Studies on the Temperature of the Gastrointestinal Tract

Twelfth Report

Influence of Ingestion of Water on the Temperature in the Upper Alimentary Tract

By

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In the fourth report¹⁾, the influence of ingestion of water on the intragastric temperature was systematically studied with a platinum resistance thermometer²⁾. Recently a new thermistor thermometer, designed to measure the temperature of two points of the gastrointestinal tract was constructed by us and presented in the previous report³⁾. Using this thermometer I studied the influence of ingestion of water, the volume and temperature of which were varied, on the intraesophageal, intragastric and intraduodenal temperatures.

Although several reports have been published concerning the said influence on the intragastric temperature, only two reports⁴⁾⁵⁾ concerning the intraduodenal temperature and one report⁶⁾ concerning the intraesophageal temperature have been presented. Therefore, satisfactory and systematic study of the influence of ingestion of water on the temperature in the upper alimentary tract, especially the esophagus and duodenum, is scant.

EXPERIMENTAL

Methods and Materials

Two thermistors, one attached at the end and the other 25 cm. from the end of a Miller-Abbott tube, were used for measurement of temperatures in two points of the upper alimentary tract simultaneously as reported in the previous report³⁾. The intraesophageal and intraduodenal temperatures were measured respectively with the intragastric temperature.

In the measurement of intraesophageal and intragastric temperatures, the thermistor at the end of the tube was swallowed 50 cm. from the incisor, consequently the second one was placed in the esophagus 25 cm. from the incisor.

In case of the intraduodenal and intragastric temperatures, the thermistor at the end of the tube was introduced into the duodenum about 10 cm. distal to the pylorus of the stomach on the fluoroscopic examination, so the second one was placed in the body of the stomach about 15 cm. proximal from the pylorus. The distance from the incisor were varied in each case according to the shape and tonus of the stomach as well as the body size.

Then, the measurement of two temperatures was performed in half-supine position in the fasting state at least four hours after meals. About 30 minutes after introduction of the thermistors, when the temperature became constant, water was drunk orally along the tube. The volumes and temperatures of the water drunk were as follows: 250 cc. of 50°C, 150 cc. of 50°C, 250 cc. of 15°C, and 150 cc. of 15°C. The time needed for drinking was 45 seconds in case of 150 cc. and 75 seconds in case of 250 cc. Each case was measured on seven normal adults who had no sign of gastrointestinal disorder. Although in the fourth report¹⁾ the water was introduced directly into the stomach through the tube, in the present experiment the water was drunk orally to observe the change of temperature in the esophagus in the physiological condition. The temperatures were measured every thirty seconds for thirty minutes following the drinking.

Results

The intraesophageal, intragastric and intraduodenal temperatures immediately prior to the drinking water and their changes in 0, 2, 6, 10, 18 and 30 minutes after the drinking are shown in Tables I and II. The changes in them after drinking 250 cc. of 15°C water and 250 cc. of 50°C water are shown in Figs. 1 and 2. In case of 150 cc. of 15 and 50°C water, similar figures were obtained.

The intraesophageal temperature fell rapidly while drinking 15°C water, rose rapidly in the first two minutes after drinking, and then rose slowly for the next six minutes. After eight minutes it reached within 0.1°C of the level before drinking. In case of 50°C water, the trend of the change was quite the same as that of 15°C water except the direction of the curves. On the logarithmic scale it shows a nearly straight line as shown in Figs. 3 and 4, and represents a power function. The empirical formula is given in Table III.

The intragastric temperature while drinking water dropped or rose according to the temperature of the water drunk. Immediately thereafter it reached the maximum change and then began to recover, at first rapidly, then progressively more slowly. However, the speed of the recovery is slower than that of the intraesophageal temperature, and it shows an almost straight line on the semi-logarithmic scale and represents an exponential function. The empirical formula is given also in Table III. The intragastric temperature was measured twice on the same case: one measured with the intraesophageal and the other with intraduodenal temperature. In the former the thermistor was placed in the upper part of the stomach and in the latter in the lower part of it. The curves are shown in Figs. 5 and 6. The change in the lower part of the stomach is not always greater than that in the upper part, and between these changes no

TABLE I

Maximum (Max.), Minimum (Min.), Mean and Standard Deviation
(St. d.) of Intragastric (Stom.) and Intraesophageal (Esoph.)
Temperatures before Drinking Water, and their Changes
0, 2, 6, 10, 18 and 30 minutes after Drinking
Water of Various Temperatures and Volumes

