

The Electrocardiographic Responses Provoked by Apneic Facial Immersion in Hot Water

Ryosuke OKANO

Abstract

The purpose of this study was to elucidate the characteristic of electrocardiographic response provoked by apneic facial immersion in hot water. Nineteen healthy Japanese male subjects (19.8 ± 1.1 y.o.) participated in this study. The electrocardiogram was recorded under the following 5 conditions: 1) Breath holding in air (BHA); 2) Facial immersion breathing through a snorkel (FIBS); 3) Apneic facial immersion of 5°C water (5°C AFI); 4) Apneic facial immersion of 35°C water (35°C AFI); 5) Apneic facial immersion of 45°C water (45°C AFI). The relative change rate of R-R interval to the value in rest and the incident rate of arrhythmia were compared focusing on the results of 45°C AFI.

From these results, it was revealed that the bradycardiac response and incident rate of arrhythmias provoked by 45°C AFI were nearly the same as those provoked by 35°C AFI.

key words : electrocardiographic response, hot water, apneic facial immersion, R-R interval, arrhythmia

I. Introduction

The incidence of remarkable bradycardia and lethal arrhythmia provoked by apneic facial immersion (AFI) is thought to be connected with one of the causes in drowning, so the AFI test is very significant for medical check-up for swimming^{1,2)}. Although there is much literature related to the variations of cardiovascular system provoked by AFI, the used experimental water temperature in most of the studies^{1~6)} is limited to 0°C through 35°C of neutral temperature (which has no heat exchange between human body and the outside environment). To the best of my knowledge, there were only a few studies^{7,8)} in which the water temperature of 35°C~40°C was used, and the sole study in which the water temperature more than 40°C was used was that of Yamaji et al⁹⁾. However his study paid no attention to the incidence of arrhythmias provoked by AFI of different water temperature.

Consequently this study was conducted to elucidate the characteristic of electrocardiographic response (R-R interval and arrhythmia) provoked by apneic facial immersion in hot water by comparing the electrocardiographic changes under various conditions.

II. Subjects and Methods

Nineteen healthy Japanese male subjects (Age : 19.8 ± 1.1 y.o., Stature : 170.8 ± 6.3 cm, Weight : 63.0 ± 10.7 , Mean value \pm SD) participated in this study. They had no habit of daily regular exercise. After 10 minutes sitting rest, the subjects carried out breath holding in air (BHA), facial immersion breathing through a snorkel (FIBS), AFI of 5°C water (5°C AFI), AFI of 35°C water (35°C AFI), and AFI of 45°C water (45°C AFI). The time interval in each experiment was 5 minutes, and each experiment was done in random order every subject.

The respiratory stage in breath holding was inhalatory one, and the immersion time was 45 seconds. The reason for it was that the maximal bradycardia had been often observed within 45 seconds from the beginning of apneic facial immersion²⁾. The electrocardiogram (DS-5600 system, FUKUDA DENSHI Inc., Chest bipolar lead CM_5) was recorded during 30 seconds in rest, entire time in immersion, and 60 seconds in recovery.

The mean values of 10 consecutive R-R intervals in rest, 3 consecutive R-R intervals every 5 seconds in load, and 3 consecutive R-R intervals every 10 seconds in recovery were used. In addition the incidence of arrhythmia was monitored in every situation.

The comparison of mean values was made by paired t-test. The correlation coefficient was evaluated using Pearson's product moment correlation coefficient. The comparison of ratios was made by Chi-Square test, and the modification of Yates was applied in case that the sample number was 5 or less. A significant level was set at $p < 0.05$ in each case.

III. Results

The variations of relative change rates (mean values) of R-R intervals to the values in each rest were depicted in Fig.1. R-R interval began to prolong after 10 seconds in FIBS and after 15 seconds in 5°C AFI, 35°C AFI, and 45°C AFI and in 5°C AFI it continued to prolong to 45 seconds during load. On the contrary, R-R interval in BHA remained a little shortened even after 15 seconds. In addition the mean relative change rates of R-R intervals in 4 conditions except BHA prolonged from rest to 45 seconds significantly during load. The mean relative change rate in R-R interval at 45 seconds during load (%R-R_{45sec}) of 5°C AFI ($60.2 \pm 40.0\%$, $p < 0.001$) was greater and that of BHA ($-4.2 \pm 13.9\%$, $p < 0.001$) was less than that of 45°C AFI ($20.2 \pm 19.3\%$) significantly.

But there was no significant difference between %R-R_{45sec} of 45°C AFI, FIBS (20.4±23.4%), and 35°C AFI (15.5±14.8%). Furthermore, every correlation coefficient between the values of 45°C AFI and 4 other conditions was significant, and especially that between the values of 45°C AFI and 35°C AFI was very high (BHA : r=0.564, p<0.05, FIBS : r=0.476, p<0.05, 5°C AFI : r=0.483, p<0.05, 35°C AFI : r=0.729, p<0.01).

