

Respiratory Protection Provided by Five New Contagion Masks

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ABSTRACT

GUYTON, H. GERALD (U.S. Army Biological Laboratories, Fort Detrick, Frederick, Md.) AND HERBERT M. DECKER. Respiratory protection provided by five new contagion masks. *Appl. Microbiol.* **11**:66-68. 1963.—The effectiveness of five recently developed contagion masks in filtering air-borne particles (1 to 5 μ diam) has been reported. One mask, available in four sizes, was 99% efficient. This mask can be reused after sterilization. The other four masks are available in only one size and are intended to be used one time only. Two of these four disposable types were more than 90% efficient but the variability of their respective test results was much greater than that for the reusable mask. The two remaining disposable types were less than 80% efficient. Two of these contagion-mask types were worn by hospital personnel for periods of up to 8 hr to determine the effect of such prolonged use on aerosol filtration efficiency. No significant decrease in filtration efficiency was noted. Physicians, nurses, and other hospital personnel who wear masks will benefit from the increased individual respiratory protection afforded by improved contagion masks. Concurrently, the incidence of hospital patient air-borne infections should be greatly reduced.

Interest in respiratory protection has been stimulated recently by studies relating to the role that air-borne contagion plays in the transmission of disease. Recent investigations have shown that effective surgical asepsis results in a marked decrease of hospital staphylococcal infections (Adams et al., 1959).

Guyton, Buchanan, and Lense (1956) reported that three commercially available contagion masks were less than 40% effective in filtering air-borne particles (1 to 5 μ diam). One of these masks, the widely used tie-on surgical mask consisting of five thicknesses of gauze (44 \times 36 threads per inch), was only 18% effective. At the urging of the medical profession (Blair, 1959), manufacturers of contagion masks have attempted to fabricate and market masks that will effectively remove biological contamination from both inhaled and exhaled air.

At least four new surgical masks have been developed and their effectiveness reported. One of these is a deflection-type mask (Shooter, Smith, and Hunter, 1958) that deflects the expired air stream from the operative field. Two others are filter-type masks that filter both inspira-

tory and expiratory air through a glass medium (Adams, Fahlman, and Lord, 1959). Another type combines both the deflection and filtration principles (Kiser and Hitchcock, 1958).

The purpose of this study was to compare the aerosol filtration efficiencies of the newest types of commercially available masks with the results obtained in the 1956 study. Major hospital suppliers and manufacturers of respiratory protective equipment were contacted for brochures and information. As a result, five types of contagion masks were obtained from three sources (Apasco Corp., Wolfeboro, N.H.; C. R. Bard, Inc., Murray Hill, N.J.; Minnesota Mining & Manufacturing Co., St. Paul, Minn.; one manufacturer had three types available). These five types are pictured in Fig. 1. A brief description of each is given in Table 1.

MATERIALS AND METHODS

Test facility. The test chamber for human subjects was a room 16 by 9 by 10 ft. On two opposite sides of the test chamber were two smaller rooms that served as airlocks (Fig. 2). The exposure chamber was maintained under a reduced air pressure in relation to the airlocks, to prevent escape of the test aerosol. Samplers and test items were placed on subjects in the airlocks before they entered the test chamber.

A Binks nozzle (Binks Manufacturing Co., Chicago, Ill.)

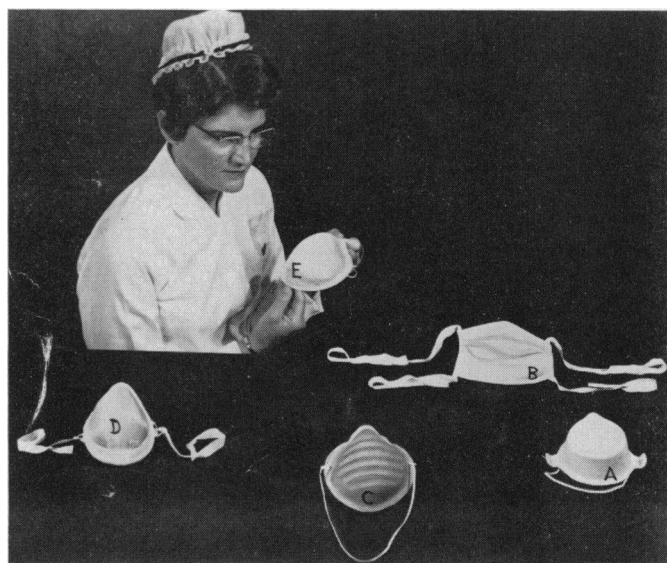


FIG. 1. Five types of contagion masks evaluated.

