemia due to a disturbance in the oxygen/nitrogen protoxide mixture are rare. They are usually due to technical problems with the mixing valves, or to human error; or possibly sabotage, as certain civil parties believed in the case of the sensational trial surrounding “the Poitiers Affair” in 1984. It was suspected that the nitrous oxide and oxygen lines had been deliberately reversed, to explain the death of a female patient.
but this argument was not upheld by the court, which acquitted the persons accused (4).

According to Herff and co-authors, the frequency of deaths relating to the use of nitrous oxide in general anesthesia is certainly underestimated, and in a survey of the general press conducted between April 2004 and March 2006 in Germany, Switzerland and Austria, the authors found six cases in which patients died (7). In the six cases concerned, the court accused the technician responsible of cross-connecting the pipes, and at the same time proceeded against the anesthetist for not having discovered the mistake!

In our own cases, the normal procedure would appear to have been followed. In the event, it was a mistake in the labelling of the medical gases which was responsible for the incident and which led the technician to connect the oxygen from the old installation to the compressed air valve and vice versa. To correct the mistake the technician crossed the pipes over (Fig. 1). The photo shows the changeover required to correct the mistake, although the labelling had still to be changed and does not correspond to the situation prior to the incident. The technician who connected the old pipes to the new ones in the surgical unit did so conscientiously and it was the initial labelling error that caused the incident. Accordingly, the hospital’s technical manager gave permission to make the old surgical unit available again and, as a check, objectification of the work done and repressurisation of the system. At no time was an analysis made of what had actually been delivered in each circuit.

Thus clinically, the two cases of hypoxemia reported have somewhat different origins. In the first case, the hypoxemia was due to an absence of pre-oxygenation since the mixture actually administered contained nothing but air. With the pediatric patient, it was in fact the administration of a hypoxic mixture (N₂O/air!) which caused the desaturation. In both cases, it was thanks to the expertise of the anesthetists that a fatal outcome was prevented.

Subsequent to the incident, the company concerned admitted that the EC control standards had not been complied with. NF EN 737-3 European standard provides all the required procedures concerning works on medical gases installations (5). Tubes identification and non-inversion are part of the requirements. After the work, the tubes must be flushed, pressure checked and gases analysis must be performed and certified by the company and the hospital pharmacist.

The head of the anesthetics department refused to resume medical activities in the old surgical unit until certification by an approved body of the quality and conformity of the product delivered to all the outlets in the surgical unit and the recovery room had been provided and validated by letter co-signed by the hospital manager. The fluids were analysed on the day itself by the company pharmacist and a technician in charge of the quality control of these products, and surgical activities were resumed in this part of the old surgical unit the next day.

Thankfully, this type of incident is extremely rare, but it does raise a number of specific questions, primarily that of responsibility. In this regard, the hospital manager, the company that carried out the work, the hospital pharmacist responsible for supplying the drugs and for the quality of the gases
supplied, the anesthetics department in the person of its chief, as well as the anesthetist directly responsible for whatever he administers to his patient, could all be implicated and could see their liability involved at a level that only a judicial authority, should one be requested to do so, could assess. As regards the company that supplied the medical gases and carried out the works, the situation is particularly complicated since it prohibits any work on medical gas supply systems by a hospital’s internal technical departments so as to prevent incidents of this nature. In the present case, the company in question had engaged a subcontractor who, it may be assumed, was himself approved. In the end, it was due to a pipe labelling and identification error going back several months when the connections were incorrectly prepared.

The incident reported here occurred upstream from the surgical unit. The rare incidents reported in the literature usually have to do with one anesthetic device and hence a single patient (1, 6). The consequences here could have been much more serious, as the gas supplied all the operating rooms in the same wing of the surgical unit. The loss of oxygen supply to the recovery room, which the technical department thought was connected to the gas supply unit in the new block, when the works were going on, shows that plans at the disposal of the engineers can also be erroneous.

