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A Tonometer for Measurement of Tissue Turgor in the Human Finger Tip.*

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Because of the frequency of involvement of the finger tip in vascular disease, a method to measure quantitatively physical changes in the finger tip is needed. We have devised for this purpose a mechanical palpator, based upon the principle of the Schioetz tonometer and capable of detecting quantitatively small changes in tissue turgidity. Heretofore only rough estimation of these changes could be made by simple palpation. Schade and others[1, 2, 3] have employed

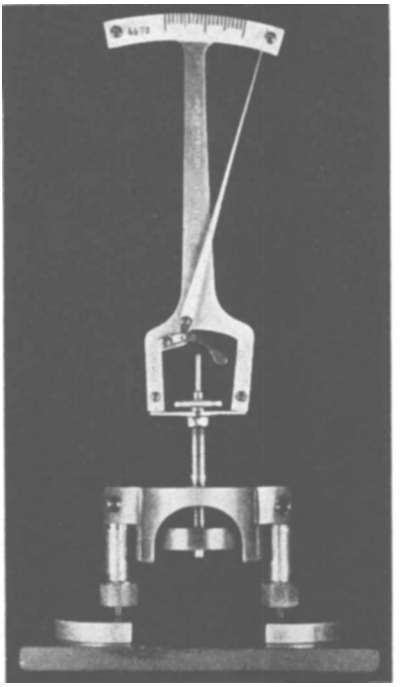

FIG. 1.
Figure showing apparatus mounted for use.

1 Schade, H., *Z. f. exp. Path. u. Therap.*, 1912, **11**, 369.
2 Inouye, K., *Acta Scholæ Med.*, 1931-32, **14**, 229.
3 Rondelli, N., *Minerva Med.*, 1934, **1**, 810.

related principles in their elastometer studies in edema in other parts of the body.

The apparatus (Fig. 1) is small, simple, accurate and easily applied. It consists of the head of a Schioetz tonometer adapted to a specially constructed base (Fig. 2) so that when the plunger which protrudes through the lower end of *a* (Fig. 2) is forced upward and flush with the lower circular surface of *a* by the application of a flat rigid surface, the pointer will register zero on the scale. The distance between parts *f* and *g* is made equal to the distance to which the plunger protrudes through the base of *a*. This distance is maintained by a spring mechanism *i* which also permits the entire apparatus to be brought down until parts *g* and *f* are approximated.

In making a determination, we place the patient in a sitting position with the forearm resting at heart level comfortably upon a table. The patient's arm is then adjusted so that the wrist is dorsiflexed and the finger to be studied rests with the dorsal surface of the two terminal phalanges upon a glass slab (see Fig. 1). The apparatus is then placed upon the glass slab over the finger tip so that the plunger rests directly above the most prominent point of the finger pad. Part *a* is then screwed up or down in part *b* until the distal end of the plunger just touches the surface of the finger pad.

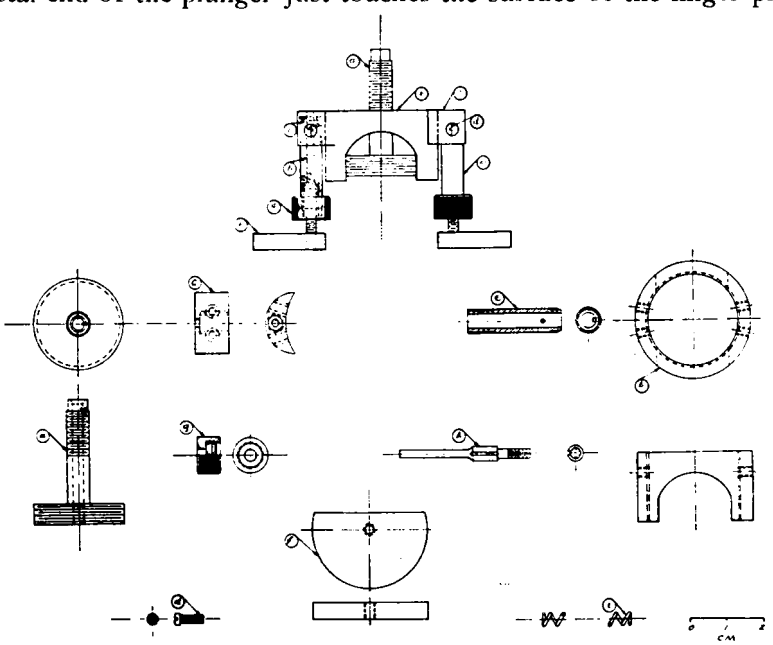

FIG. 2.

Details of construction of the base of the tonometer (all parts brass except steel spring, *i*).

Fine adjustment is permitted by the fine threading of the base of part *a* (80 to the inch). Pressure is then applied on part *b* until part *g* approximates part *f*. This permits the plunger to rest freely upon the finger tip.

It is obvious that if the tissues of the finger pad were perfectly rigid the end of the plunger would be forced upward until the pointer would register zero upon the scale. Since the tissues are not perfectly rigid and there are variations in tissue turgor, the plunger will sink into the tissues, compressing them until the resistance of the tissues equals the weight of the plunger. Therefore, the pointer will come to rest at some point upon the scale above zero, depending upon the tissue turgor, and these variations in scale readings may be used as quantitative expressions of tissue turgidity.

No movement of the hand or finger tip is permitted during a determination. In all determinations at least 3 readings were made which agreed within ±0.5 units.

