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WRONG GAS ("GREEN FOR DANGER")

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"Wrong gas" cases continue to occur throughout the world. We should be concerned with how and why this is so, which requires us to analyse, not only the technical causation of particular accidents but also the background of public, professional and commercial opinion and practice. There can be no clearer example of the absolutely innocent victim : that is what makes all of us feel such a peculiar degree of horror, and should induce all responsible parties to give their highest priority to defensive measures.

TWO RECENT INCIDENTS IN HONG KONG

The first was a fatal incident at Canossa Hospital in January 1989. The patient (55 years old, female and a heavy smoker) was undergoing relatively minor surgery to correct a 3-week-old foot injury, when, 10 minutes after induction of anaesthesia and while the anaesthetist's back was turned to prepare an injection, her heart suddenly stopped, she was observed to be grey and the diagnosis made was of "cardiac arrest". The nature of the gas in the pipeline had changed **during the operation** without anyone in the operating room touching any of the relevant apparatus; apparently an unprecedented event. If the cause had been correctly identified within seconds, there was a chance of the patient surviving, but otherwise not. Any criticism to be made of the actions of the surgical team must be tempered by realising both that fact and that there were several well-known causes to be considered of a sudden cardiac arrest occurring during anaesthesia : one expects anything wrong with the gas supply to be manifest at the outset.

The proximal causative event took place on the ground floor of the hospital, which has a central piped oxygen system supplied from transportable, vacuum-insulated liquid gas containers (LGC)(Other abbreviations sometimes used are VGL or DOT-4L). A new one was delivered and hooked up to the system an hour earlier, but in the meantime no gas was drawn from the system anywhere in the hospital. That container was labelled and fitted as for liquid oxygen, but in fact contained nitrogen. Mixing of gases in the pipeline was so slow as to give rise to the above definitely-established sequence of events.

The following should have prevented delivery and acceptance of the fatal container.

(a) Labels at the very top ("float cover") missing.
(b) Only two-thirds full, and therefore about 100 lbs lighter than a full container of oxygen.
(c) High pressure within the container at the time of delivery - pressure relief valve not operating correctly.

The above and the following additional features strongly indicate how the misfitting and mis-delivery occurred.

(d) Oxygen liquid inlet nozzle brand new.
(e) Stuck-on liquid oxygen label new.
(f) Liquid nitrogen within the container < 10 p.p.m. oxygen, so that the filling had been done by a skilled person.
(g) Containers of oxygen or nitrogen, filled or waiting ω be filled, stood each in a separate area at the supply company plant. Though known to the skilled hands these areas were not demarcated.
(h) Loading was done by the night-duty fork-lift driver and not by the delivery men. This special practice was tolerated to allow the lorry to leave the factory immediately after the driver and his mate arrived for duty (in time to catch the ferry), instead of bringing them in early or making some other arrangement. He picked it up from in or near the usual area for filled liquid oxygen containers.

It is beyond reasonable doubt that the fatal container had been stripped of identifying labels (except part of the original label applied by the manufacturer of the container) and then part-filled with nitrogen, at the gas company's plant though contrary to normal rules, either for test or as a mobile reservoir. The fitting of an oxygen nozzle and label can then be seen as the well-intentioned

act of someone who came across the container in an ambiguous location and with only part of a label visible to indicate its purpose (the job takes only a minute or so). The Coroner's Inquest stopped short of identifying that person, or who had earlier done the filling, but the verdict of "Death due to wrong supply of gas to hospital" and the jury's recommendations strongly implicate the quality of management at the supply company.

THE CARITAS INCIDENT

Incredibly, only 18 months later, a compressed gas cylinder from the same source came close to killing 3 patients at Caritas Hospital. Reports say that it was fitted and marked as a nitrous oxide cylinder but in fact contained carbon dioxide. The most widely-touted theory is that staff of the supply company (but presumably then in conspiracy with the hospital staff) were engaged in refilling cylinders on their own account and selling their employer's product "out of the back door". In the face of evidence as plain as a pikestaff, an adverse Coroner's verdict, successful prosecution in the magistrates courts and a formal enquiry by the governmental licensing authority (Fire Services Department), nothing effective had been done in the interval to tackle the real, basic, managerial problems.

In certain relevant areas, management performance is very different now. Not in all areas, however. Delivery of compressed gas cylinders can still be done in a hair-raising manner, with the use of a wire strop under the valve assembly to lift them (1), swinging them out at the end of the wire to their chosen landing place, trundling (even two cylinders at once) - all on a public right of way, within feet of a busy bus-route.