TABLE 1. Description of contagion masks evaluated

| Mask type | Description* | Filter medium | Facial attachment | Disposable |
|-----------|--|--|----------------------------------|------------|
| A | Cup-shaped. Molded from foamed polystyrene. | Vinyon and glass fibers (non-woven) | Elastic headband | Yes |
| B | Size, 6.5 by 3.5 in.; filter medium secured between two gauze layers. A pleat-like pouch provides added dead-air space. | Bonded glass fiber mat | Two cloth ties at top and bottom | Yes |
| C | Cup-shaped with horizontal corrugations to prevent collapsing and to enlarge filtering areas. Has flanged periphery. | Synthetic fiber (nonwoven) shell impregnated with a water-insoluble sizing agent | Elastic headband | Yes |
| D | Cup-shaped. Fabricated from two layers of 20-mesh screen with filter medium between. A malleable copper wire covered by a removable washable cloth pad rings the periphery. Available in four sizes. | Glass fiber | Two cloth ties | No |
| E | Cup-shaped. | Same as type C | Elastic headband | Yes |

* All five types utilize a flexible metal band across the nosepiece to improve the fit.

was used to introduce the challenge aerosol into the exposure chamber. The test organism used was the nonpathogenic spore-forming bacterium, *Bacillus subtilis* var. *niger* (often referred to as *B. globigii*). The bacterial spore suspension was atomized continuously during the test to permit maintenance of a dynamic aerosol. The mass median diameter of particles in this aerosol was 2.1 μ , with 95% of the particulates between 1.0 and 5.0 μ . The aerosol concentration in the chamber during a test was recorded continuously by a smoke penetration meter (Naval Research Laboratory, Washington, D.C.). This instrument enabled the test operator to maintain a constant cloud concentration throughout the test period.

Subjects. Male technicians (30) employed at Fort Detrick volunteered as test subjects. All were familiarized with the purpose of the test program. They were instructed to don and adjust their respective contagion masks to give the best possible respiratory protection. A mirror was available for their convenience. A mouth collector sampler (Guyton, Decker, and Anton, 1959) designed for mask evaluation was used to collect the spores penetrating the test items. The sampler apparatus consisted of a rubber mouthpiece that contained a metal cartridge packed with absorbent cotton to a standard resistance. This mouth sampler barely protruded beyond a subject's lips. The contagion masks to be tested were placed over the sampler. Previous experience had shown that the mouth sampler gave a minimum of interference with the evaluation of test items. Each subject inhaled

through his mouth and exhaled through his nose so that only the inspiratory air would be sampled.

Test procedure. Experience in designing tests with human subjects indicated that a minimum of three replicate observations per subject was necessary for each mask type evaluated. The test plan was formulated and the test schedule randomized so the results of this evaluation would be statistically valid.

Four subjects were employed in each test. After donning a clean set of clothing, including slippers and caps, the subjects entered Airlock 1, where the mouth collector sampler was fitted into the subject's mouth. Immediately after this, the test item was placed over the mouth collector sampler and fitted by the subject in such a manner as to minimize peripheral leakage. The subjects entered Airlock 2, where they remained for 15 sec, and then entered the test chamber containing the *B. subtilis* var. *niger* aerosol. They were seated in the chamber for a 5-min exposure to the challenge aerosol, then returned to Airlock 2 and remained there for 5 min, until the aerosol had been flushed away by incoming clean air. After this, they entered Airlock 1, where the test items were released and the cotton was aseptically removed from the mouth collector cartridge and placed in a bottle of sterile water.

The test aerosol was sampled continuously during the test period to determine the average cloud concentration.

TABLE 2. Respiratory protection of five new contagion masks (aerosols of 1 to 5 μ particle size)

| Mask type | Efficiency % | 95% Confidence limits | |
|-----------|-----------------|-----------------------|-------|
| | | Lower | Upper |
| A | 95.7 | 79.1 | 99.1 |
| B | 90.2 | 83.0 | 94.3 |
| C | 70.9 | 61.4 | 78.1 |
| D | 99.1 | 89.0 | 99.9 |
| E | 79.5 | 47.4 | 92.0 |

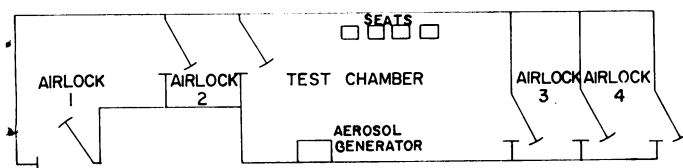


FIG. 2. Test facility.

