# Staff Meeting Bulletin
# Hospitals of the » » »
# University of Minnesota

## Anesthetic Explosions

Volume XI Friday, June 7, 1940 Number 30

STAFF MEETING BULLETIN
HOSPITALS OF THE . . .
UNIVERSITY OF MINNESOTA

Volume XI | Friday, June 7, 1940 | Number 30

INDEX



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William A. O'Brien, M.D.

## I. LAST WEEK

Date: May 31, 1940

Place: Recreation Room,
Powell Hall

Time: 12:15 to 1:15 P.M.

Program: Movie: "Book Worm"

Laboratory Aids in
Diseases of Pancreas
Wm. O. Clarke

Discussion
G. T. Evans
C. J. Watson
O. H. Wangensteen

Present: 114

Gertrude Gunn
Record Librarian

- - -

## II. MOVIE

Title: "Farmyard Symphony"

A Walt Disney Short

Released by: R-K-O.

- - -

## III. ANNOUNCEMENTS

### CENTER FOR CONTINUATION STUDY

Course in Gynecological Tumors -
June 6, 7, 8, 1940.

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Orientation . . . Mr. Nolte, Dr. O'Brien
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Cancer as seen in
Minnesota Study. . . . . . Dr. O'Brien
Problems of Lay Education
in Cancer . . . . . . . . . . . Mr. Hill
Histological Diagnosis
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Newer Information as
to Tumor Etiology . . . . . . . Dr. Bell
Some Aspects of the Biology
of Radiation Absorption . . Dr. Hartley
General Principles of
Radiation Therapy . . . . . Dr. McKelvey
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Continuation Study Lounge.
Surgical Relief of Pain . . . Dr. Peyton
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Carcinoma of Vulva . . . . . Dr. McLennan
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Surface Irradiation and
Their Application to
Gynecological Tumors . . . Dr. Stenstrom
Chorionepithelioma . . . . Dr. McKelvey
Gynecological Sarcomas . . Dr. McLennan
Group Discussions . . . . . . . . Staff

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Unless otherwise indicated, or later announced, all sessions will be in the Library of the Center for Continuation Study.

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## IV. ANESTHETIC EXPLOSIONS

Ralph T. Knight
Jane Musselman

### Case Report

The following accident occurred on January 11, 1940 at 5:00 P.M. The outdoor temperature was 22° above zero. The operating room temperature was about 80°, with 12% relative humidity as shown by a Tycos humidiguide strapped to the oxygen cylinder on the anesthesia machine. The door of the operating room was open into the corridor. A slow, forced exhaust system was drawing air out of the room through grills under the balcony.

The patient was a male, aged 30 years, height 6'1", weight 190. He had a 10-year history of tuberculosis involving the left lung. The operation was a third stage thoracoplasty. The anesthesia apparatus was a Model T Heidbrink, equipped with the latest model Heidbrink double-chamber carbon dioxide absorber, designed in such a way that the exhaled gases are directed all the way through the soda lime into the re-breathing bag before they can be returned to the patient. The cyclopropane cylinder was attached to the machine by an additional bracket and was served by a kinet-o-meter needle valve with dry float gauge. The flow tubing from this valve led to a sleeve in the inspiration tube between the absorber and the patient.

The anesthesia procedure was as follows: Anesthesia was induced with cyclopropane, and a #7 (15 mm.) intratracheal tube of the Magill type was inserted through the mouth. This was connected to the respiratory tubing by means of an Adams' connector set. The tube was not gas-tight in the trachea. Therefore the pharynx was packed with a moist gauze strip with satisfactory results.

At intervals throughout the anesthesia the cap on the Adams connector was removed, and an ordinary 16 French urethral catheter was passed through the tracheal tube for aspiration of secretion. The suction was by means of a water faucet type of sucker. The blood pressure varied from 114/66 to 124/80, and 110/70, but during the last 5 minutes of the operation it rapidly fell to 80/50. Blood transfusion had been started and the patient was held on the table until the remainder of the 500 cc. could be run in. It is our custom to bronchoscope these patients at the end of operation to remove all secretion from the bronchial tree. The patient was therefore held under anesthesia for this purpose while the transfusion was completed, and the bronchoscopy was deferred during this time. While waiting the gauze pack was removed, and all mucus and saliva was suctioned out of the nose and throat. This allowed some leakage of gas and anesthesia decreased. In order to have the patient ready for bronchoscopy the nurse-anesthetist added to the mixture a flow of about 300 cc. per minute of cyclopropane and some ether vapor for 3 minutes, and then shut off both. As the anesthesia was still a little light she attempted to increase it by hand pressure upon the bag during each inspiration. With the third or fourth inspiration under pressure the explosion occurred. Only the anesthetist, the patient and one other person were in the room when the explosion occurred. The third person was an instrument nurse who was setting the instrument table for the next case and was 8 feet from the nearest of the patient group. She had turned around just in time to see the bag burst with a blue haze. I was standing 20 feet away through the doorway within sight. On hearing the report I wheeled around, saw the blue haze in the room and saw the anesthetist rising with her hands over her face. I was the first to reach the patient, and found his color excellent, his pulse full, strong and regular, with a rate of approximately 90. Artificial respiration was started at once, another machine was wheeled in quickly from the corridor, attached to the intratracheal tube, and an attempt was immediately begun to introduce oxygen by manual bag pressure. It was impossible to expand the chest at all. About 1/2 cupful of blood was quickly aspirated through the tracheal tube, and oxygen inflation was again attempted unsuccessfully. Cyanosis came on and deepened, and the pulse gradually failed.

Autopsy revealed no hemothorax, no pneumothorax, and no traumatic changes in the left lung which was the seat of the active tuberculosis and which had been treated by 3 stages of thoracoplasty. With the exception of 2 small areas in the periphery, the right lung was entirely filled with clotted blood.

