Effect of Rate of Gland Function on pH, Viscosity, Total Solids, Calcium, and Magnesium in Unstimulated Parotid Fluid (33677)

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Previous reports from this laboratory have established physiologic levels for uric acid (1) and total protein (2) in unstimulated parotid fluid and have studied the effect of rate of flow on these variables. A formula for additional constituents of such fluid was also offered (3). The present study explores the effect of the rate of gland function on total solids, pH, viscosity, calcium, and magnesium in human parotid fluid collected without exogenous stimulation.

Materials and Methods. Subjects were 309 healthy males between 17 and 22 years of age. Each had been found physically fit by recent medical examination. Times of arising and retiring, physical exertion, intake of foods and liquids, as well as environmental and emotional exposure were very similar for all participants. The homogeneity of this population was previously discussed (4).

Parotid sampling was undertaken at approximately 7:30 a.m. with subjects in the fasting state. Sampling continued over a period of 90 min and every effort was made to minimize conditions which might affect flow. Parotid fluid was collected under oil with tubes in an ice bath. The particulars of this procedure for the collection of unstimulated parotid fluid have been presented (5).

The pH was measured on a Beckman research pH meter. Viscosity was determined on a Hellige viscometer (no. 1200) by comparing flow rate against that of water in calibrated capillaries. Samples were dried to constant weight under vacuum to ascertain total solid content. Calcium and magnesium levels were determined by atomic absorption spectroscopy after dilution of parotid fluid 1:10 with an aqueous solution containing 0.89% lanthanum oxide and 0.4% hydrochloric acid (6).

Minute secretion rates (μg/min) were computed for total solids, calcium, and magnesium.

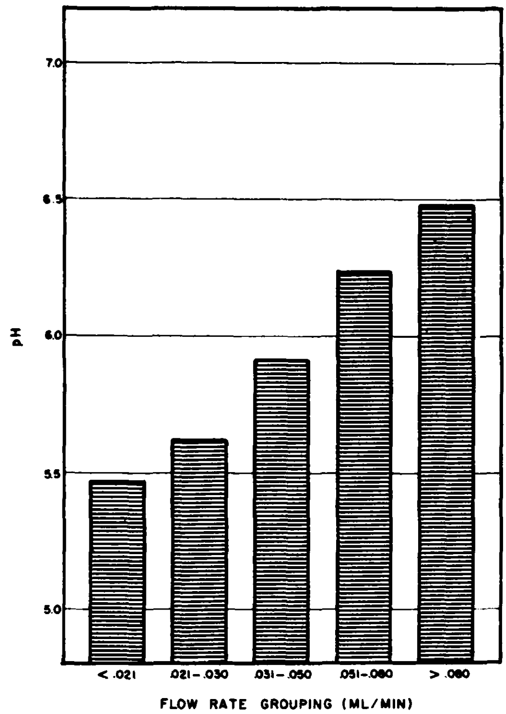

FIG. 1. Parotid fluid pH for flow rate groups (n = 309).

Results. Descriptive statistics for the measured parotid fluid variables for all 309 subjects are presented in Table I. Analyses of variance were performed to test for differences between days in the measured variables. Over the 27 days of sampling, there was no significant day effect on parotid flow rate but, for each of the 5 other measured variables, differences between days were significant at the 0.01 level. Means for the computed variables, minute secretion rates, for total solids, calcium, and magnesium were 318, 1.61, and 0.15 μg/min, respectively.

Correlation coefficients were calculated and a correlation matrix established for all mea-

TABLE I. Descriptive Statistics for Measured Parotid Fluid Variables (309 subjects).

Parotid fluid variables	Mean	SD	Percentiles 25	50	75
Flow rate (ml/min)	0.049	0.033	0.026	0.036	0.059
Total solids (g/100 ml)	0.72	0.25	0.54	0.67	0.81
pH (units)	5.92	0.51	5.56	5.92	6.28
Viscosity (cP)	1.08	0.05	1.05	1.09	1.10
Calcium (meq/liter)	1.63	0.51	1.22	1.58	1.89
Magnesium (meq/liter)	0.25	0.12	0.15	0.23	0.31

sured variables for the entire group of 309 subjects. Significant ($p < .01$) negative correlations were found between flow rate and total solids, flow rate and viscosity, flow rate and calcium, and flow rate and magnesium (Table II). A significant ($p < .01$) positive correlation was noted for flow rate and pH.

