The Simultaneous Emptying and Absorption of Ethanol from the Human Stomach

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Emptying and absorption of ethanol from the stomach were studied using test meals of 350 ml containing phenol red and ethanol (60 mg/ml) instilled into the stomachs of 7 healthy subjects. Emptying was allowed to proceed normally and the gastric contents were aspirated at different intervals on different days. Emptying was compared to water meals of equal volume containing no ethanol. Emptying of ethanol meals and water meals proceeded at the same rate up to 30 min when about 90% of the meal had left the stomach. Absorption of ethanol was related directly to the time present in the stomach. The mean coefficient of absorption of ethanol was 4.7 ml/min, and this was constant throughout the 30 min. Acid output in response to ethanol meals was equal to that in response to water meals.

In a previous study reported from this laboratory, the amount of ethanol absorbed by the stomach was found to be related directly to the amount ingested. The amount of ethanol absorbed by the stomach in 30 min, using a constant volume of test meal (350 ml), was approximately 28% of an ingested dose (1). In those studies, emptying was delayed artificially by glucose (100 g/liter), in order to keep the volume leaving the stomach constant and to assess the effect of varying the concentration of ethanol ingested. There have not been previous detailed studies of the emptying time of ethanol from the human stomach. In the present study, emptying and absorption of ethanol were measured simultaneously.

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METHODS

Procedure

A total of 237 test meals (117 of water, 120 of ethanol) was given to 7 healthy male subjects. All subjects were accustomed to swallowing gastric tubes. The procedure for the test meals was similar to that described in previous reports (1, 2). Briefly, the fasting subject swallowed a 3-mm diam stomach tube and then drank 250 ml of water. This was then aspirated and discarded. The test meal of 350 ml of water, with or without ethanol, contained phenol red as a nonabsorbable marker dye (3, 4), and was instilled into the stomach. In each test the gastric contents were totally aspirated at some different multiple of 5–30 min, or until the stomach

was empty. Another 250 ml of water was swallowed and aspirated to recover any residual gastric contents. The order of the tests with different intervals between ingestion and aspiration was randomly assigned.,

The volume of the gastric contents was recorded and samples were taken for estimation of concentrations of titratable acid, phenol red and ethanol. The concentration of acid was determined by titrating a 1.0-ml sample of juice with 0.1 N NaOH to pH 7.0 using a glass electrode and automatic titrator.* Phenol red concentration was measured spectrophotometrically (Unicam SP 500) † at a wave length of 555 $m\mu$. The concentration of ethanol was determined by the alcohol dehydrogenase-diphosphopyridine nucleotide method (Modification 2) of Lundquist and Wolthers, as described by Lundquist (5).

Two types of test meals were used. One meal contained only water and phenol red. The other contained water, phenol red and ethanol in a concentration of 60.26 mg/ml.

Calculations

The concentrations of phenol red, acid and ethanol were measured in each ingested meal and in the gastric contents recovered. The amount of ethanol absorbed was calculated from the result of the difference between the amount ingested minus the amount recovered from the stomach minus the amount assessed as passing the pylorus. Acid output per unit time was calculated from the volume and concentration of acid recovered plus the amount assessed as having left the stomach. These calculations have been described in detail in previous publications (1, 6, 7). The volume of original meal left in the stomach was calculated from the formula:

$$V_2 \times \frac{C2}{C1}$$

where V_2 was the volume of gastric contents recovered, *C2* was the concentration of phenol red in those contents, and *C1* was the concentration of phenol red in the meal ingested. A coefficient of absorption (1) (*k*) was calculated also:

$$k\ (\text{ml/min}) = \frac{\text{rate of ethanol absorbed (mg/min)}}{\text{mean concentration of ethanol in stomach (mg/ml)}}$$

A regression line for the time ethanol was in the stomach and the amount absorbed was calculated by the method of least squares (8).

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RESULTS

Emptying of ethanol compared to water. The rate of emptying of ethanol, as indicated by the volume of original meal left in the stomach at various 5-min intervals, was about equal to that of water (Fig 1). At the end of 30 min, the mean volume (M±SE) of the original meal was 54.1 ml (±14.1 ml) for ethanol and 32.5 ml (±13.3 ml) for water. The rate at which ethanol and water meals emptied from the stomach showed an exponential curve (Fig 2).

Absorption of ethanol. The amount of ethanol absorbed was related directly to the period it remained in the stomach (Fig 3). The coefficient of correlation between the amount absorbed and the time was significant ($r = 0.844$, $p < 0.001$). The regression line was calculated as $y = 0.091 + 0.211 \times$ (Fig 3). The coefficient of absorption of ethanol is given in Table 1. This coefficient was constant at the various times measured.

Acid output in response to ethanol or water. Acid output in response to ethanol test meals (in which sufficient contents were recovered to estimate titratable activity) was not different from that in response to water meals (Table 2).

