EXPLOSION HAZARDS IN ANAESTHESIA

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ON REVIEWING THE LITERATURE on this subject, one is impressed with the relative scarcity of deaths due to this catastrophe in anaesthesia. Dr. G. J. Thomas (1) reports that deaths due to fire and explosions in the operating room occur in approximately one in 80,000 to 100,000 anaesthetic administrations. It is probable that fires or explosions, of either major or minor proportion, occur approximately five times in 100,000 cases. Thus we see that the rates of mortality and morbidity due to explosions are low in comparison to the over-all rates in anaesthesia. However, because of the prominence such accidents are given in the lay press, and the rather unkind attitude of the courts, we must always keep them very much in mind and take every precaution to prevent further occurrences. In my own practice I have exceeded the above statistics as I have been associated with three fires or explosions. Fortunately none has been very serious or fatal.

In the past, precautionary suggestions to the hospitals and anaesthetists have been very much at variance: more humidity or less, use of conductive flooring or not, use of conductive footwear or not, use of conductive rubber tubing and connections or not. It is probable that much of this confusion has been brought about by lack of uniform standards in the manufacture of these products and therefore difficulty of interpretation of the results. In recent months some uniformity among manufacturers has been achieved and it is probable that more realistic recommendations will soon be forthcoming. Whenever safety measures are under discussion the standard reference authority is the National Fire Protective Association pamphlet, *Recommended Safe Practices* (6).

There are three factors necessary to permit a fire or explosion: (1) a combustible gas or vapour, (2) oxygen, (3) a source of ignition. It is evident that in almost every anaesthetic, with the exception of nitrous oxide, trilene combination, the first two factors are always present. We must realize that ether is just as flammable as cyclopropane, and that nitrous oxide in a mixture will not decrease the explosion hazard. In fact nitrous oxide will support a fire or explosion as it is broken down to nitrogen and oxygen.

It has been suggested that the use of flammable agents should be stopped, and in fact in some hospitals in the United States there is a ban on cyclopropane. This would apply a rather hazardous limitation on our practice, as many of our techniques depend on the use of one or more flammable agents. We feel very strongly, however, that such a regulation could apply when cautery, X-ray, etc., are to be used. John Bullough (2) in the *Lancet* suggests the use of "T" connections and a hose to draw off flammable agents to prevent dangerous accumulations of such gases or vapours in the operating room. I do not feel that this method

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would appeal to many of the anaesthetists in this country. Therefore it is to the source of ignition that we must turn to reduce this hazard. It is probable that with adequate care and education, all such sources of ignition could be eliminated or controlled to such an extent as to prevent any future fires or explosions. Thomas (1), Orr (3), Jackson (4), and Dillon (5), in recent articles, are in essential agreement as to the means of controlling or limiting all sources of ignition. The human factor is the hardest to control.

All electrical connections should be of explosion-proof type or situated at least five feet from the floor with no extension cord connections where concentrations of gas may ignite. Caution should not be used without the specific consent of the anaesthetist and then not within two feet of the patient's mouth or of the gas machine if a flammable mixture is being used. X-ray equipment must be used with extreme caution as even the latest models produce open sparks. Open flame, smoking, etc., must be absolutely prohibited near any anaesthetic location.

Static electricity is the cause of most explosions on record and is also the most difficult to control. To this end wool, silk, nylon, etc., are banned in the operating and recovery rooms, relative humidity should be between 50 and 60 per cent; and there should be a constant circulation of the air in the operating rooms. Air conditioning is helpful though not essential. There are some who argue against its use on the grounds of increased static due to removal of carbon particles from the air.

The floors in the operating and recovery rooms should be of conductive type in order to equalize charges between equipment and personnel in the rooms. Terrazzo flooring with closely spaced brass grids or one of the newer conductive composition floors are probably best. All equipment—tables, chairs, machines, etc.—should be grounded to the floor by long open-link brass or bronze chains. The longer the chains, the more contact with the floor and therefore the better the grounding. They can be fastened diagonally under the tables and stools to be out of the way. They must also be regularly cleaned of dirt and wax with brush and detergent to maintain their conductivity.

Conductive rubber should be used throughout the operating room on mattresses, pillows, tubing, bags, masks, etc., and on the anaesthetic machine. It is important to ensure that there is no insulating material, such as plastic connectors, to permit charges to develop. Conductive footwear helps to maintain an equality of potential between the personnel in the room. Moistened leather soles do a similar service. There are apparently some objections to conductive shoes because, it is stated, coatings of wax and dirt are non-conductive and render them useless. Regular cleaning would overcome this objection if it were valid.