The 309 subjects were divided into 5 flow rate groups and the variables were studied as a function of flow rate. Means for flow rate, in ascending order, for the groups were 0.019, 0.025, 0.039, 0.063, and 0.117 ml/min (Table III).

Differences between the means for the flow rate groups were significant at the .01 level for pH, total solids, calcium, and magnesium, and at the .05 level for viscosity. The pH increased with increasing flow rate, while the remaining four variables decreased as flow rate increased.

Discussion. It was pointed out by Hildes and Ferguson (7) that parotid fluid is always hypo-osmotic and that the degree of hypotonicity decreases as the rate of secretion increases. Rutberg (8) suggests that the hypo-osmolality of saliva is due to the reabsorption of sodium chloride without water in the striated duct, such as is the case in the distal convoluted tubule of the kidney. We have also noted this increase in osmolality with increases in stimulated parotid flow (9). When parotid fluid was collected at a mean flow rate of 1.24 ml/min, the osmolality mean was 78.9 mosmoles/kg. At the elevated rate of 2.25 ml/min, the osmolality mean increased to 180.4 mosmoles/kg. Even this relatively high level was markedly hypotonic in respect to plasma. There is increasing evidence that this ever-present hypotonicity is due primarily to the reabsorption of sodium in excess of water (10–15). This reabsorptive process would create an osmotic

TABLE II. Correlation Coefficients and Probability Values for Interrelationships of Parotid Fluid Measured Variables.

Parotid fluid variables	Total solids	pH	Viscosity	Calcium	Magnesium
Flow rate	−0.42[a]	0.55	−0.17	−0.32	−0.58
	<.01	<.01	<.01	<.01	<.01
Total solids		0.24	0.35	0.51	0.53
		<.01	<.01	<.01	<.01
pH	−0.24		0.01	−0.29	−0.53
	<.01		NS	<.01	<.01
Viscosity	0.35	0.01		0.15	0.16
	<.01	NS		<.05	<.01
Calcium	0.51	−0.29	0.15		0.59
	<.01	<.01	<.05		<.01

[a] Coefficient and probability level at which coefficient differs from zero.

TABLE III. Effect of Flow Rate on Parotid Fluid Variables.

Flow rate grouping (ml/min)	No. of subjects	pH (units) Mean	pH (units) SD	Viscosity (cP) Mean	Viscosity (cP) SD	Total solids (g/100 ml) Mean	Total solids (g/100 ml) SD	Calcium (meq/liter) Mean	Calcium (meq/liter) SD	Magnesium (meq/liter) Mean	Magnesium (meq/liter) SD
<0.021	15	5.47	0.41	1.10	0.04	0.94	0.26	2.08	0.39	0.42	0.18
0.021–0.030	90	5.62	0.45	1.09	0.06	0.82	0.25	1.88	0.54	0.34	0.12
0.031–0.050	102	5.91	0.45	1.08	0.04	0.71	0.24	1.54	0.44	0.25	0.08
0.051–0.080	61	6.14	0.37	1.09	0.05	0.65	0.18	1.48	0.47	0.18	0.05
>0.080	41	6.48	0.34	1.06	0.06	0.51	0.13	1.39	0.43	0.12	0.05

gradient down which water would diffuse passively, and it is the latter that will be assigned the primary responsibility for the majority of the differences found between flow rate groups in the present study.

Correlation coefficients found in the present study make it clear that total solids, viscosity, calcium, and magnesium all decrease with increases in unstimulated parotid flow rate. On the other hand, pH increased with this increased flow rate. Since only one saliva sample was available for each subject, these correlations are, of course, of the between-subjects type. The negative correlation coefficients can be interpreted as pointing out only that the low-flowing subjects tended to have higher levels of these constituents in their saliva than did their faster-flowing colleagues.

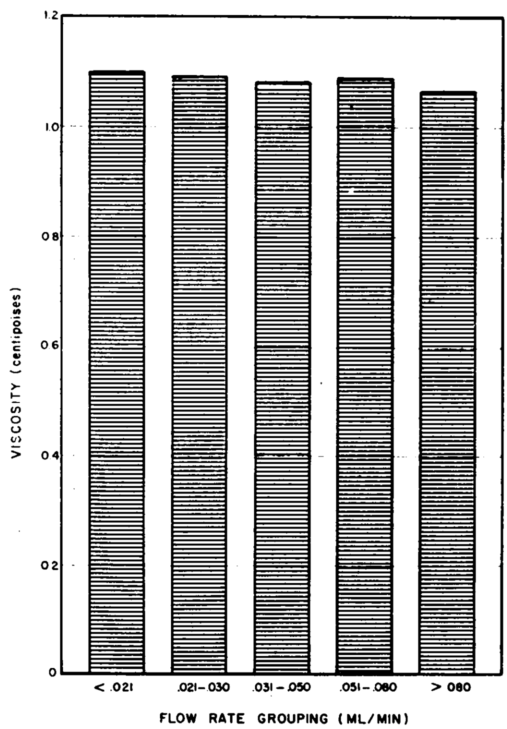

FIG. 2. Parotid fluid viscosity for flow rate groups ($n = 309$).

