A Plexiglas helmet and catheter protection assembly for chronic intravenous administration of drugs in small primates[1]

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A restraint and catheter-protection system consisting of a Plexiglas helmet and a nylon-tubing protector line has been developed to permit the long-term study of drug self-administration in monkeys. Frequent observations of monkeys in the system over a period exceeding a year have shown that the technique satisfies the requirements for long-term study of drug administration through an indwelling catheter and avoids several recurring problems inherent in other protection systems. Additional applications of the helmet and protector line are discussed.

A diversity of catheter-protection and restraint systems for long-term intravenous self-administration of drugs in the monkey are available (Pickens, Hauck, & Bloom, 1966; Trost, Talley, & Whitney, 1969; Yanagita, Deneau, & Seevers, 1965). Chairs, harnesses of steel tubing, leather vests, and steel plates bolted to the skull have all served as important constituents of drug self-administration techniques designed to minimize repeated handling or reduce excessive restraint. Restraint chairs, although extremely useful, have presented a variety of problems for the health of the animals in our laboratory. Circulatory disorders, edema, partial paralysis, and muscle atrophy to the hind limbs have been encountered after prolonged periods of restraint. Any of these conditions can lead to interruption or termination of the experiment. Other units, including harnesses of stainless-steel tubing (Yanagita, Deneau, & Seevers, 1965) and leather vest (Pickens, Hauck, & Bloom, 1966), are lightweight and minimize restraint; however, problems arising from skin abrasions and catheter accessability have not been entirely resolved. Even close-fitting soft leather horsehide vests designed in our laboratory do not completely overcome these difficulties. Finally, units have been designed to attach the catheter protection components to the skull of the animal (Trost, Talley, & Whitney, 1969). While animals remain fit and catheters are out of reach, the surgical procedure for the head attachment is arduous. In addition, problems may arise from infection or exuberant granulation tissue, which may loosen the attachment plate bolted to the skull.

In an effort to develop an inexpensive lightweight system that would minimize restraint and avoid the noted difficulties, a Plexiglas helmet with catheter protection hardware was designed and has substantially satisfied the important requirements for long-term self-administration studies.

APPARATUS

The entire catheter-protection and restraint assembly consisting of a Plexiglas helmet, tubing and spring protector, and catheter storage well and connector, is shown in Fig. 1.

Plexiglas Helmet

The helmet consists of two pieces of Plexiglas that are formed into semiellipsoids approximately the shape of the primate profile. Although Plexiglas may be formed by many methods, the pressure process is both practical and simple. This procedure requires an oven capable of 180°C, an air pressure unit with regulator capable of delivering up to 25 or 30 lbs of pressure, and two aluminum templates.

To construct the helmet, a Plexiglas sheet 7 x 7 1/2 in. square x 3/16 in. thick is clamped between the templates. One template has an opening slightly larger than the size and shape of the primate profile, while the other template has a compressed-air hose fitting mounted in a center hole. After the clamped templates and Plexiglas are heated to a temperature of 180°C or greater, they are removed and attached to the air pressure line. Pressure is then applied and maintained to achieve the desired shape for one side of the helmet (Fig. 2). Higher oven temperatures will require considerably less pressure. To form the remaining side of the helmet, the template is turned over and the steps are repeated.

Following completion of the two halves, the excess Plexiglas is trimmed away leaving enough flange area to bolt the halves together and to mount the catheter storage well and connector (Fig. 3a). Openings for the face and neck are cut and ventilation holes drilled to prevent eczema

