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EXPERIENCES WITH THE HARDY–WOLFF–GOODELL DOLORIMETER * †

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PAIN is the most common symptom that brings patients to the physician, yet it is a most difficult symptom for him to evaluate. Few patients have the ability to analyze this most unpleasant experience, or the words to indicate its severity. Various clinical methods have been suggested for measuring pain in an objective fashion, in an effort to minimize the subjective reaction of the test subject. The best known of these is the thermal radiation method developed by Hardy, Wolff and Goodell (1). They have designed a "dolorimeter" in which the heat source is a 500 watt incandescent lamp. The beam of light is focused by a condensing lens on a measured area of blackened skin. A rheostat and shutter timing device provide flexibility in control of the heat units reaching the skin in each testing dose. The usual exposure time is three seconds, and the instrument dial is read directly in millicalories per second per square centimeter. The average threshold for pain is indicated on the dial as a narrow range of values about the 220 millicalorie reading.

Our work with this instrument was not designed to reduplicate the studies which have been so expertly documented by the originators of the testing method. These studies are too well known to require detailed presentation here, but four subnotes have been appended which summarize the experiments and the interpretations to which we will subsequently refer. Our purpose in using the instrument was to determine whether or not it could furnish us with reliable data on the degree of pain which patients in our "pain clinic" claimed to suffer.

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However, before we could interpret tests done on patients, it was important that we become experienced subjects ourselves. As we gained experience, two questions evolved that required clarification: (1) Under what conditions is the pain "threshold" a constant? (2) Can an individual's threshold and tolerance for pain ever be free of "reaction" and be a "perception" only?

After more than one hundred hours of testing each other according to the described technics for determining pain threshold and the "dol" scale, we have arrived at some impressions that we believe should be recorded.

Our first difficulties were technical. The majority of these have been mentioned by Hardy, Wolff and Goodell in their articles, but some need further emphasis. In the first place, the instrument dials may not be accurate in terms of the number of millicalories actually reaching the skin since the output of the lamp is subject to variations with age and use. It is necessary at the outset of every experiment to calibrate the instrument with a standardized radiometer. It is also necessary to make certain that the opening and closing of the shutter is in accordance with the specified time intervals indicated on the instrument panel. Furthermore, it can be demonstrated that the pain threshold can vary with the intensity of the blackening of the skin, with the particular area of skin selected for testing (forehead, hand or forearm), with the time interval between tests, and with the pressure of the skin against the aperture.

The second difficulty lay in deciding the end point, that is, the painful experience that we would select as marking (a) the threshold for pain and (b) the degrees above threshold that marked out the steps to ceiling pain. In testing for the threshold we watched for the point at which the sensation of heat suddenly seemed to swell to a sharp prick or stab of pain just before the shutter closed. At the beginning of each experiment this end point could be identified quite readily in the neighborhood of 210 to 220 millicalories. There was more variability in the end point for ceiling pain. At times we could steel ourselves to heat intensities that burned the skin. At other times lower intensities seemed to swell more suddenly into pain and the threat of tissue damage made us pull back involuntarily from the instrument. This was particularly true when the usual three second exposure was used. If the instrument was set to deliver 100 millicalories continuously, the threat was less sudden and we could more readily tolerate ceiling pain. At the end of some fifteen seconds the pain would rise to an almost intolerable degree, but if we continued the exposure beyond a half minute or so this peak intensity passed, and although a burning pain would still be present, a pain which seemed to wax and wane persistently, it was within the limits of tolerance. On occasions we have submitted to exposures of this kind for from twenty to forty minutes. Such exposures produced deep burns that took a long time to heal, but we were convinced that there was such

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a thing as a ceiling for pain and that the destruction of the superficial sensory fibers marked the end of the zenith in this painful experience.

Up to this point in these experiments our experiences conform with those reported by Hardy, Wolff and Goodell. These authors had called attention to all the sources of error we had noted. They had emphasized the relative constancy of the pain threshold and the individual variability of the tolerance level. Indeed, they assumed that the threshold was a measure of "perception," while the tolerance for pain represented individual "reaction" to pain.