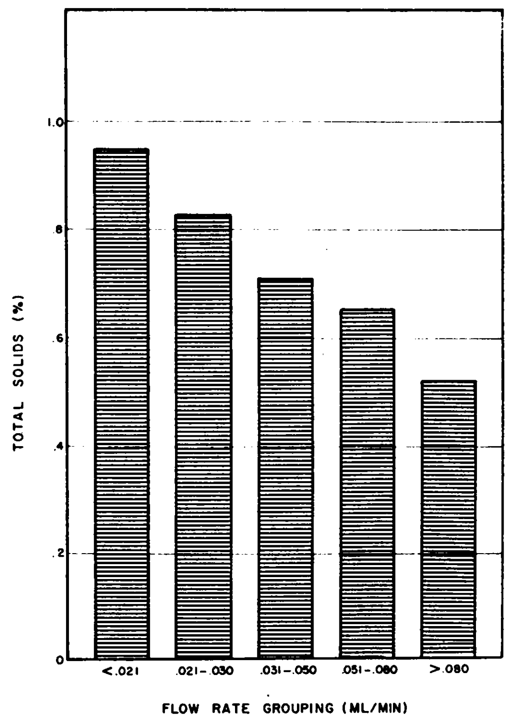

FIG. 3. Parotid fluid total solids for flow rate groups ($n = 309$).

Explanations for the influence of flow rate on the variables in this study must be tentative in that evidence regarding reabsorption

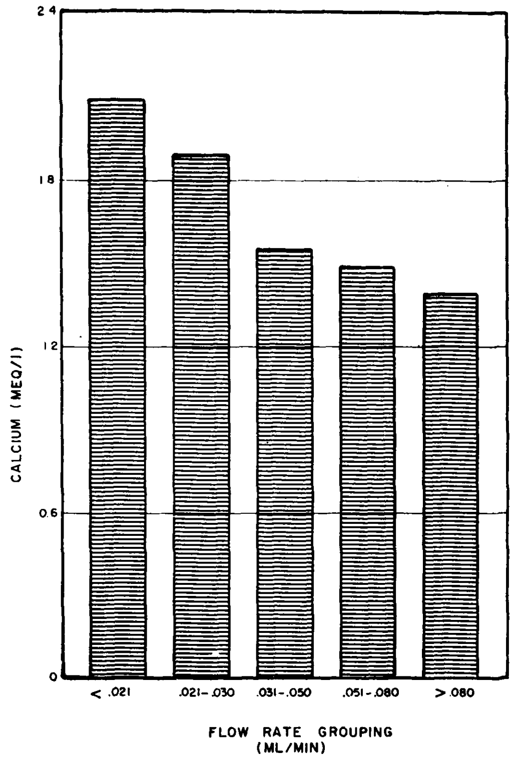

FIG. 4. Parotid fluid calcium concentration for flow rate groups ($n = 309$).

and/or secretion of these constituents, even in the experimental animal, is not available. The net effect of flow rate changes is similar for total solids, viscosity, calcium, and magnesium. The indication is that the longer a portion of parotid fluid spends in the duct network (the lower the rate of flow), the higher the values for these variables become. While the possibilities of ductal secretion in this regard have not been ruled out, it is plausible to suggest that these changes might represent an accentuated influence of passive diffusion of water down the osmotic gradient produced by reabsorption of sodium.

The results of a recently completed experiment lend support to these contentions. Unstimulated parotid fluid was collected both before and after the oral administration of atropine sulfate (0.02 gr). Parotid flow was decreased significantly and, along with this decreased flow, significant increases were noted for calcium, magnesium, total solids, viscosity, and total protein. The pH and bicarbonate concentration decreased significantly.

