

## Control of Methoxyflurane Concentrations from a Boyle Apparatus

JOSEPH C. HOFFMAN, M.D.

There are two provisions for controlling the concentration of anesthetic emerging from a Boyle apparatus. Inflowing gases enter the jar through a hole whose size varies with the position of a lever. Alternatively, the degree of contact the gases make with the liquid anesthetic in the jar depends on the position of a hood controlled by a plunger. This study was designed to examine how independent changes in the position of the lever and height of the hood affect output concentrations of anesthetic.

### METHODS

Four models of the Boyle apparatus<sup>1,2</sup> (fig. 1), one of which was the older (black) model, were examined. Methoxyflurane was used since it has a vapor pressure of 23 torr, a molecular weight of 165, and a latent heat of vaporization of 58.5 cal/gm at 20 C and, therefore, is less subject to the rapid cooling characteristic of diethyl ether and other volatile anesthetics. Outflow samples of methoxyflurane in oxygen were collected in 50-ml individually-ground glass syringes sealed with stopcocks and analyzed immediately. Samples were taken from the descending limb of the steel manifold just beyond the jar. The right-angle connection between the transverse and descending limbs promoted mixing through turbulence. Gases were analyzed in a gas chromatograph with a flame ionization detector<sup>3</sup> calibrated against commercial standards.<sup>4</sup>

The temperature of the liquid anesthetic, monitored continuously with a glass mercury thermometer, ranged from 24 to 17 C. To simplify the presentation, comparison, and in-

terpretation of data all results were converted to 20 C.

The position of the lever and the distance of the hood from the surface of the liquid anesthetic were varied at several flow rates of 0.5 to 8 l/min to determine the influence of each on outflow concentration. The distance of the hood ranged from 4 cm above to 4 cm below the surface (+4 cm and -4 cm).

### RESULTS

**The hood.** With the lever in the full "on" position, concentrations increased (to about 1.0 volumes per cent) as the hood approached the liquid anesthetic, then increased markedly (up to 3.0 volumes per cent) as the hood passed beneath the surface (fig. 2). The outflow concentration was independent of the flow of carrier gases except at low flow. The exceptions were largely due to the presence in the hood of a hole (1 mm diameter), presumably meant to equalize pressures across the hood. At low flows, especially with the hood submerged, the bypass through this hole caused large decreases in output concentrations (see fig. 2, 0.5 l/min). The hole did not prevent high pressures from being generated in the vaporizer. In fact, when the outflow was totally obstructed, with the hood submerged a few milliliters of liquid anesthetic passed via the hood and U tube into the manifold. The retrograde flow of liquid was caused by a leak to the atmosphere at the lever. The hole in the hood represented the only functional difference between the older (black) and the more recent (silver) models. The older model with a new hood performed like a new model. Individual values were always within 5 per cent of one another under any one set of conditions.

**The lever.** The lever did not function under any condition until it passed the second of four divisions separating "on" and "off." This has already been observed by Mapleson.<sup>4</sup>

\* Department of Anesthesiology, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania 19104.

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<sup>4</sup> Scott Research Laboratories, Inc., Perkasie, Pennsylvania.

How it functioned between that point and full "on" depended on whether there was a hydrostatic resistance to gas flow caused by the hood dipping into the liquid anesthetic. In any case, the concentrations produced by varying the positions of the lever were unpredictable. Moreover, with the lever almost "on" the outflow concentration could triple (especially at flows 2 l/min and below) as the hood was lifted out of the anesthetic liquid, although a fall in concentration might have been predicted.<sup>1,2</sup> Thus, intermediate positions of the lever are not recommended, since they make output concentrations unpredictable.

Under most conditions the temperature of the anesthetic liquid ranged between 21 and 23 C. A flow rate of 8 l/min for more than 30 minutes caused cooling below 17 C when the hood was at the minus-4 position. The output under these conditions was 2.1 volumes per cent.