It was when we began trying to formulate an accurate concept of the "dol" scale that serious difficulties were encountered in determining end points. These difficulties were not immediately apparent. In fact, for several experiments we thought that we were rapidly acquiring an ability to identify pain intensities not only in "dols," but in actually identifying the millicalories of heat within a narrow range. Our confidence in this ability, however, was shaken by subsequent experiments. For example, after a series of tests in which the subject thought that he was being exceptionally accurate in his estimates, he would be almost unwilling to accept the experimental results which indicated that his judgment had been seriously at fault. We have a large accumulation of records that substantiate this point but we have found it difficult to graph our findings. We are, therefore, reporting one of these test runs as an illustration. It is to be understood that in making this test, as in all other experiments, an effort was made to control sources of error, and that the time intervals between test exposures were in accordance with the published reports of Hardy, Wolff and Goodell (1, 2).

The number of millicalories of heat applied is listed for each test dose, and the subject's verbatim response is recorded. In this test the subject was not attempting to estimate the number of millicalories but was trying to state whether or not the exposure was below or above threshold ("T"). If he thought that it was above threshold, he estimated the degree of pain in terms of dols (table 1).

TABLE 1

Test Dose Applied, mc.	Subject's Response
200	"Close to threshold"
180	"No"
210	"Very near"
170	"No"
210	"Yes, lower T"
210	"Yes, T"
200	"Just short"

Up to this point the experiment progressed according to expectation. In seven test doses it seemed to be established that the subject's threshold was his usual one of about 210 millicalories; however, as the testing continued, never exceeding the established threshold, the responses were as shown in table 2.

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TABLE 2

Test Dose Applied, mc.	Response
200	"No"
200	"Yes, more than T"
200	"Heat developed rapidly, 1 dol"
200	"2 dols at least, maybe 2–3 dol"
180	"No"
190	"Just under"
200	"Yes, T, maybe 1 dol"
190	"No"
200	"Threshold"

The subject still seemed to be doing well in his tests, although the results were not as accurate as we would like in an objective method for testing patients. The experiment was interrupted for fifteen minutes and then testing of this same subject was continued (table 3).

In the course of a little over two hours this subject had been given 26 testing doses, none of them above his usual threshold for pain. It will be noted that as the testing progressed something progressively deteriorated, either the accuracy of his judgment or the condition of the testing area of skin, or both. When testing doses above threshold values were used this deterioration was even more striking. The subject was often aware of a sense of warmth and perhaps a slight stinging sensation in the testing area of skin that persisted between tests. If he had been subjected to even one test at the level of 8 dols, this sensation of "zinging" and burning heat might persist for several minutes. Many times when the India ink was removed, it was seen that hyperemia of the skin had developed that persisted for some time. With the skin in this condition further testing demonstrated that intensities far below the usual threshold for pain caused definite pain of a burning character which might be estimated as high as 5 dols.

Potelunas, Meixner and Hardy, in a recent article (3), mentioned that it is usually possible to determine the pain threshold with the use of not more than five stimuli, and they stressed the importance of not over-stimulating the test area. This is quite correct and the observations reported above merely emphasize the point. It is our opinion that a single dose above threshold may alter the sensitivity of the skin for

TABLE 3

Test Dose Applied, mc.	Response
180	"T, well, I guess"
160	"No"
160	"No"
200	"2 dols" (cringed)
160	"Threshold"
160	"1 dol"
160	"T to 1 dol"
160	"1 to 2 dols"
180	"3 to 4 dols"
150	"Just under T"

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long intervals of time and that repeated tests at subthreshold values can produce a similar change. If this opinion is justified, then the clinical usefulness of this instrument is sharply limited if a single test area is employed. If multiple areas of blackened skin are suggested as an alternative, several possible sources of error are introduced, including the assumption that the threshold is the same in any testing area. We have not found this assumption to be so, either because of differences in sensitivity of the skin, or because of problems of equal blackening, equal pressure against the aperture of the dolorimeter, sweating, and the like. To summarize our results on various skin areas, we believe that (a) if the approximate threshold is known in advance, any given area of skin can be checked as to this end point with reasonable accuracy if the number of tests is restricted to four or five exposures; beyond this point the skin tends to become sensitized; (b) a single test dose that is well above threshold is capable of completely disorienting the subject as to his original threshold. Not only may he complain of pain from tests well below threshold intensity, but he may never again be certain that he recognizes the "prick" or "stab of pain" that seemed so characteristic in his first tests. Indeed, it seems to us that the point at which we felt a pricking pain, if we could identify it at all, was definitely raised above the threshold level. The confusion in interpretation arises from the feeling of intense warmth that appears before the point at which the pricking pain is felt, and this warmth is sufficiently intense to dominate the sensory experience.