The following damage was immediately apparent upon looking at the anesthesia machine after the accident: The expiratory tube was torn from the tracheal tube connection and also from the soda lime cannister and lay riddled upon the floor. The inspiratory tubing was torn from the tracheal tube connection and was otherwise torn, but still hung from the soda lime cannister. The rebreathing bag was torn from its sleeve on the bottom of the soda lime cannister, and lay riddled upon the floor. Both valves of the soda lime cannister were badly damaged, and the cannister and cover were partly pried apart, bending the long set screw and clasp. The glass observation disc over the inspiratory valve was cleanly blown out, and we never found a single piece of it. The valve on the top of the ether jar was closed and no damage was done to this glass receptacle. The small flow tube from the cyclopropane cylinder to the sleeve in the inspiratory tubing was not damaged. There was no apparent damage to any part of the machine behind the carbon dioxide absorber.

The machine was later dismantled and examined carefully part by part. Upon taking apart the carbon dioxide absorber, the following conditions were found: The inhaler flutter valve was crumpled by the explosion and folded around the valve stop which was above it. The exhaler flutter valve was crumpled by the force of the explosion and dished against its stop indicating that the initial force of the explosion had reached this valve from the direction of the patient. The partition between the two sides of the absorber cannister was bent toward chamber No. 2 and away from chamber No. 1. The record pasted on the outside of the absorber cannister, which we habitually keep as a record of the length of time each cannister full of soda lime has been used, showed several hours of use of No.1 and no use of chamber No. 2. This indicated to us that chamber No. 1 was in the respiratory circuit at the time of the explosion. The appearance of the inside of the inhaler valve cup showed that a white soda lime dust had been sprayed through this valve in a fan-like manner. This indicated that the force of the explosion passed through the soda lime before passing through this valve.

The oxygen gauge and valve on the machine were inspected and their accuracy was tested with a large test flow meter. Both of these valves and gauges were found to be uninjured and in working order. They were not found to be entirely accurate in their measurements, both allowing a somewhat greater flow of gas than was indicated by their meters. This, however, was within limits of mechanical error and has no bearing on the cause of the explosion. The fact that these valves and gauges were uninjured and in working order indicated that the explosion had neither originated in their areas, nor had the force of the explosion extended backward to them from the region of the absorber. When these valves and gauges were taken apart, they were found to be dry and free from contaminating grease.

There is one point of uncertainty in our knowledge of exactly what happened at the time of the explosion. The nurse anesthetist states that she was pressing upon the bag when the explosion occurred. In our experience occasionally this has caused the metal sleeve to which the bag is attached to become disconnected from the absorber. Explosions have sometimes been attributed to a discharge of static at the moment of separation of this sleeve from the absorber. The nurse anesthetist states that she does not believe that this sleeve loosened at the time. I was the first to reach the machine after the explosion. In my haste to attach new tubing and a new bag from another machine in an attempt to get oxygen running to the patient, I cannot recall whether or not this sleeve was detached from the absorber. However, all of the findings enumerated above in examination of the machine indicate that the explosion originated not at this point, but on the side of the absorber toward the patient.

In considering the details of the conditions existing about the operating table, the anesthetist and the machine, two of these details have seemed to us to have possible significance: First, the anesthetist was wearing rubber gloves. Because of the rather abundant and positive sputum which is exhibited by most of the tuberculosis patients, including this one, who come up for thoracoplasty, it has been the custom for the anesthetist to put a gown over the uniform and to wear rubber gloves. It occurred to us that an especially hazardous potential might have been created by the handling of the tubing and bag with the gloves. Second, we know that a certain amount of gas was escaping around the intratracheal tube since the pharyngeal pack had been removed. A woolen blanket had been placed over the patient up to his neck a few minutes before the explosion. It seems that the value of warmth in the treatment of shock had been recently re-emphasized and woolen blankets had been brought back into the operating room on some occasions without realization that they had previously been banned as a prophylactic against static. When this blanket was lifted a few minutes after the explosion it crackled with sparks. This blanket was not being handled or moved at the time of the explosion except by the patient's respiratory movements, but it cannot be ignored as a possible source of sparks.

The anesthetist was leaning over the absorber squeezing the gas bag. She received many small scratches about the face, and several very small particles of glass entered her eyes but they were removed without damage.

R.T.K.

The hazard of death from an anesthetic explosion is calculated to be one in approximately every one hundred thousand anesthetic administrations. This makes death from explosion statistically the least of the hazards of anesthesia. However, explosion for a large part is a preventable hazard so that no anesthetic explosion is to be condoned. Emotionally, it is a very important hazard for the entire operating room personnel, and primarily for the anesthetist, who must constantly be aware of the fact that he is handling high explosive material.

With the exception of nitrous oxide and chloroform, all inhalation anesthetics in use today are inflammable or explosive within a range of concentrations using either oxygen or air as a diluent. The lower and upper limits of inflammability have been found to vary somewhat according to test conditions. In clinical anesthesia this is of little practical importance since all anesthetic administrations employ mixtures within the explosive range sometime during the course of the administration or recovery. The accompanying table of explosive properties of anesthetic gases is taken from the investigation of the United States Bureau of Mines (Table I).

The explosive concentration limits of ether in both oxygen and air, compared to cyclopropane and ethylene are to be noted. In both instances the ether concentration is below the explosive concentration for ethylene and cyclopropane.

Extensive research on the explosiveness of several gases in combination is now in progress with few figures available at present. Finch has stated that the addition of nitrous oxide to an ether oxygen mixture increases its explosibility. Blomfield found ignition points to fall as pressure is raised above normal and found that in a nitrous oxide atmosphere ignition points are lower than in an oxygen atmosphere.

A table prepared by Livingstone, Shank, and Engel, summarizing the fires and explosions reported in the literature up to 1939, is here included with a case report of an explosion with each agent. (Table II.) Table III is a summary constructed in response to a questionnaire sent to anesthetists by the Committee on Fire and Explosion of the American Society of Anesthetists and a review of the literature.

