Electro-mechanical corneal aesthesiometer

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The threshold value of corneal sensitivity to touch is of interest to ophthalmologists and neurologists. The method generally employed for its measurement is credited to von Frey, who produced the test force on the cornea by pushing a long hair against the corneal surface, the force being varied by using a series of hairs of different lengths to determine the threshold for the sensation of touch. The Cochet-Bonnet aesthesiometer (Cochet and Bonnet, 1960) is a modern adaptation of this simple device, in which a single nylon hair in a special holder operated by a thumb mechanism is used to produce all the test forces. Other force-producing systems include a spring as in Schirmer's aesthesiometer (Schirmer, 1963), but the Cochet-Bonnet still seems to be the most popular.

The Cochet-Bonnet instrument, however, has the following drawbacks:

- (1) The patient is usually afraid when he sees a hand holding a black rod advancing toward his eye. The natural tendency to blink or flinch can be overcome only by practice or by testing in the dark with infra-red illumination (Bonnet and Millodot, 1966).
- (2) The examiner cannot tell when the tip has touched the cornea except by observing the change in the bend of the hair. This reduces the accuracy of the measurement, particularly as the hair is very fine and thus difficult to see.
- (3) The nylon hair bends considerably under its own weight and usually takes the form of an arc, particularly when long. For the tip to be at right angles to the corneal surface, the handle must be held pointing slightly upward to compensate for this bend. Other factors, such as previous use and humidity, influence the shape of the hair.
- (4) The force applied to the cornea is measured indirectly. The operator must notice when the hair bends and this is the indication that a force has been applied. The manufacturer quotes a force for each length of hair, based on a 5° change of the tip angle due to bending. Fig. 1 shows how the force varies with a change in tip angle for lengths of 18, 38, and 58 mm. Since the operator has no means of measuring the tip angle, a precise estimate of the force applied cannot be made.
- (5) The shape of the nylon tip is not reproducible, and this means that the pressure distribution due to the tip's contact with the cornea will not be known.
- (6) The nylon hair cannot easily be sterilized.

After studying the Cochet-Bonnet aesthesiometer to find the relationship between the angle of bend and the force produced at the tip (Millodot and Larson, 1967), it was decided to use modern techniques to develop an improved aesthesiometer (Larson, 1968).

FIG. 1 Cochet-Bonnet aesthesiometer. Force produced at the tip for given change in tip angle

The Larson-Millodot instrument (L-M), is characterized by three features:

- (1) The probe tip is made of fine platinum wire bent double so that the tip has known and reproducible dimensions. This wire may be flame-sterilized as is the practice in microbiology.
- (2) The probe is automatically advanced toward the eye at a constant rate upon the operator's command. When the cornea is touched with a force equal to the test force, the probe is retracted quickly and automatically.
- (3) The force applied to the cornea can be set at any value within the range of this instrument and this force will not be exceeded. The range of settings for practical purposes is from 1 to 200 mg., and any force within these limits can be set with an accuracy of ± 0.5 mg.

Operation

The L-M aesthesiometer, Fig. 2a, functions in the following way. The platinum probe is mounted on an arm fastened to a torsion wire. A turns-counting dial and gearing are used to twist the wire about its longitudinal axis. The amount of twist in the wire produces the test force. Each division of the dial is equal to 0.5 mg. of force on the most recent instrument. The torsion of the wire holds the arm against a stop and one must exert the rated force to move the arm back from the stop. The backward movement of the arm is detected by a photocell system and this triggers the retracting mechanism that withdraws the carriage. The mechanism described above is mounted on a movable carriage, Fig. 2b. A push-button control starts a motor which draws the carriage forward at a fixed velocity. The photocell trigger mechanism releases the motor's clutch when the probe touches the cornea. The carriage is retracted to its starting position by a spring. The moving parts are made as light as possible to minimize inertia. The electronic control system is all solid-state. The net result is a compact unit measuring $22.5 \times 12.7 \times 10.2$ cm. and weighing $5\frac{1}{2}$ lb. (Fig. 2a, b, overleaf).

FIG. 2 (a) *L-M aesthesiometer viewed from operator's side. The platinum probe is inside the transparent shield*

(b) *L-M aesthesiometer with moving parts exposed*

Experimental use

Preliminary work has demonstrated the advantages of this instrument over previous aesthesiometers (Millodot and Larson, 1969). The platinum wire probe is made from very fine wire. This and its proximity to the patient's eye make it so out of focus as to be invisible. When the probe is retracted, it is housed in a clear plastic box; thus the patient can look through the box and fix on some more distant object. The patient is usually less disturbed by this arrangement than by that of the Cochet-Bonnet.