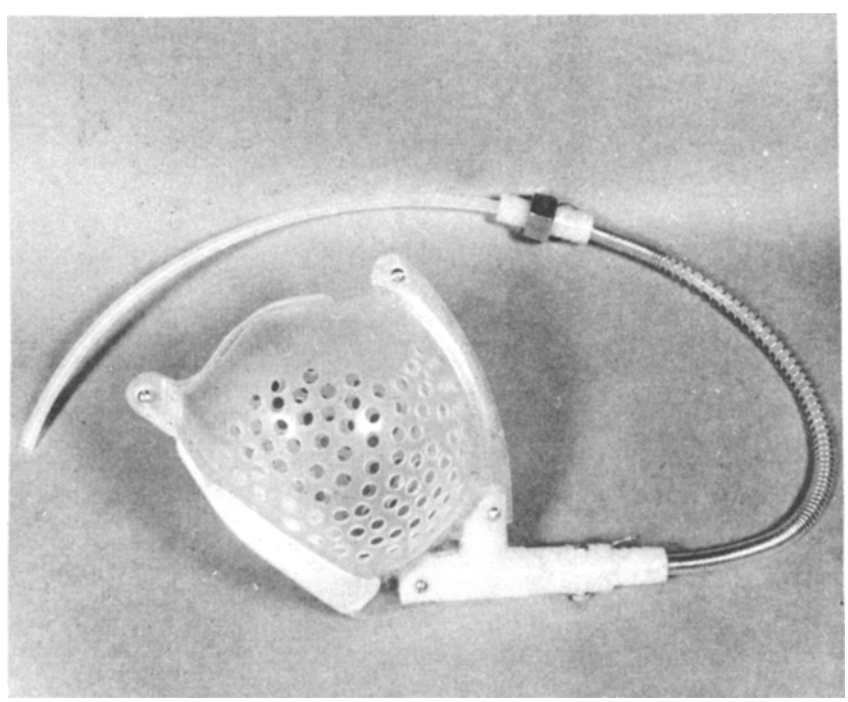
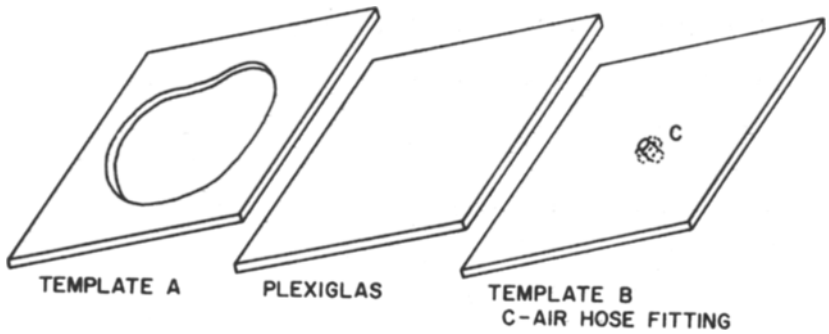


Fig. 1. Side view of helmet and catheter-protection assembly.

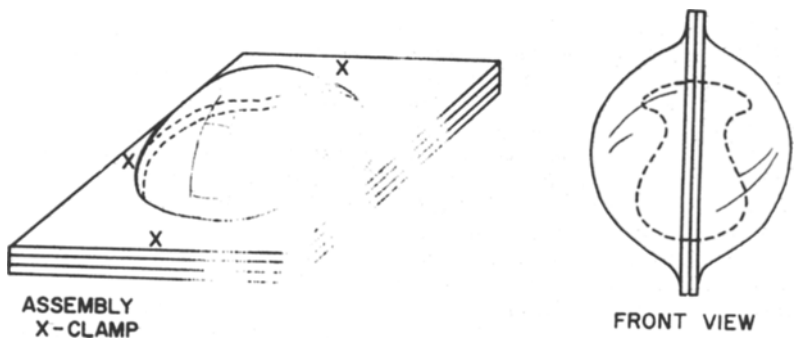
Fig. 2. Plexiglas is clamped between templates A and B, heated to required temperature and connected to air pressure line at C. Pressure is then applied to obtain desired shape. (Template A) Aluminum plate approximately 7 x 7 x ¼ in. with opening cut to required configuration (Template B) Aluminum plate matched to size of Template A with center hole tapped for mounting compressed air hose fitting, C. (Plexiglas) 3/16 in. thick Plexiglas cut to size of templates A and B. →