It is important to make sure that the anaesthetic machine is well grounded to the floor by the use of chains and conductive wheels. It was previously recommended that the Horton Intercoupler be used as an extra safeguard. This device was to reduce to a minimum the danger of static spark in the area where it was most serious by equalizing the electrical potential between the patient, operating table, anaesthetic machine, and the anaesthetist. It is no longer recommended as broken wires in it are not readily noticed and thus a false sense of security often prevails. Further, the use of conductive rubber and grounding of equipment

renders its use unnecessary. One should be very careful, when working with a flammable mixture, in breaking the connections between the machine and the patient or in moving either patient or machine. The use of the flush valve or rapid flow of any gas is also hazardous as the friction may produce enough static to ignite the gases in the machine

It is reported that the low voltage of endoscopic equipment precludes the possibility of explosion. I know of two incidents which would disprove this suggestion. Grease or oil should never be used to lubricate fittings around a gas machine or cylinder, as the pressure of the enclosed gases would cause it to explode or burn. Regulators should never be used if there is any doubt as to the state of their repair. Dust should be removed from the cylinder valve opening before it is connected to the regulator by partly opening the valve for a moment.

My own experience, as mentioned above, has included three fires or explosions. One was a fire in a faulty ether machine used for tonsillectomies. Regular inspection by a qualified electrician would have prevented it. The second was an explosion during an ether anaesthetic when a laryngoscope bulb shorted in some way during intubation. No serious damage resulted, though the patient's throat was cut by the small pieces of glass. The third was the most serious. On opening a large cylinder of oxygen, there was an explosion which caused mild first degree burns on the side of the patient's face, and second degree burns to my arm. The regulator on the oxygen cylinder disappeared in a spray of molten metal on the walls of the room and the regulator on the nitrous oxide cylinder was burned beyond use. Investigations by insurance underwriters and the Fire Marshall's Department revealed no cause. In a discussion with men from the Ohio Company it was suggested that dust could collect in the older regulators and, under proper conditions, this could explode, as a result of spontaneous combustion. The newer regulators have filter screens which prevent this accumulation of dust.

SUMMARY

I have presented a résumé of the explosion hazards and some suggestions on how to circumvent this danger. I have also presented a brief report of three personal cases of fire or explosion. It is suggested that most fires or explosions are the result of carelessness or negligence on the part of operating room personnel. Thus even when all safety measures, from the physical standpoint, are practised, it is necessary to ensure that all individuals present know of and practise all the safety precautions recommended.

RÉSUMÉ

Sur 100,000 administrations d'anesthésie, il peut survenir environ cinq explosions ou cinq incendies, ce qui n'est pas considérable, mais cela devient très important si l'on considère les réactions dans les journaux et les mauvaises conséquences légales. Aujourd'hui, les mesures préventives de ces catastrophes sont mieux définies et plus uniformes qu'elles ne l'étaient autrefois et, en conséquence, nous devrions pouvoir diminuer leur pourcentage.

Pour produire un feu ou une explosion, il faut réunir trois facteurs: (1) un combustible gaz ou vapeur, (2) de l'oxygène, (3) une source d'ignition. A part

le protoxide d'azote et le mélange protoxide et trilène, tous les mélanges gazeux sont également inflammables et il faudrait éviter de les employer là où il existe un danger d'explosion.

La meilleure façon d'aborder ce problème est par le contrôle de la source d'ignition. Les connections électriques doivent être à l'épreuve des étincelles ou situées à cinq pieds du sol. En toute éventualité, l'usage du thermocautère devrait être soumis à l'approbation de l'anesthésiste. Les vêtements de nylon, de laine ou de soie devraient être exclus des salles d'opération et des salles de réveil. On recommande de maintenir dans les salles une circulation d'air constante et un taux d'humidité variant de 50 à 60 pour cent.

Les planchers des salles d'opération doivent être conducteurs soit au moyen de fils métalliques conducteurs, soit en les recouvrant d'une composition conductrice. L'équipement complet de la salle d'opération doit être pourvu d'une mise à terre au moyen d'une chaîne à mailles ouvertes en cuivre, chaîne qu'il faut nettoyer régulièrement avec une brosse et du détergent. Les membres du personnel doivent porter des chaussures conductrices de façon à égaliser le potentiel électrique entre eux-mêmes et l'équipement. Tous les joints, les tuyaux de caoutchouc, les masques, les matelas, les oreillers, les courroies, etc., doivent être de caoutchouc conducteur de façon à prévenir les différences de potentiel en électricité statique. Les connecteurs en plastique ou les champs en coton ne devraient pas être tolérés car ils interrompent la conduction.

On suggérait, autrefois, le "metteur en communication" de Horton dans le but d'égaliser le potentiel électrique entre l'anesthésiste, le malade, la table et la machine, aujourd'hui, on a discontinué de l'employer à cause de la possibilité de l'existence ignorée de fils brisés. Toutes les sources de friction—tel un courant rapide de gaz, une disconnection rapide sur une machine à anesthésie, etc.—doivent être évitées. Là où on emploie des instruments endoscopiques, il vaut mieux employer un mélange non inflammable car autrement un circuit dans l'outillage pourrait causer une explosion.

L'auteur a été témoin, au cours de ses années de pratique, de trois explosions d'abord avec de l'électricité et une machine à éther défectueuse, ensuite avec un circuit sur un laryngoscope et enfin à cause d'un amas de poussière sur un vieux régulateur d'un gros cylindre d'oxygène. Sur les régulateurs plus récents, on a placé des filtres pour prévenir l'accumulation des poussières. Heureusement, aucun de ces accidents n'a été mortel ou sérieux.

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