

Thus, the difference in calculated allowable blood loss is small. The actual hematocrit would be 33.8 instead of the target 34 vol per cent if the small extra hemodilution were permitted.

In physiologic ranges the differences between results of equation 1 and equation 2 are clinically negligible. As an example, the figure shows the equations for an estimated blood volume of 5 l and an initial hematocrit of 45 vol per cent. In general, the simplified equation modestly overestimates the hematocrit early in isovolemic replacement, and underestimates it later, a conservative error. The oversimplified calculation increasingly underestimates the hematocrit.

The decision to risk whole blood transfusion should be made on a rational basis. In a surgical procedure entailing considerable blood loss, the physician may decide his pa-

tient will tolerate hematocrit dilutions to 30 vol per cent without significant impairment of oxygen transport to the tissue. When intraoperative hematocrits are not readily available, the decision to stop replacing with noncellular volume expander and commence replacement with bank blood is difficult to make on logical grounds. Rules of thumb are often inaccurate. A sound mathematical model for hemodilution has been verified. The development of equation 2 provides an easily remembered, convenient and useful formula for guiding the anesthesiologist. This should save many patients from the risks and expense of unnecessary whole blood transfusion.

REFERENCE

1. Moore FD: Metabolic Care of the Surgical Patient. Philadelphia, W.B. Saunders, 1959

A Scavenging Device for Venting Methylmethacrylate Monomer Vapor

GORDON TAYLOR, M.B.B.S., F.F.A.R.C.S.*

Methylmethacrylate, a self-curing acrylic cement, has been used in orthopedic surgery and to a lesser extent in dentistry and neurosurgery for several years.¹ This cement is made by mixing a powder (a mixture of polymethyl methacrylate, methylmethacrylate-styrene copolymer and barium sulfate USP†) with liquid methylmethacrylate monomer. After mixing, the texture becomes doughy and in 7-10 minutes is suitable for insertion into a patient. During the mixing of the cement, methylmethacrylate vapor is emitted. Some operating room personnel have complained of headaches and vomiting either during or after exposure to the vapor. Further, the vapor is flammable, and it is appropriate for devices to be constructed to vent this vapor. We have designed a scavenging device that has been

used successfully in our operating rooms for the past six months.

METHOD AND MATERIALS

Certain physical and chemical properties of methylmethacrylate monomer vapor are of importance when considering methods of venting. The vapor is about 3.5 times as heavy as air (vapor density 3.45).² For comparison, the vapor density of diethyl ether is 2.6. At room temperature, the vapor is flammable (flash point 50 F) and is classified as a moderate fire hazard by the National Fire Protection Agency (NFPA) and as a dangerous fire hazard by the Interstate Commerce Commission. Again for comparison, the flash point of ethyl alcohol is 55 F. The lower explosive limit of methylmethacrylate vapor is 2.1 per cent when mixed with air. The lower explosive limits of diethyl ether and ethyl alcohol when mixed with air are 1.8 per cent and 3.2 per cent, respectively. The odor threshold for methylmethacrylate vapor is 0.21 ppm, and it has a

* Assistant Professor of Anesthesia, Stanford University School of Medicine, Stanford, California 94305.

Accepted for publication July 12, 1974.

† Surgical Simplex P, North Hill Plastic Ltd., London, England.

pungent sulphidly smell.³ In addition, the threshold limit value based on the prevention of irritation rather than occurrence of systemic effects is 100 ppm.³

It would be possible to vent methylmethacrylate vapor through the central vacuum system, but this is in conflict with NFPA Code 56A, which prohibits the disposal of flammable agents in this manner. However, venting of the vapor through the nonrecirculating air conditioning system in the orthopedic operating rooms was utilized. The outflow duct was protected by a grill with an area of 4 sq feet, and an outflow of air of 200 cu feet/min. Massive dilution of the vapor occurred in the main ventilation duct, where the airflow out of the system was 62,000 cu feet/min.

A box was constructed of plywood and covered with formica and placed in front of the grill. The dimensions of the box were 36 × 36 × 20 inches (fig. 1). The front of the box sloped backwards so that the depth at the base was 18 inches. In the back of the box, a hole 30 × 18 inches (3.5 sq ft) was cut and lined with ½-inch foam rubber so that a virtually airtight fit was made with the grill of the out-

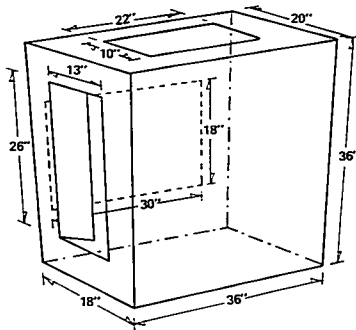


FIG. 1. Drawing of scavenger box.