Table I

Explosive Properties of Anesthetics*

| Anesthetic | Formula | Density Air = 1 | Limits of Inflammability: In Air, Lower | Limits of Inflammability: In Air, Upper | Limits of Inflammability: In Oxygen, Lower | Limits of Inflammability: In Oxygen, Upper | Minimum Ignition Temperatures 0°C: In Air | Minimum Ignition Temperatures 0°C: In Oxygen | Cu.Ft. of Atmosphere Rendered Explosive by 1 lb. anesthetic at 60°F and 1 atmosphere pressure |
|---|---|---|---|---|---|---|---|---|---|
| Ethylene | $C_2H_4$ | 0.97 | 2.75 | 28.6 | 2.90 | 79.9 | 490 | 485 | 492 |
| Propylene | $C_3H_6$ | 1.45 | 2.00 | 11.1 | 2.10 | 52.8 | 455 | - | 451 |
| Cyclopropane | $C_3H_6$ | 1.45 | 2.40 | 10.3 | 2.45 | 63.1 | 490 | - | 376 |
| Nitrous oxide | $N_2O$ | 1.52 | | Not inflammable. | | | | | |
| Ethyl Chloride | $C_2H_5Cl$ | 2.23 | 4.00 | 14.8 | | | 517 | 468 | 147 |
| Ethyl-divinyl | $(C_2H_3)_2O$ | 2.42 | 1.70 | 27.0 | 1.85 | 85.5 | 399 | 327 | 319 |
| Ether-diethyl | $(C_2H_5)_2O$ | 2.56 | 1.85 | 36.5 | 2.10 | 82.0 | 304 | 182 | 277 |
| Chloroform | $CHCl_3$ | 4.12 | | Not inflammable | | | | | |
| Helium | He | 0.13 | | Not inflammable | | | | | |
| Carbon Dioxide | $CO_2$ | 1.53 | | Not inflammable | | | | | |

*Jones: Bureau of Mines, Report of Investigation No. 3443. April 1939.

## Table II

### Fires and Explosions*

| Agent | Number | Cause | | Injuries | Deaths |
|---|---|---|---|---|---|
| Ether or | | Static | 8 | 12+ | 8 |
| Ether Oxygen | 34 | Cautery | 7 | | |
| | | Spark from meter | 5 | | |
| | | Pencil lamp | 4 | | |
| | | Not stated | 3 | | |
| | | Open flame | 1 | | |
| | | Electric bulb | 1 | | |
| | | Turning on light | 1 | | |
| | | Diathermy | 1 | | |
| | | Fulguration | 1 | | |
| | | Spark from lamp socket | 1 | | |
| | | Warm air from dental syringe | 1 | | |
| Nitrous oxide | 14 | Static | 7 | 14 | 4 |
| Oxygen | | Cautery | 2 | | |
| Ether | | Bronchoscope | 1 | | |
| | | Diathermy | 1 | | |
| | | Fluoroscopy | 1 | | |
| | | Electric plug removed from socket | 1 | | |
| | | Spirit lamp | 1 | | |

*Livingstone, H., Shank, I., Engel, R., Fire and Explosion Hazard with Anesthetic Agents. Hospitals 13: 36-47, July 1939.

| Agent | Number | Cause | | Injuries | Deaths |
|---|---|---|---|---|---|
| Ethylene | | Static | 8 | | |
| Oxygen | 14 | Cautery | 2 | 8 | 4 |
| | | Open flame | 2 | | |
| | | High $O_2$ % | 2 | | |
| Cyclopropane | | Static | 7 | | |
| Oxygen | 11 | Laryngoscope | 1 | 1 | 5 |
| | | Cautery | 1 | | |
| | | Unstated | 2 | | |
| Ethylene | | Open flame | 1 | | |
| Acetylene | 1 | Not stated | 4 | 1 | 1 |
| | | Oil | 3 | | |
| Acetylene Oxygen | 9 | Cautery | 1 | | |
| | | Static | 1 | | |
| Oxygen | 9 | Oil | 2 | 9 | 1 |
| | | Static | 1 | | |
| | | Open flame | 1 | | |
| | | Unknown | 5 | | |

Table II (Continued)

| Agent | Number | Cause | | Injuries | Deaths |
|---|---|---|---|---|---|
| Socalled "Nitrous Oxide Oxygen" | 3 | Cautery | 1 | 2 | 1 |
| | | Bronchoscopy | 2 | | |
| Ethylchloride | 2 | Cautery | 1 | 0 | 0 |
| | | X-ray | 1 | | |
| Nitrous Oxide Ethylene | 2 | Static | 1 | 1 | 2 |
| | | Diathermy | 1 | | |
| Miscellaneous | | | | | |
| Oxygen Nitrous Oxide Ether | 1 | Open flame | 1 | | |
| Cyclopropane | 1 | Static | 1 | | |
| Unstated | 1 | Moving cylinder | 1 | | |
| Total | 104 | | | 48 | 27 |
| University Hospitals 1940 (cyclopropane) | | | | 1 | 1 |
| Sloan Hospital 1940 (cyclopropane) | | | | | 1 |
| | | | | 49 | 29 |

Table III

Summary Anesthetic Explosions and Fires*

| Cause | Number | Anesthetic Agent | Injury | Deaths |
|---|---|---|---|---|
| Suction Pressure Machine | 39 | 38 ether - air | 4 | 1 |
| Spark in switch or motor of machines | | 1 cyclopropane - $O_2$ | 0 | 0 |
| X-ray | 8 | 4 ether - air | 0 | 0 |
| Fluoroscopes | | 3 ether, $N_2O$-$O_2$ | 2 | 1 |
| | | 1 cyclopropane $O_2$ | 1 | 0 |
| High frequency machines | 13 | 2 ether - air | 0 | 0 |
| | | 2 ether - $O_2$ | several | 1 |
| | | 4 ether - $N_2O$-$O_2$ | 3 | 2 |
| | | 1 ethylene - $O_2$ | 0 | 1 |
| | | 3 cyclopropane - $O_2$ | 0 | 2 |
| | | 1 unknown agent with $N_2O$-$O_2$ | 1 | 0 |
| Actual cautery | 22 | 6 ether - air | 2 | 1 |
| | | 3 ether - $O_2$ | 0 | 1 |
| | | 1 cyclopropane | 0 | 0 |
| | | 1 ethyl chloride - air | 0 | 0 |
| | | 6 ether - $N_2O$-$O_2$ | 1 | 0 |
| | | 4 ethylene $O_2$ | 3 | 2 |
| | | 1 acetylene - $O_2$ | 1 | 0 |

*Greene, B. A., Report of The Committee of Fires and Explosions - Sub-committee of Research Committee, Transaction of the American Society of Anesthetists, Inc., Vol. 4, pp. 42-46, May 1939.

