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Temperature Order Effects in the Caloric Reaction

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Abstract: Does it matter in what order the four irrigations are conducted in the caloric test? It has been suggested that warm water (44°C) elicits stronger reactions than does cold water (30°C), which might be explained simply by slight differences in water temperatures. However, if it can be shown that starting with cold water diminishes the difference between the warm and cold irrigations, it might be worthwhile to apply the cold irrigations first.

Binaural, bithermal caloric irrigation was conducted in darkness using electrooculography. Maximum slow-phase velocity was measured. One hundred and eighteen consecutive patients from our laboratory were tested with warm water first and then with cold irrigations. In a second run, 108 subjects were irrigated with cold water before the warm.

Employing cold irrigations first produces a smaller difference between the warm and the cold irrigations than does the opposite order. However, the lateral and directional preponderances, according to the formulas of Jongkees, are not affected by this change of irrigation order. The fact that initial warm-water irrigations cause the temperature effect differences to be larger than do initial cold-water irrigations is a phenomenon having only marginal clinical implications.

The caloric test aims at establishing both the absolute levels of the two lateral semicircular canals responses to standardized thermal stimuli and the relative function between the two sides. It is usually done in a standardized fashion, using either temperature to begin, conducting testing of the two sides in a defined order, and then shifting to the other temperature. A minimum of 5 minutes should be spent between the end of the nystagmic reaction and the start of the next irrigation. Temperatures usually are fixed at 30° and 44°C, but modifications of the irrigation technique exist [1]. The amount of water irrigated over a certain period should also be standardized.

The caloric reaction has been the subject of many studies and remains controversial [2]. Factors primarily suggested to influence the results in normal subjects are the order of irrigations, different effects of the two temperatures and, possibly, an inherent left-right asymmetry of the caloric responses [3–5].

It is obvious that temperature effects are important, at least as long as the thermal load imposed during an irrigation does not oversaturate the reaction. Temperatures of 30° and 44°C are symmetrical around a normal body temperature of 37°C. However, as some studies use alternative temperatures [2], this factor merits attention. Fitzgerald and Hallpike [6] measured duration of nystagmus and found longer reactions to cold water than to warm water, whereas the same finding was described by Mehra [7] in conjunction with lower maximum slow-phase velocity (SPV) for the cold water. The finding that warm water elicits more vigorous SPVs has also been found by Sills et al. [8], yet other studies have found no differences between temperatures. To our knowledge, the importance of body temperature on caloric responses has not attracted much scientific attention.

The order of irrigation may influence responses, as repeated exposure has been shown to cause habituation [9] and the tested subject may be in a diminished arousal as testing progresses, owing to mental or physi-

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cal tiredness [10–13]. The usual measure of caloric side difference, the lateral preponderance according to Jongkees' formula [14], is slightly biased owing to irrigation order effects. Furman and Jacob [2], using temperatures of 27° and 44°C, administering the cold before the warm water, and irrigating the left side before the right, found that the expected value from Jongkees' formula in normal subjects was a 5.16% weaker response on the right side. Approximate correction of this discrepancy may be accomplished simply by adding 5.16% to the lateral preponderance score in favor of the responsiveness of the side that was irrigated last for each temperature. Another method of correction aims at adjusting each caloric response by a numerical factor, specific for each laboratory, to yield an expectancy of zero for the lateral preponderance in normal subjects.

We measured the caloric responses using two different temperature orders in two prospective sequences of patients referred to our clinic for otoneurological evaluation. The only constraints on subject selection were that subjects could undergo water irrigation of both ears and that the caloric responses were not absent bilaterally. We wanted to determine whether our clinical suspicion of more vigorous reactions to the warm water held true and whether this outcome is affected by the order of temperatures. Finally, the statistical importance of such effects on the measures of side differences was tested.

MATERIAL AND METHODS

Material

In the first series (warm water first), 118 consecutive patients underwent the normal otoneurological test battery in our laboratory. No presumption of diagnosis was made. None of the subjects had bilaterally absent caloric reactions.

In the second series (cold water first), 108 consecutive patients were tested on the same basis as in the first series.

Methods

Bithermal (30° and 44°C), binaural caloric irrigation with 150 ml of water was performed in darkness and recorded by electronystagmography. Five minutes were allowed to lapse after cessation of the nystagmic reaction before the next irrigation was performed. Maximum SPV was measured in degrees per second. The lateral preponderance between the left and right sides, according to Jongkees' formula, was calculated. The directional preponderance for left and right beating nystagmus was calculated accordingly.

In the first series, the warm-water irrigation preceded the cold, whereas in the second series the cold-water irrigation preceded the warm. In both series, the right side was irrigated before the left.

Differences between the reactions to the warm and cold water were compared using Student's *t* test. A probability level of 5% was considered significant.

RESULTS

The mean SPVs and standard deviations for series one and two are displayed in Tables 1 and 2, respectively. The figures in those tables suggest that warm water in general elicits a stronger reaction than cold. This finding can, however, be explained entirely by small differences in the temperatures of the water compared to body temperatures. The study was not performed during any warm weather, and none of the patients had fever.

We wanted also to investigate whether the differences between warm and cold irrigations depend on which temperature is presented first. Such a finding could imply that the caloric reaction is order-dependent and that the dependence is larger (or smaller) for more vivid reactions. Hence, we computed the difference between the warm and cold irrigations of the right ear (mean plus or minus SD). For warm water first, the difference was 4.97 ± 9.83 degrees/sec and, for cold water first, 1.20 ± 6.97 degrees/sec. This was repeated for the left ear: For warm water first, the difference was 6.06 ± 12.40 degrees/sec and, for cold water first, 4.00 ± 8.41 degrees/sec. The data for the left and right ears in the cases in which warm water was irrigated first are added: 5.57 ± 9.12 degrees/sec; for the cases in which cold water was irrigated first, the datum is 2.47 ± 5.29 degrees/sec. This is a highly significant difference ($p < .003$ (two-tailed *t* test).

The lateral preponderance describing the caloric side difference ($p < .77$) and the directional preponderance ($p < .83$) were not affected by the order of the water temperatures.

DISCUSSION

In this series of unselected patients passing through our otoneurology laboratory, we showed that if the warm-

Table 1. Results (in degrees per second) from First Series, in Which Warm-Water Irrigation Was First (N = 118)

	Warm Right	Warm Left	Cold Right	Cold Left
Mean SPV	20.01	22.06	15.04	16.15
SD	12.98	16.31	7.42	8.01

SPV = slow-phase velocity.

Table 2. Results (in degrees per second) from Second Series, in Which Cold-Water Irrigation Was First (N = 108)

	Cold Right	Cold Left	Warm Right	Warm Left
Mean SPV	17.31	18.92	18.28	22.84
SD	10.08	10.46	11.90	13.30

SPV = slow-phase velocity.

water caloric irrigations were conducted first, the differences between the reactions of warm and cold irrigations were larger than if the cold water was administered first. However, the most often used clinical outcomes of the caloric reactions—caloric side difference and directional preponderance—were found not to be affected by the order of the irrigation temperatures.

These findings suggest that more vivid caloric reactions tend to diminish the effects of subsequent irrigations more than do smaller reactions, a phenomenon that is not strictly an order effect. As it does not affect the main outcome of the test—namely, estimating side differences—this phenomenon is of limited clinical importance. However, its study in a large sample of normal subjects could elucidate further the physiology of the caloric reaction.

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