Temp. and volume of water	Location measured	Temp. before drink- ing water	Changes in the temperature						
				Time (minutes) after drinking water					
				0	2	6	10	18	30
15°C	Stom.	37.70	Max.		-10.85	-5.40	-2.85	-1.20	-0.20
		36.65	Min.		- 4.85	-1.25	-0.85	-0.35	0
		37.42	Mean		- 7.29	-3.53	-2.01	-0.69	-0.11
		0.97	St. d.		2.18	1.53	0.82	0.56	0.02
250 cc.	Esoph.	37.10	Max.	-16.10	- 2.75	-0.60	-0.25	-0.20	-0.10
		36.40	Min.	-12.50	- 1.10	-0.20	-0.15	-0.05	0
		36.91	Mean	-14.34	- 1.99	-0.35	-0.21	-0.11	-0.06
		0.66	St. d.	1.22	0.55	0.18	0.03	0.06	0.05
15°C	Stom.	38.00	Max.		-10.15	-5.00	-3.60	-0.95	-0.35
		37.00	Min.		- 2.85	-0.75	-0.60	-0.10	0.20
		37.55	Mean		- 5.84	-2.58	-1.57	-0.53	-0.09
		0.32	St. d.		2.72	1.40	1.13	0.32	0.20
150 cc.	Esoph.	37.80	Max.	-16.00	- 2.40	-0.25	-0.25	-0.25	-0.30
		36.65	Min.	-10.50	- 0.35	0	0	0.15	0.25
		37.24	Mean	-12.75	- 1.00	-0.14	-0.09	-0.03	-0.01
		0.30	St. d.	1.92	0.70	0.09	0.08	0.12	0.18
50°C	Stom.	38.00	Max.		4.70	3.90	2.55	0.50	0.05
		37.30	Min.		2.90	1.15	0.25	-0.10	-0.20
		37.69	Mean		3.76	2.24	1.10	0.20	-0.06
		0.55	St. d.		0.85	0.91	0.82	0.21	0.40
250 cc.	Esoph.	37.60	Max.	8.30	1.50	0.50	0.25	0.20	0.20
		36.60	Min.	5.30	0.45	-0.05	-0.10	-0.20	-0.20
		37.19	Mean	6.76	0.90	0.20	0.07	0	-0.04
		0.33	St. d.	1.12	0.35	0.18	0.11	0.14	0.14
50°C	Stom.	37.90	Max.		3.90	2.00	1.25	0.35	0.15
		37.30	Min.		1.70	0.95	0.45	0.05	0
		37.61	Mean		2.66	1.52	0.82	0.21	0.05
		0.65	St. d.		1.18	0.46	0.52	0.10	0.06
150 cc.	Esoph.	37.50	Max.	8.80	1.05	0.25	0.15	0.10	0.10
		36.70	Min.	4.80	0.25	0.05	0	-0.10	-0.10
		37.20	Mean	7.26	0.72	0.14	0.07	0.01	-0.01
		0.25	St. d.	0.51	0.27	0.08	0.09	0.08	0.07

significant difference was seen.

The intraduodenal temperature did not change so rapidly as the intraesophageal or intragastric temperature. While drinking water the temperature remained at the level before drinking ; then some of them dropped or rose rapidly according to temperature of the water, but most of them slowly and with a zigzag

TABLE II

Maximum (Max.), Minimum (Min.), Mean and Standard Deviation
(St. d.) of Intragastric (Stom.) and Intraduodenal (Duod.)
Temperatures before Drinking Water, and their Changes
0, 2, 6, 10, 18 and 30 minutes after Drinking
Water of Various Temperatures and Volumes

