

DENSITIES OF COMMON SPINAL ANESTHETIC SOLUTIONS AT BODY TEMPERATURE * †

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THERE is as yet no unanimity concerning the specific gravities of cerebrospinal fluid and spinal anesthetic solutions at body temperature.

The temperature of the internal organs, presumably including cerebrospinal fluid, lies between 37 and 38 C. (1); yet the majority of spinal anesthetic solutions are administered at room temperature. The resultant mixture within the subarachnoid space will lie between room temperature and body temperature and is assumed to rise to body temperature before being fixed upon the spinal roots. The initial part of this paper deals with the qualitative testing of this assumption.

Commonly one may use small volumes in the form of hyperbaric solutions or larger volumes in the form of hypobaric solutions in order to attain spinal analgesia to a certain level. For experimental purposes, a hypothetic analgesia to the ninth thoracic dermatome was considered. The subarachnoid space contains 6 ml. at this level (2). A representative hyperbaric solution might be 2.4 ml. of 0.5 per cent tetracaine in 0.45 per cent saline solution and 5 per cent dextrose, which is 1.2 ml. of 1 per cent tetracaine (commercially prepared in physiologic saline solution) mixed with 1.2 ml. of 10 per cent dextrose. A representative hypobaric solution was considered to be 12.0 ml. of 0.1 per cent tetracaine in 0.09 per cent saline solution, which is 1.2 ml. of 1 per cent tetracaine mixed with 10.8 ml. of distilled water. Other agents were not tested because the rate of temperature rise is more dependent upon the volume of aqueous solution than upon the chemical nature of the agent, since the specific heat of water is much higher than that of dissolved substances.

The source of "body heat" was a water bath varying in temperature only from 37.5 C to 38.0 C. The membranes of the subarachnoid space and the blood vessel walls were represented by thin rubber finger cots for the small volume and rubber condoms for the larger volume. A total of 6.0 ml. of cerebrospinal fluid drawn by lumbar puncture within

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two hours of the completion of the test was placed in each finger cot or condom submerged in the water bath and allowed to attain the temperature of the water bath.

The 2.4 ml. solution at room temperature, 27 C., was placed in each of the three finger cots. Immediately the temperature of the mixture fell 2 to 3 C., but within two minutes the temperature of the water bath was again attained. This is well within the period of fixation of the fastest fixing agent, procaine, which is reported to be five minutes (3). The 12.0 ml. solution at 27 C., was placed in each of the three condoms. Immediately the resultant temperature fell 6 to 8 C., within one minute rose to 37 C., and also again attained the temperature of the water bath within two minutes. This, too, is within the range of fixation of the commonly used hypobaric agents. Therefore it appeared that the most useful densities of spinal anesthetic solutions would be those determined at body temperature.

Most values pertaining to the density of a spinal anesthetic solution are reported as specific gravity, because the instruments used measure densities of the solutions relative to water. This requires that two temperatures be known and reported, that of the solution and that of the water. In common practice the former temperature is reported in the numerator, the latter temperature in the denominator. For example, to our knowledge, the only thorough specific gravity of a solution measured at body temperature is that of 0.066 per cent nupercaine in 0.5 per cent saline solution which is reported to be 1.0036^{37}_{37} † and 0.9962^{37}_{37} (4). Unfortunately, in too many instances these two temperatures are not reported in the literature, and the present state of uncertainty exists (4, 5).

One temperature report, that of the water, may be eliminated by presenting results in the form of density. The calculation of density from specific gravity is discussed later, and it is hoped that future investigators will report completely by designating either density with one temperature or specific gravity with two.

Extrapolation to 37 C. of the pharmaceutical companies' published specific gravities at 25 C. was considered, as it has been demonstrated upon cerebrospinal fluid in the range of 74-99 F. (23-37 C.) that the specific gravity falls one-thousandth of unity for every 4.4 to 5.0 C. rise in temperature (6). However, only one temperature is usually reported; and the chemical nature of the solute appears to be important in the temperature change of specific gravity, since the specific gravity of urine, a substance whose specific gravity is similar to cerebrospinal fluid, falls one-thousandth of unity for each 3 C. rise in temperature (7).

A direct reading type Westphal Specific Gravity Balance (8, 9), accurate to five significant figures, that is, 1.0123, was used to determine the specific gravities of the tabulated solutions (table 1). The temperature of the water bath varied only from 37.0 to 37.5 C. during these

† Note that all temperatures are in degrees Centigrade unless specified to the contrary.

determinations, and the solutions measured while in the water bath are reported at 37 C. The balance was calibrated against triple distilled water at 37 C., and then each solution at 37 C. was weighed three times, the mean value being reported. The two specimens of human cerebrospinal fluid determined were collected under mineral oil and stoppered until the time of determination which was within one hour of collection. The tabulated concentrations are those of the solutions as administered subarachnoidally. Proprietary solutions were measured whenever possible, as they probably represent the solutions most used in hospitals throughout the United States. These are designated by the use of the proprietary name. Where dilutions of proprietary agents were used, this has been indicated in table 1.

