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Intratracheal Cuffs and Aeromedical Evacuation

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Intratracheal cuffs may not perform satisfactorily during aeromedical flights, because cuff pressure against the trachea (cuff tracheal pressure or CTP) varies with aircraft cabin pressure. Thus, cuff tracheal pressure may become excessive either during ascent to 8,000 feet (565 torr), a pressure to which both commercial and military aircraft are commonly depressurized, or during loss of cabin pressure, such as may take place at higher altitudes. Correction to the proper cuff pressure at 8,000 feet may also result in insufficient seal pressure following return to ground-level pressure. Since over- and underinflation[1-3] have been implicated in both tracheal damage and aspiration, we evaluated a number of commercially

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The animals involved in this study were maintained and used in accordance with the Animal Welfare Act of 1970 and the "Guide for the Care and Use of Laboratory Animals" prepared by the National Academy of Sciences–National Research Council.

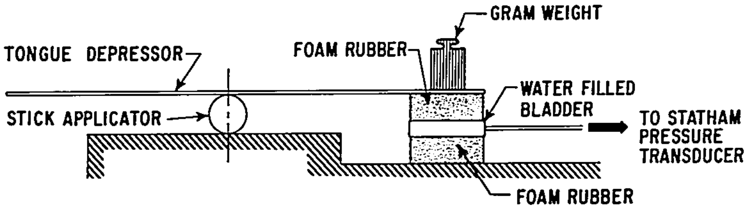

FIG. 1. System used to calibrate the tracheal-pressure balloon.

available intratracheal cuffs to determine their function during simulated aeromedical missions.

METHODS

Six intratracheal cuffs of four basic types were evaluated. They were: Rusch, Portex (conventional low-residual-volume cuffs); Kamen-Wilkinson (foam rubber cuff); Shiley, Foregger (low-pressure, high-residual-volume cuffs); and McGinnis (high-residual-volume cuff with attached control balloon). The external protective cover on the McGinnis balloon was slit to allow free expansion of the internal balloon at altitude. Each cuff was tested three times in each of four dogs. Following general anesthesia with pentobarbital sodium (25 mg/kg, iv), each dog's trachea was sprayed with a local spray anesthetic to reduce pharyngeal and laryngeal reflexes. After placement, the foam cuff was inflated by opening the pilot tube to ambient air, the McGinnis cuff was inflated until the control balloon expanded, and other cuffs were inflated until pressure could be felt in the inflating syringe.

The CTP measuring system was calibrated and tested prior to intubation as follows: CTP was measured[4] by placing a 1 × 0.5 cm bladder containing degassed water between the intratracheal cuff and the tracheal wall. The bladder was connected to a Statham P-23 series pressure transducer and a recorder. Because of the relatively high compliance of the bladder, the deflection of the recording device per unit change in applied pressure decreased as applied pressure increased. Therefore, the system was calibrated by applying one-dimensional pressures to the bladder at small increments over the entire operating range. This was done with calibrated weights, in increments of 10 grams (20 g/cm^2; 1 g/cm^2 = .735 torr) from 0 through 150 g (300 g/cm^2). The weights were placed upon a delicately balanced tongue depressor which rested against the top of the bladder, as shown in figure 1. The foam rubber beneath the bladder approximated the tracheal wall compliance. The system was then tested by decompression to 35,000 ft; the absence of significant signal deflection indicated that no artifact associated with leakage or air bubbles was present. After each endotracheal tube was inserted and after stabilization of CTP, each dog was decompressed to 8,000 feet within 40 seconds and kept at that altitude for 60 seconds. Then a 60-s decompression to 35,000 feet (179 torr) was made for a 60-s exposure, followed by compression to ground-level pressure. Seven days or more elapsed between repeated testings.

