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A CRITICISM OF
THE VALUE OF HAMMERSCHLAG'S METHOD
IN CLINICAL ESTIMATIONS OF THE SPECIFIC
GRAVITY OF THE BLOOD.

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IN the days of venesection, numerous observations were made upon the specific gravity of the blood. Large quantities of blood were clinically obtainable, and the estimations could in consequence be made by direct weighing by means of the pycnometer. As blood-letting fell more and more into disuse, sufficient quantities for the application of this method could no longer be easily secured, and the subject of the density of the blood received for a time but scant attention. Hayem, in his well-known textbook, *Du Sang*, which was published at Paris in 1889, makes a single reference to the matter, and disposes of it in a few words: "In reference to the question of specific gravity there is nothing further to be said than that it is chiefly dependent upon the number of the corpuscles." At the period at which he wrote, the pycnometric method was still the only one in general use, although Fano had some years prior to this introduced a means of indirectly estimating the specific gravity by the suspension of a drop of blood in solutions of gum of known density, and Roy had already improved upon this method by the substitution of solutions of glycerine in water. Soon, however, Lloyd Jones slightly further modified this method; Hammerschlag altered it by suggesting the use of a mixture of chloroform and benzol; and Schmaltz introduced a capillary pycnometer by which minute quantities of blood were weighed. All these methods, which rendered the observer independent of the use of the pycnometer, quickly passed into common application, and the estimation of the specific gravity was now brought within the range of easy clinical investigation.

Of the methods named, the most exact is necessarily that of the pycnometer, in which a certain quantity of blood is directly weighed and compared with the weight of a similar quantity of distilled water. Given careful manipulation, scrupulous cleanliness, and an accurate balance, the only possible error should lie in the fact that usually the blood is weighed at body-heat whilst the water is at room temperature. This source of error, as was shown by Schmaltz,¹ is so slight where small quantities are concerned as to be practically negligible, and the results obtained by the pycnometer may be regarded as correct. The method is however laborious, a costly apparatus is required, and the quantity of blood needed renders it inapplicable to ordinary clinical purposes.

Schmaltz's capillary pycnometer lacks the last mentioned objection; but the other difficulties all apply, and in addition, grave sources of fallacy appear inevitable when small quantities of blood are manipulated. Vaughan Harley in an unpublished series of observations has found that results obtained by the capillary pycnometer are inexact and variable.

The Roy or Lloyd Jones method is open to the objection that it is very laborious and a relatively large amount of blood is needed for its use.

Hammerschlag's method, on the other hand, is well adapted to clinical practice, for it is easily manipulated, does not necessitate the employment of an accurate and costly balance, and can be carried out with a very few drops of blood. It is for these reasons no doubt that this method has passed so widely into use, and is now employed in the majority of clinical observations upon the subject of the density of the blood. Such observations have of recent years become increasingly frequent in investigations into the condition of the blood in health and in disease. Many observers attach great importance to the investigation of this factor, some even going so far as to assert that, owing to a close degree of uniformity between them, the estimation of the specific gravity renders unnecessary the determination of the haemoglobin value or of the solids and proteids of a particular specimen of blood. We are not,

however, at present concerned in the consideration of this aspect of the subject. The object of this paper is to inquire into the value of the results obtained by the particular, widely-employed method in question.

Results obtained by Hammerschlag's method are commonly accepted as sufficiently exact for all clinical purposes, although very few reliable experimental data exist. Hammerschlag² himself states that figures obtained by his method are lower by 0.001 than the actual value of the specific gravity as controlled by pycnometric estimations. He appears, however, to have performed only two pycnometric control experiments, and his results—as will be seen later in the light of Levy's inquiry into the source of error in the application of this method—are open to question. Menicanti³ and Monti⁴ controlled their readings by means of Schmaltz's pycnometer, and obtained figures which corresponded closely; but the control method employed by them is itself not free from serious errors. Dieballe⁵ states that on the ground of numerous control estimations he found Hammerschlag's method to yield results which were too high by 0.003 to 0.004; he gives, however, no details as to the method by which the control was exercised. The only really satisfactory records are those by A. G. Levy,⁶ who controlled his results by the pycnometer and obtained readings uniformly higher than the actual values by 7° or 8° of the hydrometer scale. His observations are unfortunately few in number.

It appeared to me from these considerations that further investigations into the accuracy of the method were required before results obtained by this method can be finally accepted.

In the course of a series of experiments upon the blood of dogs⁷ I had occasion in a large series of cases to estimate carefully the specific gravity of the blood and its serum. Both Hammerschlag's method and the pycnometer were employed in every case. The blood used for the indirect method was obtained from the capillary circulation of the ear, care being taken to avoid the least interruption of the venous return, and only full, freely-flowing drops being accepted. That used for the pycnometer was drawn from the femoral artery. The serum used for both methods was obtained from centrifugalized blood drawn from the same artery.