DISCUSSION

Referring to our introductory questions, we would expect that the pain threshold, as tested by the dolorimeter, would be relatively constant under the following conditions: (1) All technical sources of error are controlled. (2) Only experienced subjects are used in making the test. This, in turn, implies that the subjects know exactly what end point is being sought and are devoting their full attention to the tests. (3) A minimal number of tests should be used to establish the threshold, none of them being materially above the subject's usual threshold.

The second question is more difficult to answer but we do not believe that the threshold is a measure of "perception" while tolerance is a measure of "reaction," as Wolff (4) has stated. Perception and reaction are psychologic terms that have no physiologic equivalents. It is true that there is more individual variation in the level of pain tolerance than in threshold. It will surprise no one that there should be greater agreement between different persons as to how much heat causes barely perceptible pain than in how much heat they can stand, but "reaction" is certainly a factor in the interpretation of any sensory experience, no matter what sensory modality is being tested or how intense the stimulation may be. In our tests we noticed that the ringing of a bell or a knock on the door would be enough to distract the subject so that the

test would have to be repeated before he could pass judgment on its intensity. The very fact that the test subject must devote his full attention to the test and that placebos and other forms of suggestion can so strikingly alter the pain threshold is clear evidence that psychologic factors can modify pain at any level of intensity.

SUMMARY

A study of the dolorimeter was made to determine whether or not it could be used to measure pain in clinical patients.

It was concluded that the inexperience of such subjects in the testing method would introduce new variables that would be most difficult to evaluate. In addition, these patients would be expected to have difficulty in equating two pains of different type—their own, and that of the dolorimeter.

Tests above threshold values tend to sensitize the skin. In clinical testing of patients, such sensitization would be difficult to avoid when grading pain intensities.

The dolorimeter may be useful in the hands of experts in evaluating the relative efficacy of analgesic drugs, but we doubt that the "dol" scale will prove of practical value in measuring pain in the clinic.

SUBNOTES

Technic for determining pain threshold.—The area of skin that is usually considered best for testing is in the center of the forehead. This area is first cleansed with ether or carbon tetrachloride and then painted black with fresh India ink. It is necessary that the blackening be uniform and as dense as possible. The subject is placed so that the black spot is in contact with the aperture of the dolorimeter. The shutter is then opened by pressing a button on the panel, permitting a test dose of low intensity to reach the skin for exactly three seconds. After an interval of at least a full minute, a second test can be performed, using a higher intensity of heat. The subject is aware of a sensation of warmth during these tests. He is told to watch for the point at which this sensation of warmth swells to a sharp and distinct prick or stab of pain. The point at which he experiences this prick is taken as his pain threshold.

A voltmeter on the control panel is calibrated to read the amount of heat actually reaching the skin in each test. It is read in terms of millicalories per second, per square centimeter. The accuracy of the instrument readings is checked by a standardized radiometer at the beginning of each series of tests.

Hardy, Wolff and Goodell found that the pain threshold was relatively constant in 150 individuals tested. The average value for the group was 220 mc. per second per centimeter^2. The maximal variation for the group was +15 per cent, with a variation within +5 per cent for

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the single individual, provided he concentrated on the experiment and maintained a detached, unprejudiced attitude.

Technique for determining pain tolerance.—Once the threshold has been determined, further tests are carried out at increasing intensities of heat stimulation. A point is finally reached at which the patient draws back from the aperture and refuses to submit to tests at higher values. This level is said to mark his tolerance for pain. Different individuals vary more in their tolerance for pain than in their thresholds for pain. Occasionally a subject will submit to intensities that actually burn his skin. The use of higher heat intensities merely increases the rate at which the burning takes place but does not increase the pain because, as destruction of the sensory fibers takes place, the pain sensation tends to diminish. The point at which burning begins is said to represent the ceiling for pain.

Since the pain threshold is a constant, Hardy, Wolff and Goodell take it as a measure of perception. Tolerance for pain, on the other hand, is more variable and is said to measure the individual's reaction to pain. These investigators also believe that pain does not summate, that is, ceiling pain resulting from the burning of large areas of skin would be no greater than that from burning a small area of skin.