Table III (Cont.)

| Cause | Number | Anesthetic Agent | Injury | Deaths |
|---|---|---|---|---|
| Electrostatic Sparks | 66 | 5 ether-air | 0 | 0 |
| | | 6 ether - $O_2$ | 4 | 0 |
| | | 15 ether $N_2O$-$O_2$ | 4 | 2 |
| | | 1 ethylene - air | 0 | 0 |
| | | 1 ethylene - $N_2O$ | 1 | 1 |
| | | 24 ethylene - $O_2$ | 8 | 4 |
| | | 3 - ether | | |
| | | 14 cyclopropane | 5 | 6 |
| Cigarettes or matches | 5 | 3 $O_2$ therapy equipment | 3 | 2 |
| | | 1 ether - air | 0 | 0 |
| | | 1 ethylene - acetylene $O_2$ | 0 | 0 |
| Open flame | 7 | 1 ether - air | 0 | 0 |
| | | 1 ether - $O_2$ | 0 | 1 |
| | | 3 ether $N_2O$-$O_2$ | 0 | 0 |
| | | 1 ethylene - $O_2$ | 2 | 0 |
| | | unstated agent | 0 | 1 |

| Cause | Number | Anesthetic Agent | Injury | Deaths |
|---|---|---|---|---|
| Endoscopic instruments | 4 | 1 ether - air | 1 | 0 |
| | | 1 ether - air - $O_2$ | 1 | 1 |
| | | 1 ethylene $O_2$ | not stated | |
| | | 1 cyclopropane | 0 | 0 |
| Pressure explosions due to sudden release of tank pressure into anesthetic machines without safety valves | 6 | 4 $O_2$ | 1 | 0 |
| | | 1 carbogen | 1 | 0 |
| | | 1 $N_2O$ | 0 | 0 |
| Oxygen - oil combustion | 2 | 1 broken gauge with oil in line | 1 | 0 |
| | | 1 oil containing leather washer | 0 | 0 |
| Faulty electrical wall plug | 1 | ether - $N_2O$-$O_2$ | 2 | 0 |

Table III (Cont.)

| Cause | Number | Anesthetic Agent | Injury | Deaths |
|---|---|---|---|---|
| Fire caused by ignition of combustible agent used for surgical field preparation | 5 | 5 alcoholic solutions | | |
| | | 2 ignited by cautery | 1 | 0 |
| | | 2 surgical diathermy | 0 | 1 |
| | | 1 ether | 0 | 1 |
| Miscellaneous | 14 | 1 ethylene - rapid release of tank with ignition at valve | 1 | 0 |
| | | 6 ether - $O_2$ - air ignited by same type spark | 3<br>5 cases failed to report | 0 |
| | | 5 ether - air - $O_2$ faulty wiring | No report | |
| | | 2 ether - air causes ignition or injuries not stated | | |
| Totals | | | 57+ | 32 |

One hundred seventy cases of anesthetic fires and explosions are reported, the greater majority of which have occurred during the use of ether with the ignition source spark from the electrical apparatus. Cyclopropane was used in 21 cases of the total 170 cases. Of the 32 dead, 19 were caused by lung injury and the remainder by burns or unstated cause. In 8 fatal explosions cyclopropane was used. Ethylene or ethylene ether was used in 8 fatal cases. Ether or nitrous oxide ether was employed in 10 cases of fatal explosions. (Table III).

CASE REPORTS

Diethyl ether: There have bean more ether fires than explosions, reports of which are not available in the literature because of the seeming insignificance. One hundred to two hundred such ether flares have been estimated to occur annually in England with one explosion reported in 1935. An anesthetic trolley had been in use with oxygen flowing over ether for two and one-half hours. The machine was not in use but was being wheeled from the room when a violent explosion occurred shattering the ether container and knocking two people down. The patient was also knocked from the cart. The corridor floor was laid with a rubber mat. The air was changed every two minutes and the atmosphere extremely dry. Explosion was attributed to static spark from the cart or to friction of oxygen flowing through the metal tube. No fatalities were mentioned.

Divinyl ether: No explosions of this agent have been reported to date.

Oxide ether oxygen: The fact that nitrous oxide ether atmosphere is explosive is often overlooked. From the work of Finch and Blomfield, the explosive range is probably greater than with ether oxygen alone. The patient was being operated upon for an intestinal obstruction. The anesthetic mixture had been given for fifteen minutes, delivered through a Gwathmey bubble type machine. The patient had vomited so the machine was turned off and pushed back a foot or two. The anesthesia was continued with drop ether, which was discontinued while the stomach tube was passed. The suction tube was used to clear the throat of material. Just as the suction switch was turned on, a violent explosion occurred at the anesthetist's back. The anesthetist was thrown from his stool. Ether and flying glass were scattered over the room. The patient was not injured. A bystander was cut and burned and the surgeon's gown caught fire. A spark from the switch of the suction machine was believed to have ignited ether vapors traveling along the floor from the gas machine. The ether bottle on the machine was completely pulverized by the explosion.