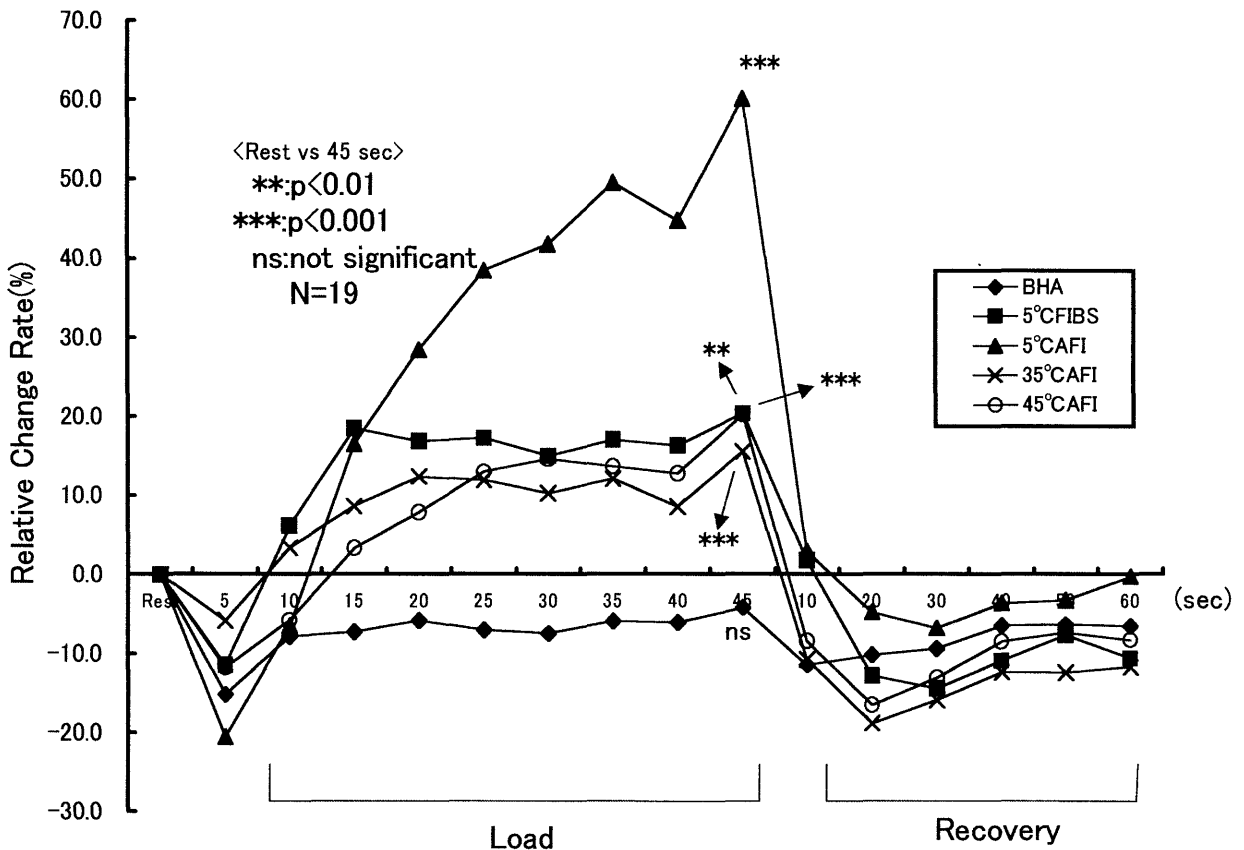


Fig.1 The variations of relative change rates of R-R intervals under 5 conditions to the values in each rest.

The mean relative change rate of the most prolonged R-R interval to the value in rest (%R-R_{max}) of FIBS and 5°C AFI was greater than that of 45°C AFI significantly. In addition %R-R_{max} of BHA was less than that of 45°C AFI significantly, and there was no significant difference between %R-R_{max}'s of 35°C AFI and 45°C AFI. (Fig. 2). Besides that, the mean value of %R-R_{max} in 35°C AFI (29.3%) was nearly the same as that in the study of Sakamoto (27.1%)⁶.