We have made determinations in the finger tips of 25 normal individuals and 20 patients with vascular disease. The 5.5 g tonometer weight was used in all determinations. In normal subjects tonometer scale readings varied from 15 to 20+ units. The values did not correlate with age. In 9 of the 25 subjects, the tissue turgor of the finger tip was too low to register upon the scale. Such readings indicate that in these individuals the counter force offered by the tissues when compressed by the 5.5 g force through that distance is less than 5.5 g. Such readings are indicated as 20+. In 12 subjects the epidermis was removed with very fine emery paper until the skin rugae were smoothed out. There was no significant difference in the determinations before and after this procedure, thus indicating that the epidermis plays a minor rôle in the values obtained in normal subjects. Repeated determinations in the same individual over periods as long as 6 weeks have shown no significant variations. The tonometer readings were found to vary with position of the finger with reference to the heart. Above heart level, they were higher, and below heart level, lower.

In 20 patients with abnormal vascular states, some striking changes have been noted. In scleroderma, for example, the values at times approached absolute rigidity. In 3 patients with marked involvement of the fingers, values varied from 1.0 to 9.0 (mean 4.2) tonometer scale units. In one patient with early changes the value was 16. In Raynaud's disease the deviations from normal were not as marked. In 3 patients determinations varied from 10 to 13 scale units. In 2 patients with unilateral edema, the affected side showed readings which were definitely lower (10.5, 3.5) than the unaffected

side (15, 14). Similar results were found in a patient with bone felon (affected side 10.5, unaffected side 20+). The changes found in edema are well exemplified in the patient with cold allergy. The patient's hand was immersed in cold water (6°C) and withdrawn from time to time for readings. The course of the turgidity of the part is shown in Fig. 3. The volume of the finger tip increased from 3081 to 3489 mm³, a change of 13.2%. In essential hypertension, arteriosclerosis, and clubbed fingers, less definite changes were noted.

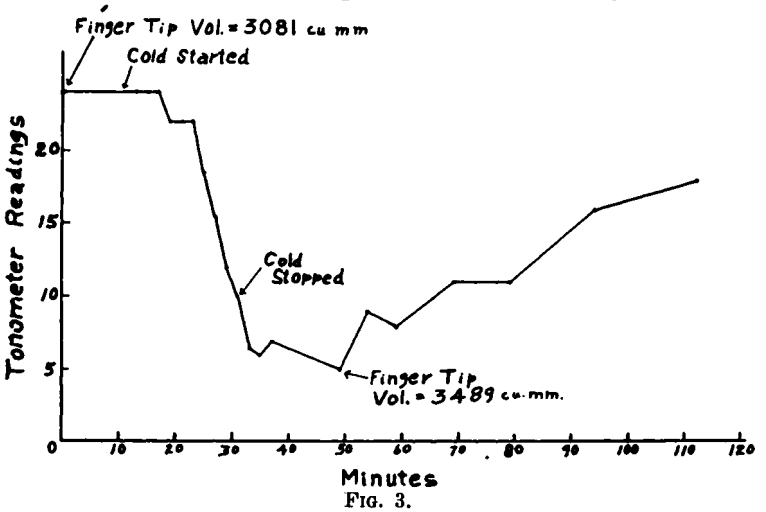

FIG. 3.

Course of tissue turgor of left index finger pad in a patient with cold allergy. The finger tip volumes were determined by a method previously described.[4]

Changes in tissue turgor of the finger pad can be quantitatively estimated by the tonometer, acting essentially as a sensitive mechanical palpator. The instrument measures the distance the plunger must traverse in order to compress the tissues sufficiently to produce a counter force equal to 5.5 g. This distance is determined by the firmness of the tissues and their ability to be displaced. Changes in these properties produced by physiologic and pathologic states may be detected quantitatively by this method and long before the ordinary methods of physical examination disclose such changes. For example, variations in these properties produced by change in position in the part above and below the heart level are easily recorded. Were the finger tip a sphere and encased in a relatively non-distensible envelope, as the eye, one could convert the tonometer scale readings into millimeters of mercury with the use of the Schioetz tonometer conversion scale. However, because of the physical characteristics of the finger tip, this cannot be done.

[4] Sodeman, W. A., *J. Clin. Invest.*, 1937, **16**, 787.

Remarkable changes in tonometer values were found in patients with diseases affecting chiefly the corium and subcutaneous tissues. This is well illustrated in scleroderma, the trophic changes of Raynaud's disease and edema. The well known increase in connective tissue and in its compactness in the former 2 diseases and the increase in interstitial fluid in the latter are sufficient to explain the increased firmness and turgidity of the finger tip found in these conditions. Since the method can be used to detect these changes, it may be used to follow objectively the progress of these conditions with or without treatment. This is particularly true early in the disease or later when changes are slight and ordinary methods of physical examination inadequate.

No significant changes could be attributed primarily to the epidermis except perhaps in 2 patients with arteriosclerosis and calloused hands. Their values of 9 and 10.5 contrast definitely with the values of 19, 20, 20+, and 20+ in remaining patients with arteriosclerosis who showed no epidermal thickening.

Conclusions. The application of a simple and accurate tonometer to the study of the tissues of the finger tip disclosed findings which may be used to follow the course of certain physiologic and pathologic states.

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Absorption of Cholecystokinin and Secretin from the Colon and Rectum.

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This work was undertaken to ascertain whether cholecystokinin and secretin may be absorbed from the colon and rectum in significant functional quantities. If so, these hormones might be so administered and serve as functional tests.

A preparation of cholecystokinin (CCK) and secretin was used which contained one dog unit of cholecystokinin in 0.3 mg and of secretin in 0.1 mg. This was administered per rectum to dogs and human subjects.

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