The number of spores collected by the cotton was determined by use of standard bacteriological plating procedures. The breathing rate of each subject was accurately determined before and after each day's tests by using a Collins chain-compensated gasometer (Warren E. Collins, Inc., Boston, Mass.). The per cent efficiency of each mask tested was calculated on the basis of the daily average of air (vol/min) breathed by the test subject.

RESULTS AND DISCUSSION

The results given in Table 2 show that mask D was the most efficient and least variable of the five types evaluated. Mask D is available in four sizes. Of the 15 test subjects, 3 had small faces and wore the "small"-size mask ("medium"-size masks were worn by the remaining subjects). The availability of this type of mask in different sizes assures a better peripheral fit for large and small faces than do single-size masks designed to fit all faces. The test results demonstrate the importance of a good peripheral fit to over-all mask effectiveness. A possible disadvantage of mask D is the fact that it is nondisposable. Consequently, it should be sterilized after each use. Masks A and B both gave more than 90% efficiency, but their respective confidence-limit ranges are greater than those for mask D. This indicates a greater variability in subject fit. Masks C and E are less efficient and reliable than the other three types.

Rockwood and O'Donoghue (1960) revealed that the effect of prolonged wearing periods on the efficiency of a contagion mask has never been reported. For example, moisture and CO₂ from the breath possibly could cause the filter medium to deteriorate, thereby decreasing mask efficiency. To determine the effect of prolonged wearing, arrangements were made through the U.S. Public Health Service Field Office, Fort Detrick, for mask-wearing trials. Twelve masks each of types A and E were worn by personnel of the U.S. Public Health Service, Staten Island, N.Y., for periods of up to 8 hr. Following this, the masks were returned to Fort Detrick for evaluation. These results, when compared with those of unused masks taken from the same production lot, showed no significant

decrease in efficiency. It was impossible to subject the remaining three mask types to such a wearing test. However, since the two basic filter media used in the five mask types were represented in the wearing tests (glass fibers, mask A; synthetic fibers, mask E), there should be no adverse prolonged wearing effect on any of the mask types.

Physicians, nurses, and other hospital personnel using masks will benefit from the increased individual respiratory protection afforded by these newly developed contagion masks. Since the air-flow direction is not critical for the filter media used in these five mask types, it is reasonable to assume that the exhaled air will be filtered to the same degree as the inhaled air. Therefore, the incidence of hospital patient infections caused by air-borne organisms should be greatly reduced.

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LITERATURE CITED

- ADAMS, R., B. FAHLMAN, AND J. LORD. 1959. New fashions in surgical attire. *Am. J. Nursing* **59**:1102-1107.
- ADAMS, R., B. FAHLMAN, E. DUBE, F. DUBE, AND S. READ. 1959. Control of infections within hospitals. *J. Am. Med. Assoc.* **169**:1557-1567.
- BLAIR, E. H. M. 1959. Oh, for a mask—effective, comfortable, inexpensive, and disposable! *Nursing Outlook* **7**:40-42.
- GUYTON, H. G., L. M. BUCHANAN, AND F. T. LENSE. 1956. Evaluation of respiratory protection of contagion masks. *Appl. Microbiol.* **4**:141-143.
- GUYTON, H. G., H. M. DECKER, AND G. T. ANTON. 1959. Emergency respiratory protection against radiological and biological aerosols. *A.M.A. Arch. Ind. Health* **20**:91-95.
- KISER, J. C., AND C. R. HITCHCOCK. 1958. Comparative studies with a new plastic surgical mask. *Surgery* **44**:936-939.
- ROCKWOOD, C. A., AND D. H. O'DONOGHUE. 1960. The surgical mask: its development, usage and efficiency. *A.M.A. Arch. Surg.* **80**:963-971.
- SHOOTER, R. A., M. A. SMITH, AND C. J. W. HUNTER. 1958. A study of surgical masks. *Brit. J. Surg.* **47**:246-249.