Relatively simple explanations can therefore be offered for the flow rate effects noted in the present study. Even at the highest flow rate observed in this study the fluid was markedly hypo-osmotic, probably as a result of reabsorption of sodium in excess of water. As saliva remains longer in the duct system (as flow rate decreases) the passive diffusion of water down the osmotic gradient, resulting from sodium reabsorption, would become dominant. An apparent overall concentration would result, thus accounting for the increases noted in the levels of total solids, calcium, and magnesium. An increase in total protein brought about by decreased flow rate is probably instrumental in producing the measured increase in viscosity. As gland function decreases, the amount of bicarbonate produced by glycolysis decreases sharply, and this leads to the decreased pH noted in the present study.

Summary. Parotid fluid was collected with-

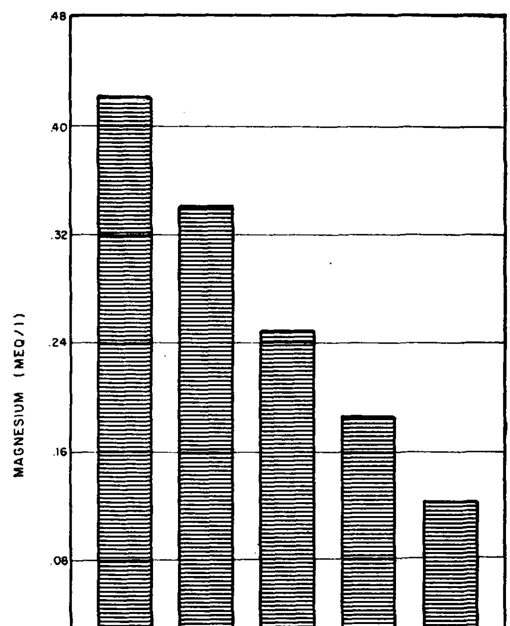

FIG. 5. Parotid fluid magnesium concentration for flow rate groups ($n = 309$).

out exogenous stimulation from 309 healthy young adult males. Subjects with rates of flow less than 0.018 ml/min were excluded due to sample size requirements. The mean rate of flow for all participants was 0.049 ml/min. Other means were: total solids, 0.72%; pH 5.92, viscosity, 1.08 cP; calcium 1.63 meq/liter, and magnesium 0.25 meq/liter. Rate of flow exerted a significant negative effect on total solids, viscoscity, calcium, and magnesium. The positive correlation between flow and pH was explained as reflecting a parallel relationship between bicarbonate and flow rate. These changes are compatible with the premise that, at these very low levels of gland function, decreases in flow rate bring into dominance the process of passive diffusion of water from the saliva down an osmotic gradient produced by sodium reabsorption. This tentative explanation is offered in the absence of definitive data regarding ductal secretion of the variables under study.

1. Shannon, I. L. and Terry, J. M., USAF School of Aerospace Med. Tech. Rept. **66-26** (1966).

2. Shannon, I. L. and Terry, J. M., USAF School of Aerospace Med. Tech. Rept. **66-30** (1966).

3. Shannon, I. L., J. Dental Res. **46**, 309 (1967).

4. Shannon, I. L., Prigmore, J. R., and Beering, S. C., J. Clin. Endocrinol. Metab. **23**, 1258 (1964).

5. Shannon, I. L., J. Oral Med. **22**, 75 (1967).

6. Windeler, A. S. and Shannon, I. L., Arch. Oral Biol. **12**, 1063 (1967).

7. Hildes, J. A. and Ferguson, M. H., Can. J. Biochem. Physiol. **33**, 217 (1955).

8. Rutberg, U., Acta Odontol. Scand., Suppl. **19**, 30 (1961).

9. Shannon, I. L and Segreto, V. A., USAF School of Aerospace Med. Tech. Rept. **68-3** (1968).

10. Martinez, J. R., Holzgreve, H., and Frick, A., Arch. Ges. Physiol. **290**, 124 (1966).

11. Holzgreve, H., Martinez, J. R., and Vogel, A., Arch. Ges. Physiol. **290**, 134 (1966).

12. Young, J. A. and Schogel, E., Arch. Ges. Physiol. **291**, 85 (1966).

13. Young, J. A., Fromter, E., Schogel, E., and Hamann, K. F., Arch. Ges. Physiol. **295**, 157 (1967).

14. Young, J. A., Fromter, E., Schogel, E., and Hamann, K. F., *in* "Secretory Mechanisms of Salivary Gland" (L. H. Schneyer and C. A. Schneyer, eds.), p. 11. Academic Press, New York, (1967).

15. Mangos, J. A. and Braun, G., Arch. Ges. Physiol. **290**, 184 (1966).

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