The question of the anesthetist’s reactions is also an interesting point: this type of incident is utterly disconcerting as it goes against our clinical logic and we are confronted with contradictory values. With current practices, it is difficult to ask what was actually delivered by the anesthetic machines, particularly as the pressure gauges and flow meters were working perfectly and the two anesthetic machines had been properly checked before induction of the anesthetic, in accordance with relevant standards.

The first remark, however, is that no account was taken of the oxygen analyser in the respirator which read 21%, whereas the patient had been pre-oxygenated prior to her operation with supposedly pure oxygen. External oxygen sensors (now replaced on modern machines of the same series by a fully integral system), sometimes produce artefacts and errors. Moreover, in such an exceptional situation, the first reaction was probably not to believe the only result displayed. But low O2 concentration in the fresh gas flow must be analysed “from the patient to the wall” and an error in supply also systematically suspected. It was the conjunction of several things – the hypoxemia, the two abnormal FiO2 values displayed on the two gas analysers, one in the respirator and one in the monitoring device – that enabled rapid diagnosis of the incident. As regards the other operating room, it was in fact the patient who, as a result of his hypoxemia, turned out to be the means of diagnosing the malfunction in the centralised gas supply system!

The question of the anesthetists’ experience is yet another point. Weller and colleagues observed the reactions of twenty anesthesia specialists confronted with a failure in the centralised oxygen system in anesthesia simulators (12). They observed that the clinical response consisted of immediate and appropriate care for the patients and a concern to ensure their safety. At the same time, however, of this initial, appropriate response, they observed a number of deviations from optimal management concerning the cause and management of the origin of the simulated incident. Lorraway and co-authors carried out a similar simulation among anesthetists receiving training. They concluded that the anesthetists were not familiar with the management of a medical gas supply failure. An anesthesia simulator would be an effective means of correcting this knowledge gap (9).

Lastly, current anaesthetic devices and ICU respirators include oxygen analysers, but oxygen is delivered in many places and situations without sensors, including paediatric Mapleson devices used for inductions, oxygen given in the recovery room or in the wards. Whilst technical faults and defective equipment account for only a small fraction of critical anesthetic incidents, they are associated with serious morbidity and mortality (2). And in addition to the anesthetist’s reaction, perhaps the entire hospital could be involved. Weller and co-authors report an incident concerning the centralised supply of an entire main hospital building and a secondary hospital that occurred while earthworks were being carried out (12).

Schumacher and co-authors report a massive O2 leak caused by the accidental separation due to wear and electrolytic action of a metal weld at the O2 reservoirs outside the hospital with a general pressure drop in the hospital circuits, and more particularly in the circuits in a surgical unit with thirty operating rooms, all in use at the time (10). Hence every anesthetist might do well to take a careful look at the situation in his own hospital. What procedures are in place to deal with incidents in the main supply to the hospital or to part of the hospital? Is there an O2 supply plan per bottle to ensure continuity of supply?
CONCLUSION

The organisation of modern medicine, the closure of old structures, the grouping and the amalgamation of hospitals will confront the majority of anaesthetists with the need to renovate, restructure or rebuild their surgical units. This means, if nothing else, that they must be informed of the precise nature of the works undertaken, and coordinated as regards the programme and general feasibility, and personally involved in them.

Strict observance of European standard could have permit to avoid the incidents presented here. But the procedure could be also improved by the systematic analysis of the gas supplied in presence of both the pharmacist and the head of department of anesthesia. And it’s the anesthetics department chief’s responsibility to ensure that every anesthetist perform a particular O₂ concentration check before entering a patient in the operating room after such works.

To guard against any consequences for the patient in medico-legal terms, the facts reported here fully justify the head of the department in obtaining, in the event of work on a medical gas pipe, a document from an approved body and from the hospital manager certifying that the system and the environment for which he is responsible have been fully approved and are in accordance with what he expects.

References