Ethylene: An ethylene explosion has been reported in which an obstetrical patient was killed. Seventy-five per cent ethylene and twenty-five per cent oxygen had been given intermittently during the second stage of labor, when after four or five administrations a violent explosion occurred. The anesthetist was blown from her chair. The patient cried out and attempted to rise to a sitting posture and immediately fell back into opisthotonos and began to cough quantities of foamy blood and became unconscious. Tracheotomy was performed but the patient expired 50 minutes after the explosion. The rubber tubing was torn in several places as well as the rebreathing chamber. The rubber tubing had a coil of wire running from end to end, which was one measure thought to be useful in preventing accumulation of static charge. Explosion was thought to be due to static spark generated by removing and replacing the rubber mask on the patient's face.

Ethylene ether: An ethylene ether mixture had been administered with a model G. McKesson machine, not equipped with absorber, for one hour for a pelvic operation. The operating room was air conditioned with a relative humidity about 55%. As the surgeon was pulling a suture through the skin he felt a concussion. The anesthetist had not removed the mask from the face, but had started administering one hundred per cent oxygen a few minutes before. No cautery, suction, or electrical apparatus had been used. The operating room was equipped with mercury switches and safety wall plugs. After the concussion the tubing from mask to machine was aflame. The fire was extinguished. The patient's color and pulse remained good with only a small amount of bloody mucous appearing from the mouth. She was transfused, put in an oxygen tent, and regained consciousness - to die suddenly the following day. Postmortem showed small lacerations in the bronchi and multiple small hemorrhagic areas in the pulmonary tissue. It was felt static within the machine caused the explosion.

Ethyl chloride: Ethyl chloride in five to twenty per cent concentration in air forms an inflammable mixture, which in the case reported burst into flame when cautery was used to open an abscess previously sprayed with ethyl chloride.

Acetylene: Acetylene has not been used to any extent in this country, although its use, especially in Germany, has been fairly common. One case of an explosion has been reported, which occurred when a patient lighted a cigarette twenty minutes following a short acetylene anesthesia. The patient was not injured.

Cyclopropane: In addition to our own case which is described above, a second example of a cyclopropane explosion is included, not because it is deemed necessary to emphasize the explosibility of cyclopropane, the temperature ignition point of which is actually higher than than of ethylene or ether vapor but rather because the explosion occurred despite the fact that many of the recommended safety measures were employed at the time.

The explosion occurred at the Leahy Clinic in 1938. The relative humidity was 60 to 65%. An electrical connection existed by chains between table, gas machine, and floor. The gas machine and patient were connected by means of wire indented in the tubing with dangle chain from the mask to the patient's face. The floor was terrazo with grounded, embedded brass strips. The anesthetist's stool was painted metal with rubber feet and sponge rubber cushion, protected by oil cloth like fabric. No electrical apparatus was in use except the usual overhead lighting fixture. Cyclopropane was being used with carbon dioxide absorption technique, delivered from a Connell machine. No cyclopropane had been added to the mixture for ten minutes. The wound was sutured and the surgeon had left. The explosion occurred, rupturing the mask on the face, lacerating the posterior pharyngeal wall. The patient died fifteen minutes later. The condition of the valves showed explosion occurred in the mask and breathing tube. The explosion was attributed to static electricity, perhaps a spark discharged from the anesthetist and generated by his sliding forward and rising from his stool.

## EXPLOSION HAZARD

In order that an explosion may occur, four factors are necessary, the combustible material, an oxygen supply, an ignition source, and a proper distribution of the oxygen with respect to the combustible material.

The first and second conditions are satisfied whenever any inhalation anesthetic agent, with the exception of nitrous oxide and chloroform, are employed. It is to be especially noted that nitrous oxide itself functions as an oxygen supply when mixed with an inflammable material. Ignition sources may be classified into three groups: flame, spark, and heated material. Flames include open light, matches, spirit lamps, and fires. Sparks include electrical arcs and short circuits, such as in motors, induction coils, diathermy x-ray, and fluoroscopic machine, switches, extension cords; loose connections, occurring at light plugs, bulbs, and with defective wiring; static sparks from charges generated by any moving object and material. Among sources of static especially to be noted are woolen blankets and clothing, silk clothing and rubber soled shoes. Heated materials include glowing metal, electrical light filaments, cigars, cigarettes, and cauteries, and a radio knife. The control of sources of ignition may be largely gained by installation of proper electrical equipment and its constant check and inspection by competent electricians and by establishing and adhering to proper safety regulations concerning smoking, use of flames, cautery, the making and breaking of electrical contacts. Static electricity, the cause of most serious fires and explosions is the most difficult ignition source to understand and to control. Static may be generated by impact, pressure, friction, cleavage and induction. Simple movement such as the anesthetist sitting down on his stool have generated five hundred volts, covering patient with a blanket twenty-five hundred volts, pulling cloth cover from the rubber pad on the operating table three to four thousand volts. However, Farrand in his discussion of Dr. Horton's paper, stated that "the magnitude of the static charge does not necessarily indicate its ability to ignite an explosive gas. The heat produced by that discharge is proportional to the charge, and the charge is dependent upon the capacity of the storing body as well as the potential. The potential does, however, indicate the possibility of rupturing the gas. It is not likely that gas will rupture below a few hundred volts." Specific information on the quantities of charge necessary for ignition of varying concentrations of gases with differing humidity and temperature conditions is not available at present, but is under investigation.

The fourth factor, that of oxygen distribution, requires the intimate mixture of the explosive agent with oxygen in proper proportion. This is another condition which is fulfilled at some time during every anesthetic employing an explosive agent.

## PREVENTION OF EXPLOSION

It is in the attempt to control static that most safety measures have been advanced beyond the basic safety rules. Measures advocated are humidification with forty-five to fifty per cent given as a safe lower level originally. Humidification is still considered an effective measure of allowing static charge to leak off charged objects, but the lower limits have been raised to sixty or sixty-five per cent. In addition to humidification, operating rooms should be adequately ventilated with six or more air changes per hour. Grounding, unless universal, is considered to be a hazard since it allows greater potential differences to be present when an ungrounded object is brought into a grounded area. A conductive flooring which is grounded is considered to be the best means of establishing universal grounding. Such a conductive rubber flooring is available at present commercially, but has not been universally accepted as an adequate device. When such a flooring is employed, it is essential that no object resting on the floor is insulated from it. This would naturally preclude the wearing of shoes with nonconductive rubber soles and the use of rubber tips on platform feet, rubber wheeled carts, etc. Drag chains on such objects have been shown to provide adequate contact. In the absence of a conductive flooring, washing the floors with a 4% solution of calcium chloride each day to hold a film of moisture and thereby increase conductivity is advised.