Temp. and volume of water	Location measured	Temp. before drink- ing water	Changes in the temperature						
				Time (minutes) after drinking water					
				0	2	6	10	18	30
15°C	Stom.	37.95	Max.		-8.95	-6.40	-4.35	-1.50	-0.60
		36.75	Min.		-3.10	-1.20	-0.75	-0.30	0.10
		37.50	Mean		-5.74	-3.52	-2.39	-0.90	-0.26
		0.45	St. d.		2.32	2.18	1.19	0.53	0.20
250 cc.	Duod.	37.95	Max.	-0.20	-2.15	-3.65	-1.90	-1.05	-0.45
		36.85	Min.	0	-0.35	-0.25	-0.25	-0.05	0.05
		37.56	Mean	-0.05	-1.09	-1.34	-0.98	-0.38	-0.19
		0.76	St. d.	0.09	0.56	1.80	0.57	0.33	0.13
15°C	Stom.	37.75	Max.		-6.25	-4.40	-2.70	-0.75	-0.40
		37.00	Min.		-2.85	-1.35	-0.50	-0.10	0.10
		37.43	Mean		-5.31	-3.04	-1.35	-0.36	-0.10
		0.19	St. d.		1.26	1.02	0.81	0.26	0.16
150 cc.	Duod.	37.80	Max.	-1.40	-3.30	-1.65	-0.75	-0.35	-0.35
		37.00	Min.	0	-0.10	-0.35	-0.20	-0.10	0
		37.46	Mean	-0.27	-1.51	-0.82	-0.53	-0.20	-0.17
		0.67	St. d.	0.50	1.31	0.43	0.19	0.08	0.14
50°C	Stom.	37.80	Max.		4.50	2.00	1.25	0.30	0.05
		37.35	Min.		1.70	0.90	0.15	-0.15	-0.25
		37.59	Mean		3.07	1.46	0.61	0.07	-0.07
		1.73	St. d.		0.93	0.47	0.41	0.06	0.13
250 cc.	Duod.	37.95	Max.	0.70	1.65	1.05	0.45	0.10	0.05
		37.40	Min.	0	0.15	0.05	-0.15	-0.30	-0.40
		37.63	Mean	0.26	0.97	0.69	0.12	-0.06	-0.14
		1.08	St. d.	0.31	0.53	0.35	0.20	0.18	0.16
50°C	Stom.	38.00	Max.		3.65	1.80	0.90	0.60	0.25
		36.85	Min.		1.00	0.60	0.35	0	-0.25
		37.44	Mean		2.17	1.14	0.67	0.21	-0.01
		0.68	St. d.		0.96	0.39	0.24	0.19	0.17
150 cc.	Duod.	38.05	Max.	0.20	1.45	1.10	0.45	0.40	0.15
		36.85	Min.	0	0.10	0.05	-0.10	-0.15	-0.35
		37.48	Mean	0.06	0.76	0.41	0.22	0.05	-0.08
		0.28	St. d.	0.09	0.47	0.35	0.20	0.19	0.20

course. Their maximum change appeared between thirty seconds and eight minutes. Some of the curves of the intraduodenal temperature are shown in Fig. 7. A definite type of curve was not found contrary to the intraesophageal and intragastric temperatures. It was always accompanied by fluctuation of lesser degree, so that it formed a zigzag line, which could not be found in the

Fig. 1. The changes in the temperature after drinking 250 cc. of 15°C water. — intragastric temperature, ---- intraesophageal temperature, -.-.- intraduodenal temperature.

Fig. 2. The changes in the temperature after drinking 250 cc. of 50°C water. — intragastric temperature, ---- intraesophageal temperature, -.-.- intraduodenal temperature.

curve of the intragastric temperature measured simultaneously. According to the time when the maximum change appeared it was divided into two groups: one was the early type, in which the maximum change appeared within the first two

Fig. 3. The changes in the intraesophageal temperature after drinking 15°C water (Logarithmic scale). — 250 cc., ---- 150 cc.

Fig. 4. The changes in the intraesophageal temperature after drinking 50°C water (Logarithmic scale). — 250 cc., ---- 150 cc.

minutes and reached 3 or 4°C; the other was the slow type, in which the maximum change appeared during four to eight minutes and remained below 2°C. The curve of the early type is more like that of the stomach than the slow type.

TABLE III
Empirical Formulas of Changes in the Intraesophageal
(Esophagus) and Intragastric (Stomach) Temperatures
after Drinking 15°C and 50°C Water

Y = change in temperature (°C). t = time after drinking water (minutes). (E) = intragastric temperature measured simultaneously with the intraesophageal temperature. (D) = intragastric temperature measured simultaneously with the intraduodenal temperature.

Temp. of water	Volume of water	Esophagus	Stomach
15°C	250 cc.	$Y = -4.54 t^{-1.38}$	(E) $Y = -8.99 e^{-0.15t}$ (D) $Y = -7.41 e^{-0.11t}$
15°C	150 cc.	$Y = -2.71 t^{-1.36}$	(E) $Y = -6.65 e^{-0.15t}$ (D) $Y = -7.50 e^{-0.17t}$
50°C	250 cc.	$Y = 2.01 t^{-1.35}$	(E) $Y = 7.01 e^{-0.20t}$ (D) $Y = 7.46 e^{-0.27t}$
50°C	150 cc.	$Y = 1.78 t^{-1.40}$	(E) $Y = 4.06 e^{-0.17t}$ (D) $Y = 2.88 e^{-0.15t}$

DISCUSSION

The details of the change in the intragastric temperature produced by introducing water through the tube were presented in the fourth report¹¹. However, in the present experiment the water was drunk orally instead of being introduced directly into the stomach through the tube. Though the curve of the recovery shows a straight line on the semi-logarithmic scale in both experiments, in comparison with the results reported previously, the changes in this experiment are somewhat different: the changes immediately and a few minutes after ingestion were smaller and the recoveries were slower. The water was not insulated by the rubber tube and heat conduction between water and surrounding tissue could take place readily, consequently the temperature of the ingested water was closer to that of the stomach. This shows that the upper alimentary tract acts as a buffer to the temperature of ingested fluid. It is interesting that the changes in the temperature in upper and lower parts of the stomach after drinking water of the same temperature and the same volume exhibit no significant difference as shown in Figs. 5 and 6. The intragastric temperatures of various parts of the stomach are almost the same, except immediately following introduction of water⁷.