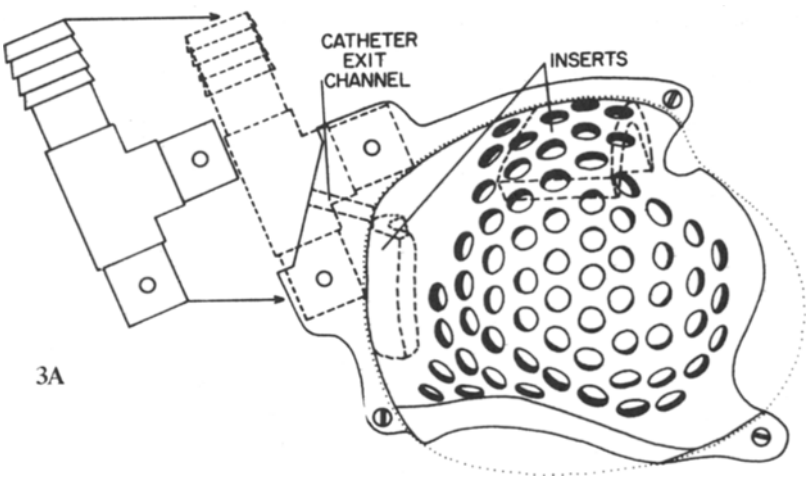


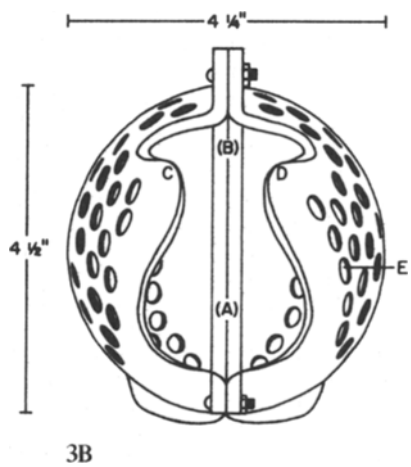
and other skin irritations on the primate's scalp (Fig. 3a, 3b, and 3c). All surfaces which have been cut or drilled must be sanded and contoured to avoid abrasions and lesions. As an additional precaution, a thick flange molded from epoxy cement is added to the edges of the neck opening and smoothly contoured (Fig. 3c).

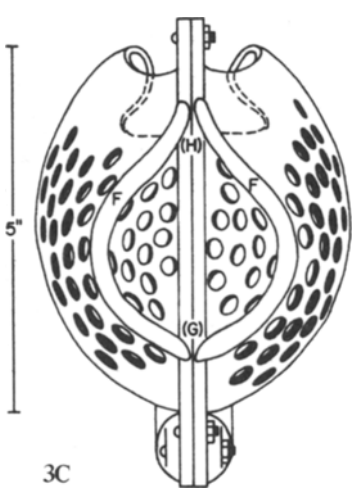
Helmets can be made to accommodate primates of varying sizes by altering the

Fig. 3a. Side view of helmet indicating position of catheter storage well and connector unit attaching tubing spring protector assembly (Fig. 4P).









3b. Front view of helmet. (A) Opening must allow ample room for mastication and storage of nominal quantities of food in food pouch. (B) Eye slots may be sufficiently large to enable direct forward vision and allow animal limited access to the eyes; however, protruding flanges C and D should be left to prevent animal from extending entire hand and wrist through opening. (C & D) Noted. (E) Numerous holes drilled over large areas of the helmet will serve to lighten the overall weight of the unit, ventilate, enhance audition, and enable limited access for grooming; however, care must be taken to limit size and location to prevent access to critical regions around catheter (s) or other devices requiring protection.

3c. Bottom view of helmet. (F) A flange is bonded to the edge of the neck opening to prevent abrasioning of neck and shoulder. General Purpose epoxy cement (The Carters Ink Co., Cambridge, Mass.) has proven to be an excellent adhesive and easily molded to desired shape during proper stage of drying. (G & H) Curvature of neck opening at these locations is necessary to prevent pinching of skin.