#### DISCUSSION

The purpose of the study was to separate the effects of the lever and those of the hood in controlling output concentrations. Maple-son used trichlorethylene to examine the apparatus with the hood above the liquid.<sup>4</sup>

The apparatus could provide concentrations of methoxyflurane of 2.78 volumes per cent at

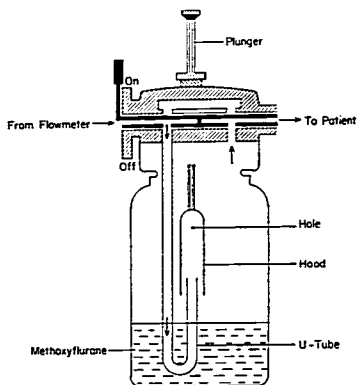


FIG. 1. Diagram of Boyle Apparatus (after Macintosh, Mushin and Epstein).

20 C. This represents an efficiency of 84 per cent. These figures may be compared with the value of 1.7 volumes per cent at 20 C from the Heidbrink vaporizer fully open at 4 l/min examined by Takahashi *et al.*<sup>5</sup> (Where there was no hole in the hood the efficiency approached 100 per cent—fig. 2.) Of course, the vaporization of more volatile anesthetics

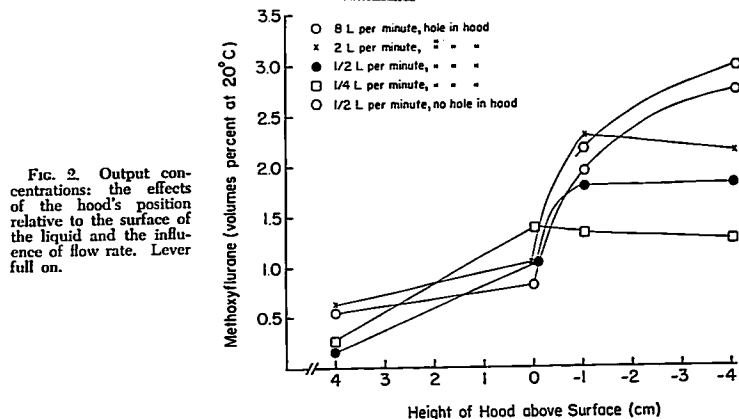


FIG. 2. Output concentrations: the effects of the hood's position relative to the surface of the liquid and the influence of flow rate. Lever full on.

will appear less efficient because of cooling. For anesthetics as soluble as methoxyflurane it is difficult to achieve an effective alveolar concentration with inspired concentrations much lower than 3 per cent. This question has been examined in detail by Eger,<sup>6</sup> who demonstrated the need for high inflow rates and high concentrations during induction of methoxyflurane anesthesia with an out-of-circuit vaporizer.

The output concentration of anesthetic depended more on the position of the hood than on the flow rate of carrier gas. However, at low flows (less than 2 l/min) the diversion through the hole in the hood caused a noticeable fall in the output concentration (fig. 2).

Though imprecise, the whole range of possible concentrations can be achieved by changing the position of the hood. Using intermediate positions of the lever complicated attempts to control the concentrations and, in some circumstances, caused increases in output when decreases were anticipated. The explanation is that with the hood submerged the hydrostatic resistance to flow causes some gases to bypass the jar. Removal of the hood from the liquid facilitates gas flow through the jar and concentrations may rise. Since the graduations for the lever serve no useful purpose, the ar-

angement might be better served by a spring-loaded mechanism designed for either the "on" or the "off" mode.

While the foregoing discussion could relate *in principle* to any volatile anesthetic, absolute concentrations of certain other vapors (notably halothane) could reach potentially dangerous levels, as may be predicted from their vapor pressure and potency.

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#### CASE REPORTS

### Fatal Massive Necrosis of the Liver after Repeated Exposure to Methoxyflurane

MARIO STEFANINI, M.D.,\* ALEXANDER HERLAND, M.D.,†  
EUGENE P. KOSYAK, M.D.†

Hepatotoxic effects following the use of methoxyflurane (Penthrane) are rare.<sup>1</sup> A case of acute hepatitis after a second administration of methoxyflurane has been reported by Klein

and Jeffries.<sup>2</sup> Their patient developed hepatic cell necrosis with jaundice, but ultimately recovered. These authors also refer to two other cases of fatal atrophy of the liver following the use of methoxyflurane. In the present report we discuss a case of fatal massive necrosis of the liver which followed a second administration of methoxyflurane and may have resulted from acquired hypersensitivity to the drug.

\* Pathologist, Saint Elizabeth Hospital.  
† Staff member, Hoopston Community Memorial Hospital.

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