The change in the intraesophageal temperature was obviously different from the change in the intragastric temperature and the differences between them were statistically significant in all four cases. The maximum change

Fig. 5. The changes in the intragastric temperature after drinking 15°C water (Semi-logarithmic scale). — 250 cc., measured with the intraesophageal temperature, ---- 250 cc., measured with the intraduodenal temperature, - · - · - 150 cc., measured with the intraesophageal temperature, · · · · · 150 cc., measured with the intraduodenal temperature.

appeared while drinking water and was always greater than the change in the intragastric temperature. This shows that the water contacts at first the esophagus, exchanging heat as mentioned above, and then reaches the stomach. The differences in the change of the temperature between 150 cc. and 250 cc. of 15°C water, as well as between 150 cc. and 250 cc. of 50°C water were very small and not statistically significant. As the water merely passes through the esophagus and does not stay there, the difference in volume between 150 cc. and 250 cc. does not cause a significant change in intraesophageal temperature.

The change of the intraduodenal temperature is very characteristic. Contrary to the intraesophageal and intragastric temperatures, the intraduodenal temperature did not change during and immediately after drinking the water. In some cases (the early type) the maximum change occurred within two minutes, but in most cases (the slow type) it gradually appeared between two and eight minutes after drinking water. The curve of the temperature change shows a zigzag course within about 2°C. This fact

Fig. 6. The changes in the intragastric temperature after drinking 50°C water (Semi-logarithmic scale). — 250 cc., measured with the intraesophageal temperature, ---- 250 cc., measured with the intraduodenal temperature, - · - · - 150 cc., measured with the intraesophageal temperature, · · · · 150 cc., measured with the intraduodenal temperature.

Fig. 7. The changes in the intraduodenal temperature after drinking 250 cc. of 50°C water (above the zero line) and 250 cc. of 15°C water (below the zero line). ---- early type, — slow type.

shows that the water which passed through the esophagus was at first accumulated in the stomach and then ejected intermittently through the pylorus of the stomach under the control of pyloric function. The earlier the maximum change appeared, the greater it was. However, the maximum change in the intraduodenal temperature was never reached until the maximum change in the intragastric temperature had taken place. In this case the duodenopyloric reflex⁸⁾⁹⁾ is a problem to be considered, as reported previously¹⁰⁾. Moreover, statistically significant differences in the changes were not observed between 150 cc. and 250 cc. of 15°C water, and between those of 50°C water. The shape, tonus, peristalsis and capacity of the stomach, and the tonus of the pylorus have more influence on the change in intraduodenal temperature than the difference in volume and temperature of the water drunk. On fluoroscopic examination it was observed that there were many different shapes and motilities of the stomach individually.

In conclusion, the changes in intraesophageal and intragastric temperatures after ingestion of water are more physical than physiologic, whereas the corresponding changes in intraduodenal temperature are more physiologic.

SUMMARY

The changes in the intraesophageal, intragastric, and intraduodenal temperatures of healthy adults after drinking 15 and 50°C water were studied and the following facts were confirmed.

I. The intraesophageal temperature :

1. The maximum change appears during and immediately after drinking, and is always greater than that in the intragastric temperature.
2. The recovery to the temperature before drinking is faster than that of the intragastric temperature.
3. The curve of the change exhibits a straight line on the logarithmic scale, and represents a power function.

II. The intragastric temperature :

1. The results reported previously¹⁾ are substantiated.
2. The upper and lower parts of the stomach behave equally in the changes.

III. The intraduodenal temperature :

1. The curve of the change shows a zigzag line.
2. The maximum change appears between 30 seconds and eight minutes after the drinking, and is usually smaller than those of intraesophageal and intragastric temperatures.
3. The change never exceeds that of the intragastric temperature.
4. The individual variation in the change is greater than those in

the intraesophageal and intragastric temperatures.

5. The curve of recovery does not represent any simple mathematical function.

6. It changes more physiologically than physically contrary to the other two temperatures which behave more physically.

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