In employing Hammerschlag's method, the chloroform-benzol mixture was adjusted beforehand to the anticipated density. A drop was then carefully blown from a pipette into the centre of the fluid, care being taken to avoid imparting an impetus towards either an upward or a downward tendency. Along with occasional stirrings, small quantities of chloroform or benzol were then added accordingly as the drop tended to rise or fall. Whenever it had become stationary at at one level the mixture was filtered through fine muslin, its density estimated by means of a hydrometer, and the process repeated with a fresh drop. Generally three or four estimations were made, and the mean taken when the results differed. As a rule, however, the variations were very slight. Thus in one case the estimation of four successive drops of the same serum gave these results: 1.026, 1.028, 1.026, and 1.026. The hydrometer used was one of conveniently small size such as is generally used for this purpose. The same instrument was employed in all the observations. The reading was in each case taken at the point of lowest level of the intersection of the hydrometer scale by the fluid meniscus. I experienced no great inconvenience from the difficulties that are occasionally attributed to this method. Thus, Busch and Kerr⁸ speak of the danger of the inclusion of an air bubble in the drop; this did, it is true, sometimes occur, but it was easily recognized and a fresh drop used. Askanazy⁹ refers to the difficulty of stirring the mixture without breaking the drop; this I found could generally be overcome by using a small-sized drop. Von Limbeck¹⁰ points out that the drop may break, and one portion rise whilst the other falls; this actually occurred on a few occasions as the result, no doubt, of the absorption of one or other of the constituents of the chloroform-benzol mixture. This mishap can generally be prevented by rapid manipulation, for as Zuntz has shown,¹¹ absorption occurs only after the lapse of some little time. When it did occur the mixture was strained and the observation repeated. On a few rare occasions, too, a portion of the drop would adhere to the sides or bottom of a glass which had not been thoroughly dried; in that case attention was confined to the portion still floating and the reading controlled by a second estimation.

The results of my observations are recorded in Tables I—IV. Thirty-three control estimations in all were made. Of these, 13 were made upon the blood of normal dogs (Table I); 12

TABLE I.—Specific Gravity of Normal Blood.

Experiment	1	2	3	4	5	6	7	8	9	10	11	12	13	Average.
Hammerschlag ...	1.072	1.069	1.068	1.065	1.067	1.071	1.070	1.070	1.067	1.069	1.067	1.069	1.066	1.068
Pycnometer ...	1.061	1.058	1.056	1.052	1.055	1.059	1.057	1.058	1.054	1.059	1.053	1.057	1.054	1.056
Difference ...	0.011	0.011	0.012	0.013	0.012	0.012	0.013	0.012	0.013	0.010	0.014	0.012	0.012	0.012

TABLE II.—Specific Gravity of Normal Blood Serum.

Experiment	1	2	3	4	5	6	7	8	9	10	11	12	Average.
Hammerschlag ...	1.040	1.037	1.038	1.035	1.035	1.035	1.047	1.037	1.034	1.037	1.035	1.036	1.037
Pycnometer ...	1.029	1.027	1.025	1.022	1.024	1.023	1.035	1.026	1.023	1.025	1.023	1.024	1.025
Difference ...	0.011	0.010	0.013	0.013	0.011	0.012	0.012	0.011	0.011	1.012	0.012	0.012	0.012

TABLE III.—Specific Gravity of Anaemic Blood.

Experiment.	1	2	3	4	Average.
Hammerschlag ...	1.066	1.061	1.065	1.052	1.061
Pycnometer ...	1.055	1.049	1.052	1.041	1.049
Difference ...	0.011	0.012	0.013	0.011	0.012

TABLE IV.—Specific Gravity of Anaemic Blood Serum.

Experiment.	1	2	3	4	Average.
Hammerschlag ...	1.033	1.033	1.038	1.031	1.034
Pycnometer ...	1.023	1.021	1.026	1.020	1.022
Difference ...	0.010	0.012	0.012	0.011	0.012

upon the blood serum of normal dogs (Table II); 4 upon the blood of dogs rendered anaemic by bleeding (Table III); and 4 upon the blood serum of similarly anaemic dogs (Table IV).