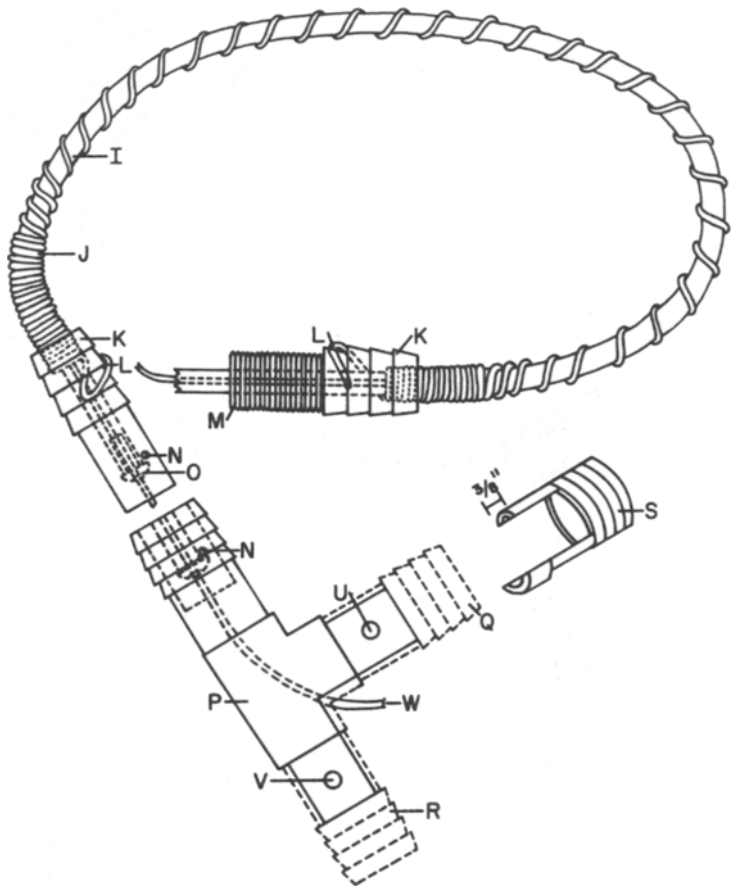


Fig. 4. Tubing, spring protector, and catheter storage well. (I) ¼-in. O. D. nylon tubing (Arizona Plastic Intrusion Co., 2547 W. Jackson, Pheonix, Arizona) is inserted through spring for protection of catheters or other devices. Method used to retain tubing in assembly is discussed in (N), (J) Standard ¼-in. I.D. screen door spring. On most animals, spring may be expanded over ¼-in. nylon tubing as indicated, to lighten overall weight of assembly. This will still provide adequate protection from animal chewing, twisting, and kinking tube. On aggression and hyperactive animals it may be necessary to leave coils intact. (K) ½ in. nylon insert couplings (Plastiline, Inc., 1251 N. E. 48th St., Pompano Beach, Florida) are cut in half to fabricate spring mount connecting units for both ends of spring assembly. (L) To lock spring into nylon connector unit, a length of spring is uncoiled and inserted through a small hole (drilled at an angle) approximately 1 in. from the flanged end. Slight kinking or bending in the opposite direction of coil will prevent spring from twisting out. (M) A portion of the connector may be threaded and used in conjunction with appropriate hardware for mounting or attaching as required. (N) A small hole properly aligned in (K) and (P) for insertion of a bolt will serve to lock spring assembly onto helmet. (O) A No. 10 machine bolt, with a small hole drilled through the center to allow passage of catheter, is twisted into the end of nylon tubing to prevent the tubing from pulling or working out of spring. (P) The catheter storage well and connecting assembly is constructed from a ¾-in. nylon insert tee (Man. SN 16-02) manufactured by Plastiline, Inc. (Q & R) Sections Q and R, indicated by dashed lines, are removed from (P) to enable mounting on flange of helmet (Fig. 3a). Figure S indicates removed section. (S) Noted. (U & V) Holes drilled through sections of (P) to bolt assembly to protruding flange of helmet (Fig. 3a).

template opening used in constructing the helmet. Inserts of soft leather or rubber bonded to the interior surface of the helmet produce a better fit in some animals (Fig. 3a). In our laboratory macaques ranging from 4 to 25 lbs have been fitted successfully. The helmet indicated in Figs. 3a, 3b, and 3c is for animals in the approximate weight range of 15 to 25 lbs.

Tubing, Spring Protector, and Catheter Storage Well

This part of the assembly is designed to protect the catheter between the helmet and cage wall. Standard plumbing and hardware supplies that are lightweight, durable, and inexpensive have proven to be quite adequate for this purpose (Fig. 4). The tubing used is ¼-in. O.D. nylon tubing (Fig. 4I), which is inserted through a standard ¼-in I. D. screen door spring to prevent twisting, kinking, and availability to the S. On both ends of this line, ½-in. nylon insert couplings are attached to the spring (Fig. 4K). To lock the spring into the nylon connector, a length of spring is uncoiled and inserted through a small hole drilled at an angle 1 in. from the flanged end of the connector. The straightened end of the spring must be bent to prevent it from twisting out (Figs. 4K and 4L). The nylon insert coupling on the end of the line extending to the cage wall is threaded to accommodate appropriate hardware for mounting on the cage (Fig. 4M). The catheter storage well and connecting assembly is constructed from a ¾-in. nylon insert tee (Fig. 4P) and serves to connect the tubing and spring protector to the helmet and to store the catheter when the animal is to be disconnected from the protector line and removed from the cage. Sections of two legs of the tee are removed so that the tee may be bolted to the flange of the helmet (Figs. 4Q, 4R, and 4S). The nylon insert coupling (Fig. 4K) is then inserted in the unmodified leg of the tee (Fig. 4P). A bolt through the tee and the nylon insert coupling will prevent disconnection (Fig. 4N).

Silicon Rubber Tubing

A single length of silicon rubber tubing, extending from the infusion pump to a large vein, is used as a catheter. The specifications of this tubing and the surgical procedure for implantation are discussed elsewhere (Trost, Talley, & Whitney, 1969; Craig, Trost, & Talley, 1969). After the catheter has been implanted, it is extended subcutaneously to the animal's head at midline over the occipital crest. From the top of the head, it exits through an incision in the scalp and out an exit hole in the helmet into the catheter storage well. From the nylon tee, it is threaded through the tubing and spring protector to an infusion pump outside the cage.