"GREEN FOR DANGER"(2)

None of the Caritas patients suffered lasting ill effects - pure good fortune for them and the company. In a recent British case of carbon dioxide substitution, there was permanent brain damage leading to a court award for damages of £ 1.65 million. It can happen in fiction also. Christianna Brand (2) imagines a murder done by repainting a carbon-dioxide cylinder so that it seems to be an oxygen cylinder - the pin index system of connections was unknown at the time or the plan would have failed. There are two reasons for bringing a detective novel in to this discussion. First, it is a WELL-KNOWN book, having been made into a BBC radio series and a film with no less than Alistair Sim as the star. Second, the problem of disbelief of the operating room personnel leading to failure to take the only useful steps quickly enough, is very clearly put.

Pg. 52 "I suppose you will think this is funny too - but would it be possible to have the wrong gas in a cylinder? Would it be possible to empty one and fill it with something else?" Barney, far from being amused, was shocked to the core by such a suggestion. "Good heavens, no. It would be impossible. It takes terrific pressure to fill these things; that's why they're made so strong." (Note, not impossible - very easy - for an LGC)

Pg. 53 "Besides, we were looking for accidents, not miracles; you don't expect an elephant to come out of a rabbit hole. Short of a mistake on the part of the manufacturers, which is out of the question....."

Pg. 123 "You can't alter the gas in a cylinder; so you alter the cylinder. ..... An oxygen cylinder is an oxygen cylinder; one just doesn't doubt it."

The point being made is that the nature of the work of the operating room team **precludes** attention being paid to the possibility of anything as outlandishly improbable as "wrong gas". This is shown repeatedly, by these quotations from "Green for Danger", and by the facts of various real-life cases:-

There were **three** patients at Caritas hospital : having given trouble once, the dud cylinder was used twice more. In the Canossa incident it wasn't until another anaesthetic went wrong in the adjacent operating room that anyone suspected the truth. There were **three** deaths in the "Argon case" (3). In the first known case involving LGCs (4) there were were two patients affected simultaneously : by amazing good fortune, neither died because gas kept flowing from two containers and oxygen

content never fell to zero. For yet other cases which make the same point, see notes 5-7.

Much has been done and more could be done at user level - improved training, the pin-index system, patient monitoring systems, airway oxygen monitors, etc., but from analysing the cases cited, the conclusion must be that, no matter how good the measures taken in the operating room, this is the last, desperate line of defence and inherently fragile. The major responsibility must lie elsewhere, where there is time for thought and planning. It lies with the managers and the industrial engineers.

WHAT, THEN, SHOULD BE DONE?

The first thing is to admit that problems exist. Only then can we hope to succeed in an examination of whether there are special difficulties with safety in the LGC system, or with the industry as a whole. In the face of the facts (1-7), no-one with responsibility has the right to plead ignorance, nor should we tolerate any suggestion that this is something for the industry alone.

There have been at least four incidents with wrongly filled LGCs, affecting 9 patients and killing 5 of them (3-5). Considering that only small hospitals in a few countries use the system, this is a very high rate. Probably 1 in 100,000 oxygen LGCs issued to hospitals world-wide has killed someone.

Enquiries about whether a formal safety assessment was conducted on the LGC system, before introduction to anaesthetic practice, have so far been fruitless. Perhaps it was not thought necessary. Yet they appear to lack the inherent safety features of the centralised gas supply system from a large static reservoir, and also those deliberately built in to the use of pressurised cylinders. Unlike the LGC, a static reservoir is replenished while still part-full, from a mobile tanker, and if an attempt is made to introduce the wrong gas, it will be difficult (and incomplete, and should be under the eye of hospital staff). Nevertheless, in one case the oxygen supply was diluted with nitrogen in this way and 2 patients died (6).

(i) Outlet and inlet nozzles of an LGC can be easily changed whilst it is full, and so can the labels. (ii) All nozzles screw in to **the same** basic fitting (iii) The pin index system was not used. (iv) The **complete** changeover of source of supply from one container to another takes place out of sight and without the knowledge of operating room personnel. (v) No colour-coding system is used on the container body (8). (vi) LGCs were used interchangeably for medical or industrial traffic (9).

Taking three elements together - the high recorded accident rate, lack of consideration to inherent safety defects of the system, and failure to apply standard safety measures used elsewhere in the industry - we have good reason to say that danger exists. The current practice in Hong Kong is to test each oxygen LGC individually for gas identity and purity, then seal it comprehensively before release. ONLY IF THIS PRACTICE CONTINUES SHOULD LGCs BE PERMITTED TO CONTINUE IN USE, EVEN AS A TEMPORARY EXPEDIENT.