The specific gravity of a solution at 37 C. relative to water at 37 C., $\frac{D_{37}}{D_{37}}$, was converted to the density of the solution at 37 C., 37, as follows: The specific gravity is the ratio of the density of the solution at 37 to the density of water at 37. By cross multiplication the density of the solution at 37 is the product of the specific gravity and the density of water at 37; that is, specific gravity = $D_{\text{solution}}/D_{\text{water}}$; $D_{\text{solution}} = \text{specific gravity} \times D_{\text{water}}$. The relative density of water at 37 C. is 0.9934 Gm. per milliliter (10) and is substituted into the aforementioned equation.

Hence, when a density is reported, only one temperature report is necessary, since the investigator, who knows both temperatures, elim-

TABLE I
DENSITIES AND SPECIFIC GRAVITIES OF TESTED SOLUTIONS

SOLUTION	Density gm./ml. 37 °	Specific Gravity $\frac{D_{37}}{D_{37}}$ *
Triple distilled water	0.9934	1.0000
Human cerebrospinal fluid		
Specimen A, xanthochromic	1.0007	1.0073
Specimen B, colorless	0.9998	1.0064
Procaine hydrochloride, 5% in 0.05% epinephrine and 0.2% sodium bisulfite †	0.9995	1.0061
Procaine hydrochloride, 2.5% in water	0.9986	1.0052
Tetracaine hydrochloride (Pontocaine), 0.5% in 0.45% saline and 5% dextrose	1.0137	1.0204
Tetracaine hydrochloride (Pontocaine), 0.1% in 0.09% saline	0.9953	1.0019
Nupercaine (dibucaine hydrochloride), 0.25% in 5% dextrose †	1.0111	1.0178
Nupercaine (dibucaine hydrochloride), 0.066% in 0.5% saline †	0.9967	1.0033
Piperocaine hydrochloride (Metycaine), 5% in Ringer's solution	1.0046	1.0113
Piperocaine hydrochloride (Metycaine), 1.5% in Ringer's solution	1.0023	1.0090
Diethoxin (Intracaine), 2.5% in 0.45% saline and 5% dextrose	1.0167	1.0235

* Temperatures are expressed in degrees Centigrade.

† Proprietary solutions. All other solutions are dilutions of a proprietary agent.

inates the water factor. It should be observed also that the density at 37 is numerically equal to the specific gravity $\frac{37}{37}$, since the relative density of water at 4 C. is 1.0000 Gm. per milliliter (10); that is, specific gravity = D solution/1.0000.

DISCUSSION

In addition to simplifying the expression of the results by omission of water as a standard, densities of spinal anesthetic solutions lead to a clearer concept of the baricity of the solutions. Anesthesiologists merely desire to know the relation of the density of the solution at body temperature to the density of the cerebrospinal fluid at body temperature. This value, which may be termed "baric gravity," if above unity indicates a hyperbaric solution and if below unity indicates a hypobaric solution. We have been determining this baric gravity mentally by comparing the specific gravity of the solution to the specific gravity of the cerebrospinal fluid. However, reliable results were obtained only if these specific gravities were computed from densities at body temperature and water at equal temperature.

If a reliable specific gravity of cerebrospinal fluid exists, the baric gravities of the reported solutions could be computed. Unfortunately it does not. One value, 1.003, at body temperature (6) has been challenged because the temperature of the reference water was in doubt (11). Another value, 1.0029 $\frac{37}{37}$, was calculated from a measured value of 1.0045 $\frac{27}{37}$ upon the assumption that the thermal coefficient of expansion of cerebrospinal fluid is identical with that of water (4). However, this does not agree with the aforementioned experimental finding that for every 4.4 to 5.0 C. rise in temperature the specific gravity falls 0.001 (6). Several sources (11, 12, 13) report a mean specific gravity of 1.007, but the two requisite temperatures are either not stated or are not the desired 37 C.

It is hoped that an adequate series of replete cerebrospinal fluid densities or specific gravities will soon supplement our two values. Our two specific gravities $\frac{37}{37}$ tend to confirm those of investigators who maintain that the mean value is 1.007. The density at 37 derived from this value is 1.000, and the baric gravity of any solution at 37 C. relative to cerebrospinal fluid at 37 C. would be numerically identical with the solution's density; that is, baric gravity = D solution/D cerebrospinal fluid = D solution/1.000. Thus, if on adequate series of cerebrospinal fluid specific gravities $\frac{37}{37}$ confirms the value, 1.007, the baric gravity $\frac{37}{37}$ of any tested solution will be numerically equal to its density at 37 C.

SUMMARY

Spinal anesthetic solutions administered at room temperature were shown qualitatively to attain body temperature before the time of fixation to the spinal roots had elapsed.

Densities of the more common spinal anesthetic solutions at body

temperature are reported, as well as their specific gravities relative to water at 37 C.

Baric gravities, computed from a comparison of the densities of solutions and cerebrospinal fluid at body temperature, will clearly represent the state of the baricities of the solutions.

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CONNECTICUT STATE SOCIETY OF ANESTHESIOLOGISTS

The annual meeting of the Connecticut State Society of Anesthesiologists will be held in conjunction with the annual meeting of the Connecticut State Medical Society in Hartford, Connecticut, on the afternoon of Thursday, May 1, 1952.

Dr. Stanley J. Sarnoff, Harvard University, will speak on, "The Physiology of Electrophrenic Respiration."

Dr. Raymond F. Courtin, Mayo Clinic, will speak on, "Electroencephalography in Clinical Anesthesia."