The results of an experiment relating the axial movement of the C-B aesthesiometer to the force developed at the tip are shown in Figs 3*a* and 3*b* (opposite) for the 0.12 mm. and 0.08 mm. diameter hairs respectively. The L-M instrument was first calibrated with weights. Then a small piece of paper was stuck to the tip of the L-M probe, shown on the left of Fig. 4*a*, to give a contact surface for the tip of the C-B hair shown on the right. The C-B was then mounted on a watchmaker's lathe carriage so that, when the leadscrew of the carriage was turned, it moved in the direction of the axis of the handle. The two aesthesiometers were lined up facing each other (Fig. 4*b*). Because of the sag in the hair, the handle of the C-B had to be inclined upwards to make the tips parallel. The voltmeter was used to monitor the movement of the L-M probe (Fig. 4*a, b*, opposite).

The C-B was screwed forward until, with the aid of a magnifying glass, the tips were seen to touch. Further rotation of the leadscrew moved the handle of the C-B forward. The dial of the voltmeter indicated when the L-M probe had moved off its stop. A dial on the leadscrew enabled the advance to be estimated to within 0.01 mm. The movement of the L-M probe itself was subtracted from the forward motion of the carriage. The result was the forward motion of the C-B to produce the force set on the L-M. The results of this experiment (Fig. 3*a* and 3*b*) are of value to those using the C-B aesthesiometer.

A very small forward movement is required to produce the rated force. One sees that a movement of only 0.1 mm. will produce the same force as a change in tip angle of 5°.

FIG. 3 Cochet-Bonnet instrument. Force produced for a given forward movement of the handle after the tip has touched (a) Hair diameter 0.12 mm. (b) Hair diameter 0.08 mm.

FIG. 4 (a) Platinum tip of L-M aesthesiometer with paper bumper on left; C-B nylon tip on right. (b) L-M aesthesiometer being used to check C-B instrument

according to Fig. 1. This apparent inconsistency is due to different test conditions in each case. Fig. 5 illustrates the test conditions (i) for Fig. 1, and (ii) for Fig. 3, and it can be seen that the direction of application of the force is different. Calculations based on the deflections of beams, as calculated in the strength of materials, indicate that, in fact, the results shown in Fig. 3 are reasonable.

Anyone wanting the lowest possible force for a given bend at the tip should hold the C-B as shown in Fig. 5c. Holding it as shown in 5b will result in a higher force, perhaps as much as six times higher.

A second experiment with the set-up of Fig. 4b was performed to discover if the L-M mechanism produced shock forces at the tip of the probe. It seems reasonable to suppose that the L-M would produce forces at the tip due to the inertia of the probe and the arm supporting it. If these forces were large enough, they would cause the lower force settings of the instrument to be invalid. The C-B was used as a means of showing these impact forces. High speed photographs, 64 frames per second, were taken with a Beaulieu 16 mm. movie camera. The film frames taken before, during, and after the contact of the tips were then examined by projection, one frame at a time, to see if the C-B tip was deflected. No movement of this tip could be seen. From this it can be inferred that the impact forces are lower than the force-measuring ability of the C-B aesthesiometer. During this experiment, the C-B was fixed and the L-M was advanced and retracted automatically in its normal way. The C-B was held as shown in Fig. 5c.

FIG. 5 Position of Cochet-Bonnet aesthesiometer during experiments
(a) for results in Fig. 1
(b) for results in Fig. 3
(c) for impact tests

Summary

The corneal aesthesiometer is a device for measuring the threshold of corneal sensitivity. An improved electro-mechanical aesthesiometer, the Larson-Millodot (L-M), is described, and compared with the Cochet-Bonnet (C-B) instrument. Using the L-M as a force-measuring standard, the forward movement of the C-B required to produce a given force

was found for two diameters of hair. An experiment to check the impact forces produced by the L-M is also described. The angle at which the C-B instrument is applied to the cornea was found to have an important influence on the force applied.

References

- BONNET, R., and MILLODOT, M. (1966) *Amer. J. Optom.*, **43**, 238
COCHET, P., and BONNET, R. (1960) *Clin. ophtal.*, **4**, 12
LARSON, W. (1968) Canadian Patent No. 789,799: "Device for measuring the threshold of the sensation of touch"
MILLODOT, M., and LARSON, W. (1967) *The Contact Lens (Lond.)*, vol. 1, no. 3, p. 5
_____, _____ (1969) *Amer. J. Optom.*, **46**, 261
SCHIRMER, K. E. (1963) *Brit. J. Ophthal.*, **47**, 488