The Horton intercoupler is a means of electrically uniting the patient, operating table, the gas machine, the anesthetist, and one other object by means of five terminals which have a resistance of one megohm, interposed between any two objects so intercoupled. Its sole function is to equalize electrical static potential of connected bodies and to preclude the possibility of static sparks between any two of the connected bodies, thus reducing the hazards of statis discharge in the area where the anesthetic gas is most apt to be present. In summary there is appended a list of suggested rules for operating room safety when explosive gases are in use.

SUGGESTED RULES

1. The use of explosive agents in anesthesia whenever cautery, high frequency current, fluoroscopy or x-ray are to be employed, shall be avoided whenever possible. In such cases nitrous oxide, local, regional, spinal, or intravenous anesthesia shall be used.

2. All electrical equipment, current switches, and outlets, shall be of the vapor proof type approved by the National Underwriters Association. All equipment shall be thoroughly inspected and checked at least every three months. Low voltage shall be obtained from batteries, not by reostat from house current. All electrical connections made or broken during an anesthetic shall be done only with the knowledge of the anesthetist.

3. No smoking or open flame shall be allowed in the operating suite.

4. A relative humidity of sixty to sixty-five per cent should be maintained in the operating suite. Ventilation should provide a complete change of air at least six times every hour.

5. The Horton intercoupler shall be properly used whenever an inflammable agent is employed.

6. Incomplete grounding shall not be employed.

7. No silk or woolen garments or rubber soled shoes shall be worn by operating room personnel or visitors. No woolen blankets shall be brought into the operating room.

8. Visitors and operating room personnel shall be kept at a proper distance about two feet from the gas machine and the anesthetist.

9. The anesthetic machine shall be kept in repair and gas tight. Rebreathing technique with absorption of carbon dioxide shall be employed as much as possible. The tubing and the rebreathing bag shall be moistened with water or preferably four per cent calcium chloride solution before beginning any anesthesia. The rebreathing bag shall not be removed from the machine during an anesthetic. If it becomes necessary to separate any two parts of the closed system, the separation shall be made with the hand in

contact with both of the separated parts until the two are well separated. The anesthetist shall not sit on a rubber or leather covered stool.

BIBLIOGRAPHY

1. Allen, Clyde, and Murray, Mary
Ethylene Oxygen Anesthesia
Surg.,Gynec. & Obst. 44: 690-700, 1927

2. Bevan, Arthur Dean
The Present Status of the Anesthesia Problem.
J.A.M.A. 97: 1530-1536, Nov. 1931.

3. Bishop, Howard E.
Eliminating the dangers of ethylene
Modern Hospital, 39: 39-41, Aug. 1932.

4. Blomfield, J.
Recent investigations concerning nitrous oxide and the ignition points of some anesthetic vapors.
Proceedings Royal Society of Medicine, 19: 39-49, Oct. 1926.

5. Brown, W. Easson
Explosibility of ethylene mixtures.
J.A.M.A. 82: 1039-1040, March 1924.

6. Buchman, M.
Safeguarding the use of inflammable anesthetics.
Research Department of the Ohio Chemical & Mfg. Co., Cleveland, Ohio, #81.

7. Bulletin - Minister of Health
Risk of anesthetic explosion.
British Medical Jr., 1:74-75, Jan.1936.

8. Cheney, Merle B.
Decreasing the explosion hazard in the use of ethylene-oxygen anesthesia.
Anesthesia and Analgesia, 8:261-262, July, August, 1925.

9. Cheney, Merle B., Folkman, M. L.
Actual concentration of ethylene in the air of the operating room and a rapid method of determining the same.
Anesthesia and Analgesia, 9: 11-13, Jan.-Febr. 1930.

10. Connell, Karl
Hazard of Explosion from the point of view of the manufacture of gas machines.
Proceedings American Society of Anesthetists, April 1939.

11. Cooper, Maurice P.
The Anesthetic Fire and Explosion Hazard.
Transactions American Society of Anesthetists, 5: 2-12.

12. Davis, Carl Henry
Explosibility of Ethylene
J.A.M.A. 82:1607, May 1927.

13. Doane, Joseph C.
The advantages and dangers of anesthetics.
Modern Hospital 35: 107-116,Oct. 1930.

14. Dixon, H. B.
On the ignition points of gases in nitrous oxide.
The Lancet, 1: 247-248, Jan. 1927.

15. Draper, W. B.
The efficiency of measures for the prevention of static spark.
Col. Med., 25: 174-176, June 1928.

16. Editorial
Injury to patient from explosion of machine used in anesthetizing.
J.A.M.A. 82:329-330, Jan. 1924.

17. Editorial
An anesthetic accident
J.A.M.A. 92: 74-76, Feb. 1929

18. Editorial
Another Martyr to Anesthesia, Dalton Wilson.
Anesthesia and Analgesia, 8:129-130, May-June 1929.

19. Editorial
Anesthetic Explosion.
J.A.M.A. 96: 530, Feb. 1931.

20. Farrand, C. L.
Discussion of paper presented by J. W. Horton
Proceedings American Society of Anesthetists- April 14, 1939.

21. Featherstone, H. W.
Discussion on Anesthesia for Diathermy and Endoscopy
Lancet 2: 1077-1079, Nov. 1931.

22. Finch, G. I.
The electrical ignition of explosive anesthetic mixtures.
Proceedings Royal Society Medicine 28: 1130-1133, June 1935.

23. Flagg, Paluel
A simple test of the explosibility of the atmosphere overlying the operative field where diathermy or actual cautery is to be used.
Archives of Oto-Laryng. 25:83-84, 1937.