The arrhythmias provoked by 5 conditions were supraventricular premature contraction, ventricular premature contraction, atrioventricular junctional escaped beat, atrioventricular junctional rhythm, atrioventricular dissociation, ventricular escaped beat, first degree

atrioventricular block, sinus arrest or sino atrio block over 2.0 seconds. Ventricular premature contraction was observed only in 5°C AFI. Sinus arrest or sino atrio block over 2.0 seconds was

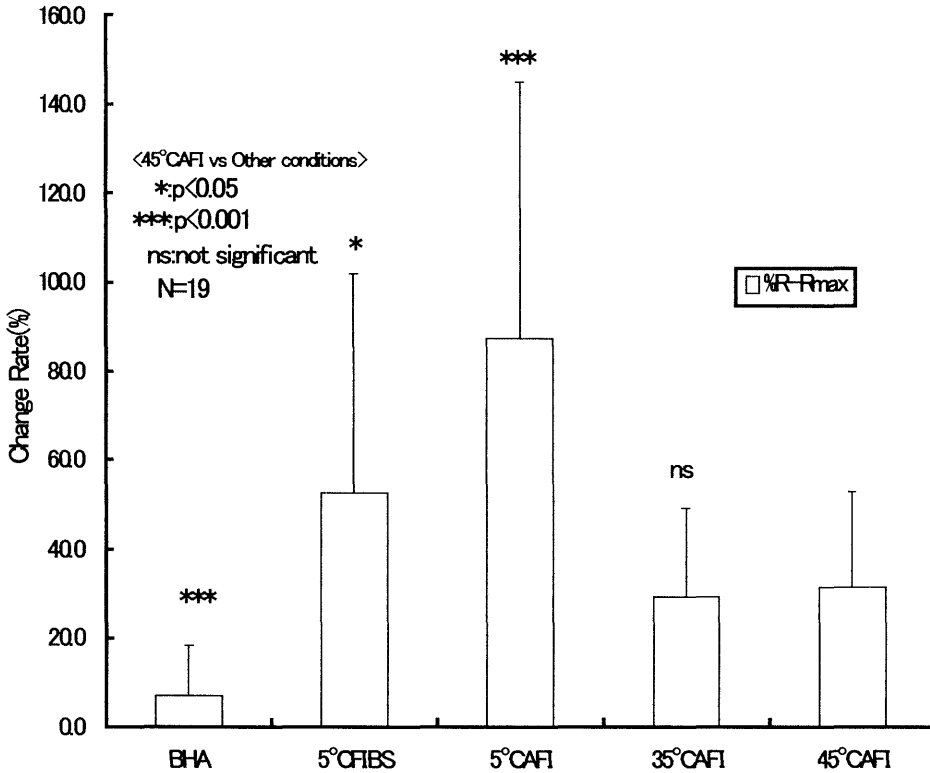


Fig.2 The comparison of %R-Rmax of 45°C AFI with those of the other various conditions.

observed in 5°C AFI and FIBS. The arrhythmias provoked by 45°C AFI was nearly the same as those by 35°C AFI.

The number of subjects who showed the arrhythmias in BHA, FIBS, 5°C AFI, 35°C AFI, and 45°C AFI were 1 (5.3%), 5 (26.3%), 11 (57.9%), 4 (21.1%), and 4 (21.1%) respectively. The incident rate of arrhythmia in 45°C AFI was less than that in 5°C AFI significantly ($p < 0.05$), but was not different from each that in 3 other conditions significantly.

IV. Discussion

R-R interval is prolonged and arrhythmias are sometimes induced by AFI^{1,2,4,6} mainly due to the stimulation of sensory receptor in the face, which excites the reflex pathway of trigeminal nerve-cardioinhibitory center in medulla-efferent vagus nerve¹⁰. This phenomenon is thought to

be modified both by the baroreflex accompanied by the increased blood pressure and the chemoreceptor reflex susceptible to the change of blood gas concentration²⁾. These electrocardiographic responses are much more remarkable when the breath is held and the cooler water is used in immersion^{1,2,4,6~9)}. This was roughly reconfirmed in the comparisons of this study focusing on 45°C AFI, and it was revealed that the maximal bradycardiac response in 35°C AFI whose temperature was neutral was nearly the same as that in the previous study. In addition electrocardiographic response in 45°C AFI was more remarkable than that in BHA. However it was impossible to insist which bradycardiac response in FIBS or 45°C AFI was more remarkable since the comparative result in %R-R_{45sec} was different from that in %R-R_{max}.

Incidentally R-R interval prolonged significantly in 45°C AFI, which showed that the sensory receptor in the face responded not only to the neutral temperature or less but also to the hot temperature, and both factors could stimulate the trigeminal nerve. Furthermore the electrocardiographic response provoked by 45°C AFI was nearly the same as that provoked by 35°C AFI since the relative change rate of R-R interval to the value in rest (both %R-R_{45sec} and %R-R_{max}) and the incident rate and kinds of arrhythmias in 45°C AFI were nearly the same as those in 35°C AFI, and the correlation coefficient between %R-R_{45sec} in 35°C AFI and 45°C AFI was very high and significant. Based on these results, it is suggested that although the electrocardiographic response provoked by AFI depends on the neutral temperature or less, it is not attenuated but kept to be maintained even in the neutral temperature or more

V. Conclusion

The bradycardiac response and incident rate of arrhythmias provoked by apneic facial immersion using hot water of 45°C were nearly the same as those provoked by apneic facial immersion of 35°C water.

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