RESULTS AND DISCUSSION

Figure 2 shows CTP changes in two conventional intratracheal cuffs (Portex and Rusch) during ascent to 8,000 and 35,000 feet. These cuffs were filled with 2 and 4 ml of air at ground level, respectively, or until slight resistance to further filling could be felt. Mean CTP's in these cuffs at ground level measured 45 and 78 torr. Concurrent with ascent to 8,000 feet, CTP increased to 64 torr in the Portex cuff and 130 torr in the Rusch cuff. Upon decompression to 35,000 feet, CTP's momentarily exceeded 135 and 230 torr, respectively. Following compression back to ground-level

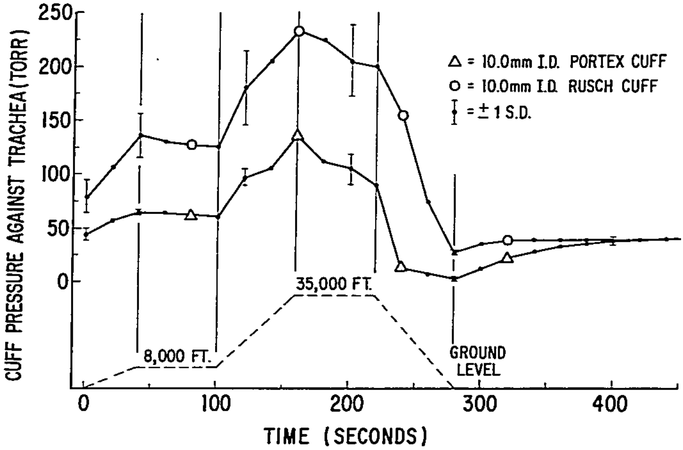

FIG. 2. Cuff tracheal pressure (CTP) responses of two conventional low-residual-volume cuffs during flight from ground level to 8,000 feet and 35,000 feet, followed by compression to ground-level pressure.

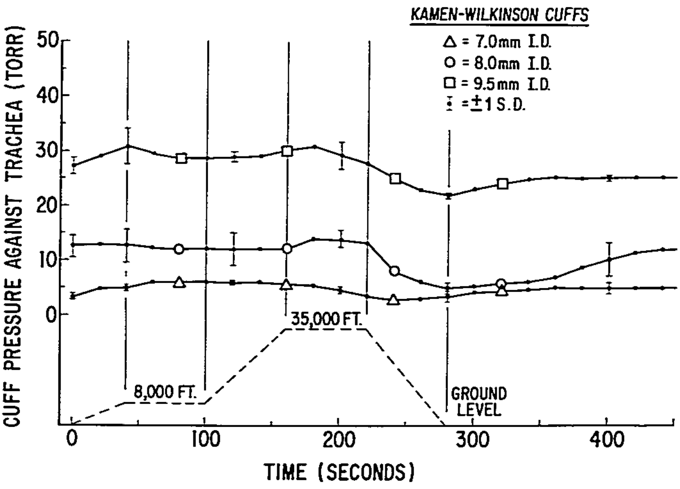

FIG. 3. Cuff tracheal-pressure responses of three sizes of foam rubber cuffs after intubation at gound-level pressure, followed by ascent to 8,000 feet, 35,000 feet, and then compression to ground-level pressure.

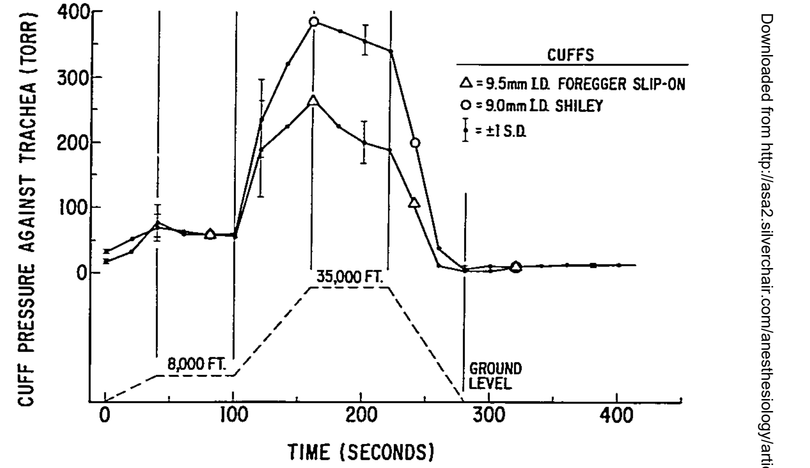

FIG. 4. Cuff pressures against the trachea following ascent to altitude with two brands of low-pressure, high-residual-volume cuffs.