24. Foreign Letters. London.
Precautions against anesthetic explosion.
J.A.M.A. 106: 932, March 1936.

25. Gordon, Isadore; Caine, Ansel M., and Baker, Wilmer.
Anesthetic explosions and fires.
Anesthesia and Analgesia 16: 39, Mar.-Apr.. 1937.

26. Griffith, Harold R.
Operating Room explosions.
Anes. & Anal. 10:281-285, Nov.-Dec. 1931.

27. Guedel, A. E.
Inhalation Anesthesia.
The Macmillan Co., New York, 1937.

28. Gould, R. B.
Report of Fatality under cyclopropane anesthesia.
Anesthesia & Analgesia 18:226-227,1939.

29. Guthrie, Donald
The Safeties of Ethylene Anesthesia.
Surg.,Gyn.,Obst. 43:703-704, Nov. 1926.

30. Hasler, J. K.
Risks of Explosion in Anesthesia.
The Practitioner 140:270-276, Mar. 1938.

31. Heaney, N. S.
Ethylene in Obstetrics.
J.A.M.A. 83: 2061-2062, Dec. 1924.

32. Henderson, Y.
The Hazard of Explosion of Anesthetics.
J.A.M.A. 94:1491-1498, May, 1939.

33. Herb, Isabella C.
Explosion of Anesthetic Gases
J.A.M.A. 85:1788-1790, Dec. 1925.

34. Herb, Isabella C.
The present status of Ethylene.
J.A.M.A. 101:1716-1719.

35. Hewer, C. Langton
Ethylene Anesthesia
The Lancet 208:173-175, June 1925.

36. Hoovor, P. L. & Culter, E. C.
Eliminating the Explosion Hazard in Operating Rooms
Modern Hospital 35:49-54, July 1930.

37. Hornor, A. P., Gardenier, Clyde B.
Further researches in the explosibility of anesthetics.
Anes. & Anal. 7:69-74, Mar.-Apr.1929.

38. Hornor, A. P. and Gardenier, C. B.
A means of intercepting explosions in anesthesia.
Anes. & Anal. 7:371-374, Nov.-Dec., 1928.

39. Horton, J. Warren
Conductive rubber flooring.
Mimeographed report from Mass. Inst. of Tech., Oct. 1939.

The Horton intercoupler unit instruction sheets, mimeographed material.
The Lahey Clinic, May, 1939.

40. Horton, J. Warren
Factors affecting the occurrence and prevention of electrostatic sparks.
Proc. Amer. Soc. of Anesthetists, Apr. 1939.

41. Ironside, Reginald
An explosion in anaesthetic apparatus.
Proc. Royal Soc. Med. 28:1127-1130, June, 1935.

42. Johnston, Franklin; Cabot, Hugh
Explosions occurring during the use of ethylene.
Arch. of Surg. 22:195-224, Feb.1931.

43. Jones, G. W.
Explosion and fire hazards of combustible anesthetics
Bur. of Mines Report of Invest. No.3443, April, 1939.

44. Jones, G. W., Kennedy, R. E.
Extinction of ethylene flames with carbon dioxide and nitrogen.
Anesthesia and Anal., 9:6-11, Jan.-Feb. 1930.

45. Knight, Ralph T.
Operating room safety.
Mimeographed material. May, 1939.

46. Kretschmer, Herman L.
Intravesical explosions as a complication of transurethral electro section
J.A.M.A. 103:1144-1145. Oct. 1934.

47. Lewis, W. B. and Boehm, E. F.
A simple method of eliminating danger of explosion due to statis spark in gas oxygen apparatus.
J.A.M.A. 84:1417, May, 1925.

48. Livingstone, H.
An attempt to lessen anesthetic hazards.
Anes. & Anal. 9:269-273, Nov.-Dec.1930.

49. Livingstone, H., Shank, I. and Engel, R.
Fire and explosion hazard with anesthetic agents
Hospitals 13:36-47, July, 1939.

50. Luckhardt, Arno B.
The potential dangers attendant on ethylene-oxygen anesthesia
J.A.M.A. 82:1603-1604, May 1924.

51. Lundy, John S.
Possible causes of explosions in gas anesthetic devices
J.A.M.A., p. 152, July 25, 1932.

52. Mackenzie, J. Ross; Colt, G. H.
General anesthesia and the atmosphere in the operating theatre.
British med. Jr., 2:938-939,Dec. 1921.

53. Medical News
J.A.M.A. 96:534, Feb. 1931.

54. Morgan, J. D.
A note on the inflammability of combustible gas mixtures.
Proc. Royal Soc. of Med., 25:123-125, Dec. 1931.

55. Newell, H. E.
The storage of nitrocellulose photographic x-ray film and combustible anesthetics.
Trans. Am. Hosp. Ass. 31:114-121, 1929.

56. Newcomber, H. Sidney
Explosion hazards and static discharge.
Anes. and Anal. 19:58-60, Jan.-Feb. 1940.

57. Oehlecker, F.
Acetylene oxygen anesthesia
Abstract in J.A.M.A., 86:1737, May, 1926.

58. Peterson, Reuben
Report of an explosion of ethylene gas resulting in the death of a maternity patient and her child.
Am. Jr. Obs. & Gyn., 18:659-665, Nov. 1929.

59. Phillips, V. B.
Safeguarding the operating room against explosions:
Modern Hosp. 46:81-88, April 1936.

A proposed code of safeguards against the anesthetic explosion hazard.
Modern Hosp. 46:80-82, May 1936.

60. Pinson, K. B.
Anesthetic explosion.
The British Med. Jr., 2:312-313, Aug. 1930.

61. Poe, James
Minimizing the fire and explosive hazard in administration of anesthetics.
Anas. & Anal. 7:295-298, Sept.-Oct., 1929.

