A simple and inexpensive transducer for quantitative measurements of penile erection during sleep

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The construction of a mercury strain-gauge transducer for measuring penile erection and scoring rules for tumescence episodes are described. The gauge device has been found to be cheap, reliable, and easy to construct. It is capable of transducing changes in circumference in the penis of adults and infants, the clitoris of congenital adrenal hyperplasia patients, and the nipples of adult females.

The attempt to ascribe some function to the rapid-eye-movement (REM) stage of sleep has been characterized by efforts to measure physiological and behavioral concomitants of REM sleep. One of the behaviors reliably associated with REM has been penile erection (Karacan, Goodenough, Shapiro, & Starker, 1966; Karacan, 1966; Fisher, 1965), and one of the most persistent problems has been the quantification of these erections.

Freund, Sedlacek, and Knob (1965) described a device that measured volume changes in the male genital, but the bulkiness and the difficulty in the fitting of this device prohibit its use during sleeping periods. A graphite-filled elastic tube was used by Jovanovic (1967) to measure erections during sleep, without disturbing the S. Graphite gauges are slow to recoalesce if the conducting medium separates. Mercury gauges overcome this problem and thus eliminate one type of artifactual resistance change. Bancroft, Jones, and Pullan (1966) used a mercury strain gauge to measure erections, but the device is not suitable for use on sleeping Ss. Fisher, Gross, and Zuch (1965) described a transducer for penile erection that was adapted by Arthur Shapiro from a commercially available mercury strain gauge.¹ As can be seen in Fig. 1, the device described here (B and C) eliminates the bulky junction (A) that was found to be a source of malfunction in our laboratory.

Elimination of this junction resulted in a small gauge, substantially free of artifacts, and very easy to fabricate. Furthermore, this transducer successfully measures a wider range of phenomena. We have reliably recorded tumescence from a large number of adult males, a number of newborn males, and some female patients with congenital adrenal hyperplasia that results in enlargement of the clitoris. Several female volunteers have reported no distress after several days of wearing our gauges about their nipples. Bulkier versions of the mercury strain gauge have been used to measure respiration (Shapiro & Cohen, 1965) and can measure digital blood flow, limb movements in infants, etc. Our gauge should be adaptable to these measures as well.

CONSTRUCTION

The final gauge circumference should be 2-4 mm smaller than the normal size of the anatomical member to be measured. For an adult-sized gauge, a piece of silicone elastic tubing (i.d. = .020 in., o.d. = .037 in.), about 7-8 cm long, is immersed in Toluene, causing the material to expand. While waiting (60 sec) for the tubing to expand, the leads for the gauge are prepared from No. 36 enamelled wire. A piece of wire, 32-36 cm long, is bent in half. Then the enamel is sanded off the bent end so that electrical contact can be made with the mercury when this end is inserted into the tubing.

Fig. 1. A. A gauge of the type used by Arthur Shapiro. B. An adult gauge. C. An infant gauge.

The expanded silicone tubing is removed from the Toluene and filled with mercury from a blunt-needled syringe. The syringe is left attached, and the bared, twisted end of one lead is inserted 0.3 to 0.4 cm into the mercury-filled tube at the free end. This is secured in place by a thin thread tied around the outside of the tubing. The syringe may now be removed, being careful to fill the tubing with mercury right to the end. The second lead is inserted, tied in, and the two ends are tied together to form a circle of the tube. The individual leads of enamel wire are twisted together and a piece of silicone tubing, the length of these leads, is expanded in Toluene and fitted over them. This tubing will shrink to approximately the correct length as the Toluene evaporates, and it is then fixed to the circle of tubing with a drop of silicone glue (such as GE's RTV-108). The silicone tubing protects the twisted leads from mechanical damage when the gauge is attached to a S. The entire fabrication takes less than 5 min.

For recording purposes, a pair of 2- to 2.5-m-long, 22-ga leads that terminate in pin plugs are soldered to the No. 36 leads, and the joints are covered with heat-shrink tubing. The long leads are secured to the S's body with tape at the abdomen, back, and neck and terminate in the plugboard with the EEG connectors. The output of the tumescence gauge is fed to the Wheatstone bridge and amplifier circuit shown in Fig. 2, and the bridge output is connected to the input of the EEG amplifier. The resistance of the gauge varies from 1 to 2 Ω over the normal circumferences encountered in our work with adults (8-10.5 cm). It is important to minimize the resistance of the leads from the gauge to the bridge because an input resistance of 3-4 Ω precludes adjusting

Fig. 2. Low impedance bridge and amplifier circuit. Diodes D1 and D2 protect the circuit from reversed polarity connections, while diodes D3 and D4 limit the unbalanced input to the amplifier.

PARTS LIST

All resistors, 5% tolerance:

R1, R10: 120 Ω

R2, R3: 220 Ω

R4: 2.5 Ω

R5: 25- Ω micropotentiometer, linear taper (balance control)

R6, R7: 1K

R8: 33K

R9: 200K micropotentiometer, linear taper (gain control)

D1, D2: 1N1392

D3, D4: 1N4148

Amp.: Nexus SQ-10, Nexus USL-1 or equivalent

the baseline of the write-out pen with the balance control. In our laboratory, the baseline of the gauge write-out pen is adjusted (R5, Fig. 2) while the gauge is minimally dilated on a standard adult-sized Plexiglas cylinder. The gauge is then placed around the other, larger end of the standard, and the gain control (R9, Fig. 2) is adjusted to provide an appropriate deflection of the pen. The amount of deflection provided for will differ, depending on the anatomical member from which recordings are taken and the requirements of the investigator.

Care must be taken not to twist the supple silicone tubing when fitting the gauge because the resulting decrease in the diameter of the mercury column causes a spuriously high resistance that destroys the essentially linear characteristics of the gauge. Figure 3 presents the results of a series of calibration measurements on an adult-sized gauge taken when the bridge was adjusted as described above. With the gauge dilated and immersed in water, temperature changes from 35 deg C to 40.5 deg C produced no measurable changes in the deflection of the write-out pen. So we are confident that the blood flow changes during tumescence do not produce a temperature artifact.

The Ss are instructed in the use of the gauge on their first night in the laboratory. The gauge is worn behind the glans of the penis.

SCORING

The events defined below are scored by noting their time of occurrence. (1) The beginning of an erection cycle is the point at which the pen first rises above the baseline (T up). (2) The point

Fig. 3. The relationship of gauge dilatation to pen deflection. Changes of 0.017 Ω in the gauge resistance produce 1 mm of pen deflection.

of maximum pen excursion for all episodes is designated T max. For an episode in which T max is not attained, the greatest deflection is called a semimaximum (Ts). (3) At some point after T max or Ts (at least 20% less than the maximum of the episode), detumescence begins and the moment the pen begins its downward deflection is called T detumescence. (4) An episode is considered complete when the pen returns to baseline. The time the pen first returns to baseline is T = 0.

Other measurements that are recorded are the duration of the erection cycle, fluctuations (F), and pulsations (P). Fluctuations consist of reversals within a given episode where another erection cycle begins before return to a flaccid (baseline) state is accomplished. Pulsations refer to rapid transient reversals of tumescence within a given episode. Both F and P are counted and recorded for a given episode.

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NOTE

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