Throughout the industry, we find that safety thinking is dominated by (i) the danger of a liquefied or a compressed gas, *per se* (ii) fire or explosion (iii) toxicity (iv) inert gases in confined spaces and (v) wrong connection. The cases discussed here demand explicit consideration of a sixth distinct source of danger - a particularly insidious and destructive one, namely, (vi) WRONG GAS (in the "right" container or pipe). Only if there is deliberate forward planning to prevent and detect occurrences of "wrong gas" have we any chance of avoiding future deaths from this cause.

Why has that planning not happened before? This can only be attributed to a management defect widespread in the industry - an ostrich-like failure to perceive what was happening and to act accordingly. Rushing about to close stable doors is not good management. Systematic appraisal, decision-making, training and enforcement are needed, combined with the capacity and the willingness to be open with one's own staff and with the world. In short, Quality Management, the adoption of management to ISO 9000, in **all** operations of the company.

CONCLUSIONS AND RECOMMENDATIONS

The transportable liquefied gas container has proved inherently unsafe as a source for hospital central oxygen supply systems. Its use should be permitted only with stringent safety precautions at least equivalent of those which now rule in Hong Kong. These should be imposed by legislation.

Countries which don't use this system yet should think twice. Colour coding, labelling and connection rules should apply to LGCs also: this may require new and special legislation. Medical gases fall within the legal definition of pharmaceutical products. Their production and supply should be governed in the same way as other medical supplies, that is, by WHO GMP standards. There is no obvious reason why they should not be subjected to both "Dangerous Goods" regulations (administered in Hong Kong by the Fire Services Department) and others administered by the Health Services Department.

Changes in the law are desirable in other areas to put pressure on companies to improve their safety. The financial penalties for gross carelessness should be enormous. The negative behaviour encouraged by present insurance law and practice should be eliminated.

Oxygen monitors should certainly be used in operating rooms, but also permanently installed on the pipeline system.

Contrary to popular and professional belief, the transmission of accident and safety information both within the compressed gas industry and with the medical sector, is extremely bad. Defensive, secretive reactions have much to do with this. Voluntary efforts should be supplemented by a formal, worldwide system.

QM to ISO 9000 should be the standard in Hong Kong. This is essential for the prosperity of the territory, quite apart from matters connected with safety.

The quasi-monopoly of the Hong Kong Oxygen and Acetylene Company Limited should cease, or the company should be subject to a stringent scheme of control as with other public service monopolies.

NOTES AND REFERENCES

1) Use of a rope sling is blacklisted in "Handbook of Compressed Gases", second edition, Van Nostrand, New York (1982), p.39. (The recommendations in this chapter are directed primarily to users, "some also" to suppliers.)

2) "Green for Danger", by Christianna Brand. First published 1945. The copy used is a 1982 Hamlyn paperback edition.

3) Noble Army Hospital, Fort McLellan, AL, U.S.A. The LGC concerned was filled with argon and the liquid argon inlet nozzle was still attached. The gas outlet nozzle was as for oxygen. See, "Newsletter for Biomedical Safety and Standards" 13(1983) 88-9. This magazine is available in Hong Kong at the E & M Services Department Library and is listed in the Hong Kong Union Catalogue of Serials, 1987.

4) Sprague & Archer, Anesthesiology 42 (1975)360-2. No further detail emerged in correspondence with Dr. Sprague. Of two "reservoirs", one had been filled with liquid nitrogen by the use of an adapter. "....the manufacturer .... is now checking the concentration in each reservoir before delivery and has taken steps to standardize liquid container fittings, labels, and colour codes in use at its plant. There is no nationwide standardization of liquid reservoir fittings or labels to which .... producers must adhere. Such standards .... would contribute to the safety of oxygen administration." (The reservoirs described thus were definitely of liquefied gas, small and transportable, though possibly of an earlier model. Why were not the recommendations adopted worldwide?) This was a Naval hospital.

5) "Newsletter of Biomedical Safety and Standards" 10(1977)75. 2 patients, 1 death.

6) Rocky Mountain News (Denver, Colorado, U.S.A.) Sept. 12, 1981. Static oxygen reservoir. 2 deaths.

7) "Wrong gas" is not due only to misfilled LGCs. A very common cause in recent years is "crossed pipes" - an interchange of oxygen and nitrous oxide supplies. See numerous cases described in the above "Newsletter ....", and medical journals. In these and other types of case it is characteristic that multiple patients are affected before the cause is found.

8) Dangerous Goods (General) Regulations, Chapter 295 of the Laws of Hong Kong, Part III, 61 and 65, require colour coding, but are not well drafted and do not deal specifically with liquefied gases for medical purposes.

9) Present practice is to distinguish medical oxygen LGCs with green sticky labels instead of red.