62. Robbins, Benjamin H.
Cyclopropane anesthesia
The Williams Wilkins Co., Balt.,1940.

63. Rouenstine, E. A.
Avoid explosions.
Mod. Hosp. 53:72. Aug. 1937.

64. Salzer, Moses
A method of eliminating the danger of explosion in the use of ethylene.
J.A.M.A. 88:315, June 1927.

Ethylene, its comparative safety.
J.A.M.A. 92:2096-2097, June 1928

65. Sholes, J. G.
Letter on operating room hazards.
The Ohio Chem. & Mfg. Co., Cleveland, Ohio. May 11, 1940.

66. Sise, L. F.
Ethylene.
The Boston Med. & Surg. Jr., 192: 287-291, Feb. 1925.

The Explosibility of nitrous oxide-ether mixture.
New Eng. Jr. Med. 208:949-950, May, 1933.

67. Steinke, Carl R.
Nitrous oxide - ether explosion.
J.A.M.A. 98:1267, Apr. 9, 1932.

68. Spaid, J. D.
Personal communication to Dr. Ralph T. Knight.

69. Taylor, E. A.
Report of sub-committee on fire and explosions.
Proc. Amer. Soc. of Anesthetists, Oct. 1938.

70. Toland, C. G. and Kroger, W. P.
Anesthetic gas mixtures, their explosion hazards.
Calif. and West. Med. 47:223-227, Oct. 1937.

71. Touell, Ralph M.
Report of a Fatal Case.
Proc. Amer. Soc. of Anesthetists, Feb. 9, 1938.

72. Transactions American Society of Anesthetists, Inc.
Feb. 9, 1938 - Symposium:
An Explosion Hazard

73. Wardell, Charles H.
Controlling fire and explosion hazards of anesthetics.
Modern Hosp. 32:59-63, Feb. 1929.

Minimizing the fire and explosion hazards of anesthetic agents.
Anesthesia-Analgesia 8:95-99, Mar.-Apr. 1929.

74. Williams, H. B.
The Explosion Hazard in Anesthesia.
J.A.M.A. 94:918-920, March 1930.

75. Woodbridge, P. D.
Hazards of explosion from the point of view of the anesthetist.
Proc. of Amer. Soc. of Anesthetists, April 14, 1939.

76. Woodbridge, P. D.; Horton, J. W.; Connell, Karl.
Prevention of ignition of anesthetic gases from statis spark.
J.A.M.A. 113:740-744, Aug. 1939.

V. GOSSIP

Bill Williams is leaving July 1 to enter practice with Dr. Sam Grantham, Joplin, Missouri. Bill, whose real name is "Bill" has had splendid training for practice. He has spent considerable time in psychology, pediatrics, and child psychiatry. Everyone was hopeful that we were to have the privilege of being associated with him for several years to come, but the fates have decreed otherwise. The ladies of the Faculty Dancing Club will miss him most, as he is by far the best dancer on the staff. Believe it or not, Harold S. Diehl, the Dean, is a very close second...Now that Bill is out of the way, he will have things all his own way. This is the season of picnics, and many have already been held. Medical and hospital picnics do not lend themselves well to reports of the afternoon's or evening's performance. At one time we had a famous picnic which appeared to be the picnic to do away with all picnics. That was in the days of three-legged races, pushing coins across the floor, and tugs of war. Doc Manson of the Commonwealth Fund is always identified with the days of real picnics. He will undoubtedly recall many of the happenings of the old days. Highlight of one picnic was the official burial of Bill Peyton's operating shoes. They were considered ready for retirement. A short time afterward a group went out to officially mark the spot but found that grave robbers had been there before them. P.S.: He's still wearing the shoes...The latest reports on the cancer situation in Minnesota indicate that we are still perverse in allowing more males than females to succumb to this disease. For some unexplained reason, we are different from the United States as a whole. The difference is not due to non-resident deaths from cancer. It was predicted in 1932 that with the growth of our urban population that the female predominance in cancer would begin to assert itself. This has already happened in Minneapolis, St. Paul, and Rochester, but not in Duluth, or the state....The course in Gynecological Tumors at the Center for Continuation Study this week is the 25th medical and hospital course this year. The first year we had six; the next year ten; the third year, twenty-two. The summer program is being planned at the present time...And speaking of summer, I am reminded that I promised to give my list of good places to eat in Minnesota. This is not all by any means, but I have personally visited these spots. The "helpers" in compiling this list have been the Public Health Nurses who know the places because they must travel over the state many times in the course of their duties. We would appreciate any additions or criticisms.. New Atlantic Hotel - Marshall, the other evening both the ham and steak were very good. I ate the ham, but Dr. Friedell was allergic to it, and he drew the steak. The long white radishes were especially good. Lee's Log Lodge - Waite Park, just outside of St. Cloud on the way to Sauk Center is tops for disjointed chicken, salad bowl, and desserts. You can have the chicken either with or without gravy. Polly Prims at Rush City, a little two by four place with super home cooking. If you get there at noon, the crew from the N. P. freight train may be ahead of you, in which case you will have to wait as the space is limited. On the way to Duluth, Hart's at Moose Lake is tops. Without being too facetious, you will be surprised to know that Mrs. Hart is a dietitian. Hart's is a "must" on every list. On the range, don't miss Wards at Virginia, or if you are going up the North Shore, be sure to stop at the Rustic Lodge at Two Harbors. Farther up at Lutzen is one of the best eating places along the North Shore. Going north from St. Cloud, Mac's at Rice is famous for its steaks. But speaking of steaks, if you happen to be in Walker, turn down toward the dock, and just before you come to the tracks you will find Dave's two by four. He burns wood which makes it pretty hot on a warm day, but it is worth it. Lowell Inn - Stillwater; Marcum's at Bemidji; Commercial Hotel, Wadena; any of the Ruttger's Lodges; Platwood, this side of Glencoe; Smith's Colonial Inn, Excelsior Blvd. Dunn Hotel, Montevideo; Ramsey Hotel, Redwood Falls; Calumet, Pipestone; Palmer, Wheaton; and the Halfway House at Cotton. Zumbro Cafeteria at Rochester is one of the best bets there. The best cup of coffee for $1.50 in Rochester, according to popular rumor, can be obtained at the Kahler.

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