APPLICATIONS

The Plexiglas helmet and associated hardware were developed to permit monkeys to self-administer drugs through an indwelling venous catheter for long periods of time without removal of the catheter by the monkey and without a

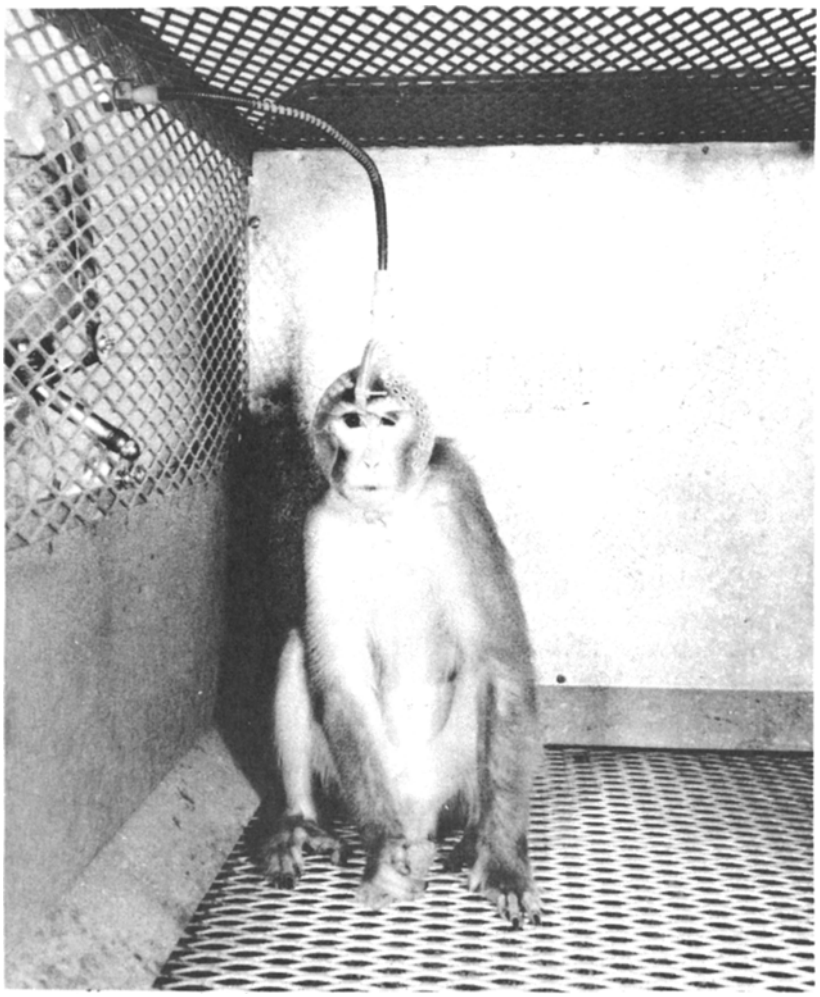


Fig. 5. 20-lb *Macaca mulatta* in assembly.

breakdown in the health of the animal. To date, 15 macaques, male and female, of varying ages and weights, have been fitted with the entire assembly for periods ranging up to 10 months (Fig. 5). With properly fitting helmets, no catheters have been removed by the Ss. No noticeable behavioral changes have resulted and adaptation to the helmet has been rapid and uneventful.

Although this protection and restraint system was devised for a drug self-administration investigation and is being used routinely in a present study, it has other applications as well. For example, in a study requiring chronic blood sampling, protective helmets were successfully used on female monkeys with uterine and femoral venous and arterial catheter implants. The helmet would also be useful for attaching audio and optical devices on primates; for introducing aerosol compounds, liquids, chemicals, compressed air, and electrical shock; for protecting the site of major head surgery or skin grafts; and for mounting radio and telemetry packages, infusion pumps, and other hardware on free-ranging animals.

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NOTES

1. The development of this apparatus was supported by the Department of Justice, Bureau of Narcotics and Dangerous Drugs, and the 6571st Aeromedical Research Laboratory. However, the views expressed herein are those of the authors and do not necessarily reflect the views of the Department of Justice, the United States Air Force, or the Department of Defense.

2. Mailing address is 6571st Aeromedical Research Laboratory, Comparative Psychology Division, Holloman Air Force Base, New Mexico 88330.

3. Animals used in this study were handled in accordance with "Guide for Laboratory Animal Facilities and Care," prepared by the National Academy of Sciences-National Research Council and in accordance with the Secretary of Agriculture Standards in "Laboratory Animal Welfare."

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