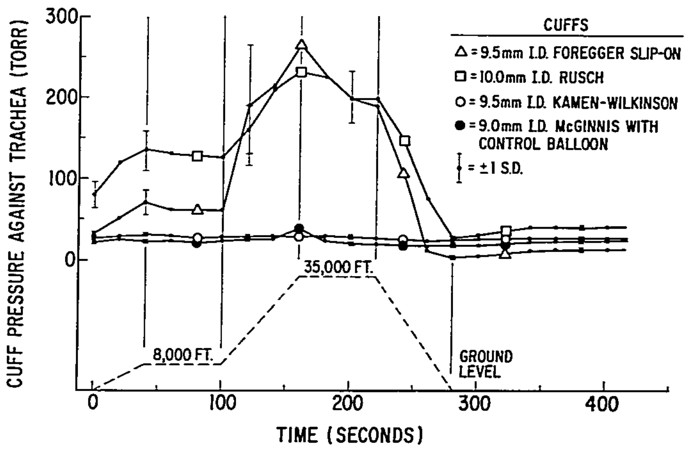

FIG. 5. Comparative pressure responses of four types of cuffs to altitude: a high-residual-volume cuff having a control balloon (McGinnis); foam rubber cuff (Kamen-Wilkinson); low-residual-volume cuff (Rusch); and high-residual-volume cuff (Foregger).

pressure, CTP's in the Portex and Rusch cuffs dropped to approximately 60 and 45 per cent of their original pressures, respectively. Six minutes later, final values were still less than the initial instilled pressures.

Figure 3 illustrates the pressure responses in three sizes of Kamen-Wilkinson foam rubber cuffs during altitude changes. Responses were relatively flat, excepting for a small reduction in CTP lasting 2–3 minutes following compression from 35,000 feet to ground-level pressure. CTP, however, was dependent upon tube size, averaging 4, 11, and 25 torr for the 7-, 8-, and 9.5-mm tubes, respectively.

Figure 4 demonstrates the CTP changes in two low-pressure, high-residual-volume cuffs (Shiley and Foregger). Although at ground level the CTP's of 20 and 32 torr, respectively, in the two cuffs were lower than that of the low-residual-volume cuffs, pressures rose to 76 and 70 torr at 8,000 feet and 385 and 260 torr at 35,000 feet.

A comparison of the McGinnis high-residual-volume cuff with its attached balloon is shown in figure 5, along with responses of a low-residual-volume cuff (Rusch), a Kamen-Wilkinson foam rubber cuff, and a high-residual-volume cuff (Foregger). The McGinnis cuff with its balloon immediately compensated for barometric pressure changes. The ground-level CTP was 20 torr. Upon ascent to 8,000 and 35,000 feet CTP's peaked briefly at 25 and 35 torr, respectively, before returning to 20 torr. Likewise, upon descent CTP fell briefly to 15 torr, returning to 20 torr within 20 seconds.

Suggested maximum safe pressures against the tracheal mucosa range from 20[5] to 60 torr,[4] yet this study has shown that conventional, low-residual-volume intratracheal cuffs exert much higher, possibly trachea-damaging, pressures, even when intubation is done at ground level. Much higher pressures were recorded during exposures at 8,000 and 35,000 feet. Similarly, if the cuff pressure were properly corrected at altitude, cuff pressure upon return to ground level could drop below 15 torr, the pressure considered necessary[5] to prevent aspiration. High-residual-volume cuffs can also exert damaging CTP when taken to altitude. The Kamen-Wilkinson foam rubber cuff, however, was relatively unaffected by altitude changes, except for a drop in pressure lasting 2–3 minutes following descent. Selection of the proper tube size is an important consideration when using the foam rubber cuff and going to altitude, since improper sizing may result in either excessively high or excessively low CTP (fig. 3). These data indicate that the McGinnis cuff, with attached balloon, gives satisfactory performance at ground-level pressure, as well as during ascent and descent.

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