Technic for establishing the "dol scale."—Hardy, Wolff and Goodell (5), after a long period of intensive testing of each other with the dolorimeter, established what they have called a dol scale. They were able to distinguish twenty-one perceptible gradations between pain threshold and the ceiling for pain. They combined two of these "jnd's" (just-noticeable differences) to make one dol. Accordingly, a scale was presented consisting of ten stimulus intensities ranging from an average of 220 mc. per second per centimeter^2 (threshold) to 480 mc. per second per centimeter^2 (ceiling). Such a dol scale would, as they indicated, have great usefulness in testing analgesic drugs, as well as degrees of pain encountered in clinical patients.

Dol scale measurements of labor pain.—Javert and Hardy (6) have reported their results of a study of pain intensity during childbirth. Thirteen women were followed throughout labor, tests being made in each phase of the stages of labor to gauge the severity of the pain. For example, immediately after a uterine contraction, while the memory of this pain was fresh in the patient's mind, heat tests were carried out to equate the pain with the corresponding number of dols produced by tests with the dolorimeter. The back of the patient's right hand was used in making the heat tests.

On the basis of these tests, checked by an additional study of 13 other cases, it has been stated that the pain in the first phase of the first stage of labor varies from 1 to 2 dols; in the second phase, from 3 to 4 dols;

in the third phase, from 5 to 7 dols; and in the fourth phase, from 8 to 10 dols. Most of their patients required some relief of their pain during the second stage of labor, which was assumed to represent ceiling pain, or 10½ dols.

REFERENCES

1. Hardy, J. D.; Wolff, H. G., and Goodell, H.: Studies on Pain; New Method for Measuring Pain Threshold; Observations on Spatial Summation of Pain, J. Clin. Investigation 18: 649–657 (July) 1940.
2. Hardy, James D.; Wolff, H. G., and Goodell, H.: Pain Threshold in Man, A. Research Nerv. & Ment. Dis., Proc. 23: 1–15, 1943.
3. Potelunas, C. B.; Meixner, M. D., and Hardy, J. D.: Measurement of Pain Threshold and Superficial Hyperalgesia in Diseases of Skin, J. Invest. Dermat. 12: 307–316 (May) 1949.
4. Wolff, H. G.; Hardy, J. D., and Goodell, H.: Studies on Pain; Measurement of Effect of Morphine, Codeine, and Other Opiates on Pain Threshold and Analysis of Their Relation to Pain Experience, J. Clin. Investigation 19: 659–680 (July) 1940.
5. Hardy, J. D.; Wolff, H. G., and Goodell, H.: Studies on Pain; Discrimination of Differences in Intensity of Pain Stimulus as Basis of Scale of Pain Intensity, J. Clin. Investigation 28: 1152–1158 (Nov.) 1947.
6. Javert, C. T., and Hardy, J. D.: Influence of Analgesics on Pain Intensity During Labor, Anesthesiology 12: 189–215 (March) 1951.

THIRD BIENNIAL WESTERN CONFERENCE

The advance program for the Third Biennial Western Conference on Anesthesiology to be held at the Ambassador Hotel, Los Angeles, California, April 8–10, has been released by the Program Chairman, Dr. Francis E. Guinney. Continuing the precedent which was established at the two previous Western Conferences, one main subject, The Nervous System, has been elected for this conference. The program follows:

Wednesday, April 8, 1953

Anatomy of the Nervous System as Applied to Anesthesiology—Verne T. Inman, M.D., Professor of Anatomy, University of California School of Medicine, San Francisco.

Physiology of the Nervous System Applicable to Anesthesiology—John Field III, M.D., Chairman, Department of Physiology, University of California School of Medicine, Los Angeles.

Pathology of the Nervous System Complicating Anesthesia—Cyril B. Courville, M. D., Professor of Pathology, College of Medical Evangelists, Los Angeles.

Round Table—Anesthesia for Central Nervous System Surgery.

E. M. Papper, M.D.—Moderator
C. Hunter Shelden, M.D.—Neuro-surgeon
John Dillon, M.D.—Physiologist
Cyril B. Courville, M.D.—Pathologist

Thursday, April 9, 1953

Pharmacology of Autonomic Blocking Agents—Mark Nickerson, Ph.D., M.D., Associate Professor of Pharmacology, University of Michigan School of Medicine, Ann Arbor.

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