On studying the tables, we find that Hammerschlag's method invariably yielded excessive readings. The error amounts on an average to a difference of 0.012 in excess of the real values. In all four series of observations the same average error is struck. On analysing the individual results, we find that in 42 per cent. of the total number of observations, the difference corresponds actually to the figure obtained as an average. In 28 per cent. it is lower by 1°, and in 18 per cent. it is higher by 1° of the hydrometer scale than the average. A difference in this connexion of a unit in the fourth place of decimals is, however, so fractional as scarcely to be worthy of serious attention, and we may consequently conclude that in 88 per cent. of the total number of observations the average error of 0.012 was actually maintained. In the remaining small percentage of cases the variation from the average was very slight indeed, surpassing it by 2° in 3 per cent. of the cases, and falling short of it by 2° in the remaining 9 per cent. The difference in the results by the two methods is thus strikingly uniform, and this uniformity is displayed in the case of anaemic as well as in the case of healthy blood and blood serum.

Since the performance of the above experiments A. G. Levy¹² has carried out an admirable research into the origin and extent of the error which occurs in the use of Hammerschlag's method. He found that the extent of the error depends upon the form and size of the hydrometer used. In order, therefore, to obtain constant results the same instrument should always be employed. The source of error depends, he found, upon the use of hydrometers which have been standardized in water or watery fluids. A mixture of chloroform and benzol, owing to its lower surface tension, exercises a less powerful traction than water upon the stem of the instrument, and the hydrometer consequently gives readings which are higher than the actual value. An error must thus always lie in the direction of an excess, and it is for this reason that we question the accuracy of the observations in which Hammerschlag obtained results that were lower than the actual value of the specific gravity. The source of the error may be obviated either by the use of a special hydrometer which has been standardized in a chloroform and benzol mixture, or by the employment of a rough method of correction, which may be applied to any hydrometer that is graduated from 1.000.¹³ It is advisable that one or other of these methods should in future be adopted in order that the results of different observers—or the results obtained by individual observers at different times with different hydrometers—may be brought into line. It is particularly advisable in the case of those observers who propose

to utilize their results for the determination, by calculation of the haemoglobin value of the blood.

CONCLUSIONS.

From the consideration of the above investigations we arrive at the following conclusions:

1. Provided the same hydrometer is used, Hammerschlag's method of estimating the specific gravity of the blood is clinically easily applied, and yields, both in health and disease, results which are uniform and reliable.

2. An error is associated with the use of this method, which is always in the direction of an excess. The excess is, however, uniform and constant.

3. As was shown by A. G. Levy, the error may readily be obviated by the use of a specially standardized hydrometer, or by the application of the rough method of correction suggested by this observer.

In conclusion, I wish to express my sincere indebtedness to Professor Vaughan Harley for many suggestions and much kindly advice, and to Dr. F. W. Goodbody for his valuable assistance in the labour of carrying out the control experiments.

NOTE AND REFERENCES.

¹ *Deut. Arch. f. klin. Med.*, 1891, xlvii, p. 145. ² *Wien. klin. Woch.*, 1890, p. 1018 and *Zett. f. klin. Med.*, 1892, xx, p. 444. ³ *Deut. Arch. f. klin. Med.*, 1892, l, p. 407. ⁴ *Arch. f. Kinderheilk.*, 1894-5, p. 223. ⁵ *Deut. Arch. f. klin. Med.*, 1896, lvii, p. 302. ⁶ *Journ. of Path. and Bact.*, 1898, p. 317. ⁷ *Journ. of Physiol.*, 1903, xxix, p. 18. ⁸ *Med. News*, 1895, lxxvii, p. 678. ⁹ *Deut. Arch. f. klin. Med.*, 1897, lix, p. 385. ¹⁰ *Grundriss d. klin. Pathol. des Blutes*, Jena, 1896, p. 45. ¹¹ *Arch. f. d. ges. Physiol.*, 1897, lxxvi, p. 549. ¹² *Proc. Roy. Soc.* 1902, lxxi, p. 171. ¹³ This process is described by the author of the research as follows: "The method consists of adjusting the proportions of a mixture of chloroform and benzol until a small drop of water immersed neither sinks nor floats. The mixture being thus of the same specific gravity as water itself, the reading of the hydrometer in it is its error at this degree, and in the case of a well-constructed and accurately graduated hydrometer, this error holds good with only a negligible increase throughout the scale."

A PASTEUR INSTITUTE FOR TEXAS.—The Texas State Legislature has made a grant of £1,000 towards the establishment and maintenance of a Pasteur Department for the treatment of hydrophobia in the State, in connexion with the State Lunatic Asylum at Austin and under its management.

INSANITY IN NEW YORK.—The statistics of the New York State Commission in Lunacy show that there has been an increase in the number of insane in the State during the past year amounting to about 40 per cent. above the normal. The observations of the Commissioners indicate that there is a relation between the increase of insanity and the development of industries which is sufficiently pronounced to render doubtful the popular belief that the isolation and monotony of farm life are conducive to insanity, especially among women.