flow duct. A second hole, 22 × 10 inches, was cut in the top of the box. A third hole, 26 × 13 inches, was cut into one side, and a closely fitting door on a piano hinge was attached to the back edge of the hole. The second and third holes had an area equal to 3.8 sq ft. The box was made in the Engineering Department

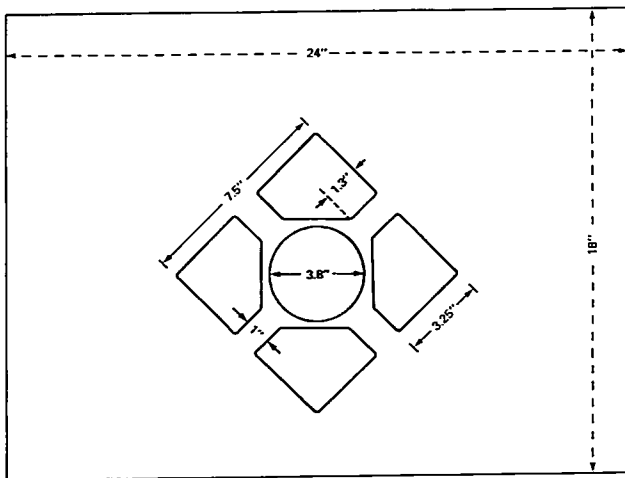


FIG. 2. Drawing of plexiglass venting sheet.

of Stanford University Hospital at a cost of \$200.

A series of holes was cut in a sheet of $\frac{1}{8}$ inch plexiglass which had dimensions of 18 x 24 inches. For ease of manufacture, holes were made in an area 7.5 inches square (fig. 2). In the center of the square a 3.8-inch circle was made with a hole cutter. The other four holes made around the circle were irregular pentagons. A $\frac{1}{2}$ -inch drill hole was made in each angle and a sabre saw used to construct the pentagon. The plexiglass venting sheet was made in the Department of Anesthesia at a cost of \$25.

During an operation when methylmethacrylate is to be used, the following protocol is followed: The box is placed in front of the grill with the door open and none of the holes obstructed in any way. When preparations are being made to mix the bone cement, the plexiglass sheet, which has been gas-sterilized, is removed from its covering and placed on the top of the box over the hole by the scrub nurse. The 5-inch cement-mixing bowl[†] is placed in the circular hole. During the mixing of the cement, the circulating nurse closes the door to the box, thereby allowing ventilation through the pentagon holes in the plexiglass. The cement is molded and kneaded in the surgeon's hands over the bowl until it is of suitable texture for insertion into the patient. When mixing of the cement is completed, the door on the box is opened to allow ventilation through the side of the box and closed again when the second batch of cement is made.

DISCUSSION

The plexiglass sheet reduces the ventilation area from 3.8 to 0.25 sq feet, and the velocity of the air flowing through the penta-

gon holes is about 300 feet/min. The recommended air velocity for venting a moderately toxic vapor such as methylmethacrylate from a fume cupboard is 100 feet/min.⁵ The venting of the vapor into the main ventilation duct and the dilution that occurs are well below the lower explosion limit. Mixing of the cement takes about 10 minutes; the air conditioning of the room is affected only minimally. The majority of the vapor is vented through the plexiglass sheet, as has been observed by operating room personnel. This was confirmed by preliminary measurements of methylmethacrylate vapor concentration in the operating room (Whitcher, personal communication). These measurements indicate that the peak concentrations of the vapor are decreased by about 75 per cent with the venting device in use. This scavenging device demonstrates that irritant, and flammable vapors may be vented efficiently from the operating room using the existing nonrecirculating air-conditioning system.

REFERENCES

1. Chamley J: Acrylic Cement in Orthopedic Surgery. Baltimore, Williams and Wilkins, 1970, p 33
2. Sax NI: Dangerous Properties of Industrial Materials. Third edition. New York, Van Nostrand Reinhold Company, 1968, p 929
3. Leonardos G, Kendall D, Barnard N: Odor threshold determinations of 53 odorant chemicals. *J Air Pollut Control Assoc* 19: 91-95, 1969
4. Committee on Threshold Limit Values: Documentation of the Threshold Limit Values for Substances in Workroom Air. Third edition. Cincinnati, Ohio, American Conference of Governmental Industrial Hygienists, 1971, p 68
5. Committee on Industrial Ventilation: Industrial Ventilation, A Manual of Recommended Practice. Twelfth edition. Lansing, Michigan, American Conference of Governmental Industrial Hygienists, 1972, p 5-22

[†] Professional Orthopedic Supplies, New York.