DISCUSSION

In a previous study in which gastric emptying was delayed by glucose (100 g/liter), the amount of ethanol absorbed by the stomach was found to be related to the concentration of the test meal ingested (1). Acid output was not increased despite increasing the concentration seven-fold from 0.8 to 5.6%.

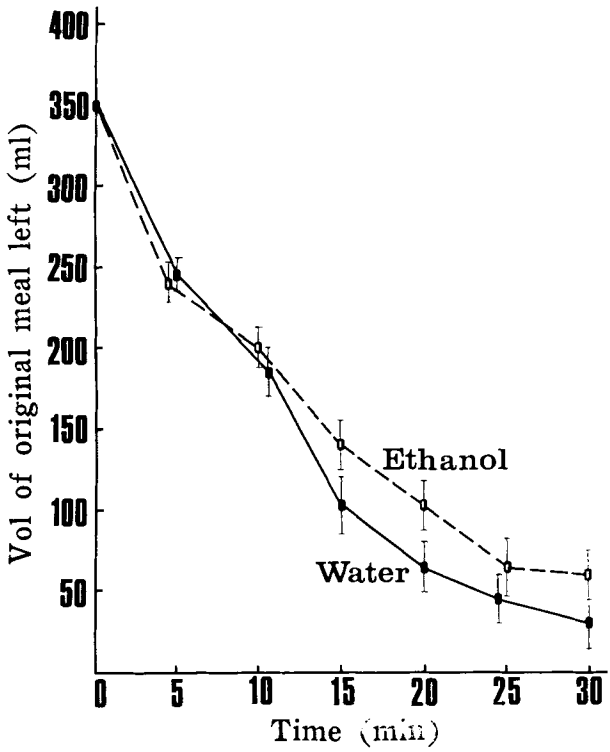

Fig 1. Emptying of ethanol and water from stomach. **Vertical bars** represent M±SE. Each point is mean of 2–4 meals in each of 7 subjects at 5, 10, and 15 min; 5 subjects at 20 min; 3 subjects at 25 and 30 min.

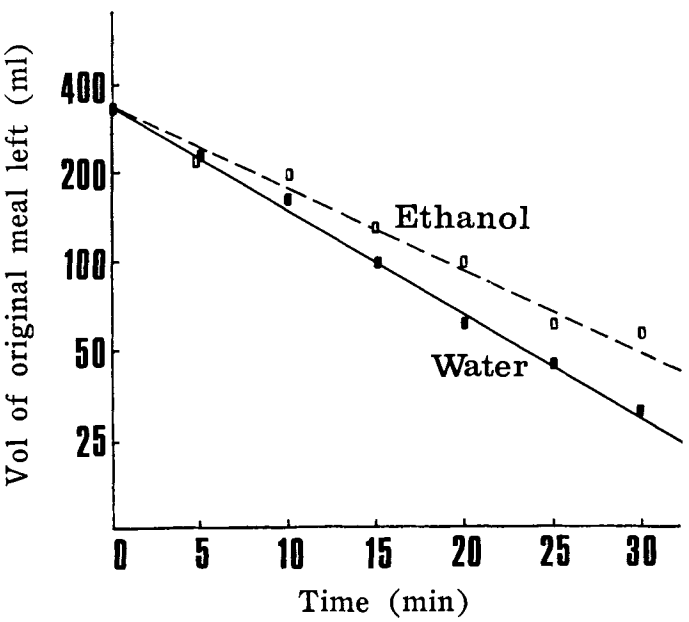

Fig 2. Emptying of ethanol and water from stomach. **Vertical axis** is a logarithmic plot. (Data from Fig 1.)

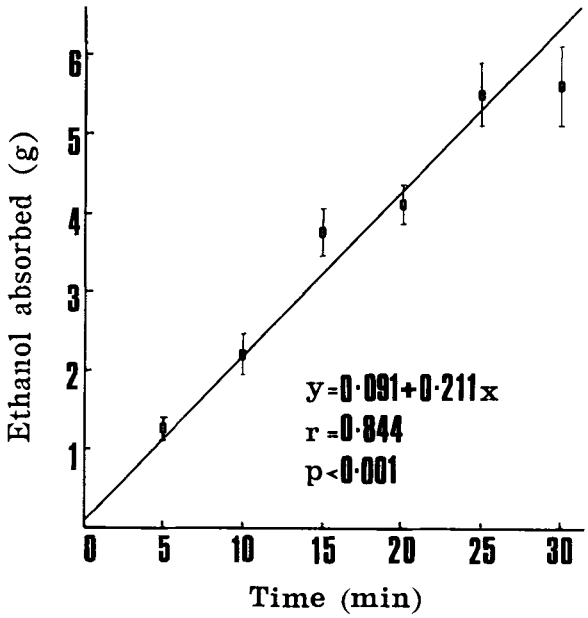

Fig 3. Relationship between amount of ethanol absorbed and time. **Vertical bars** represent M±SE. Points at 5, 10, 15, 20, 25 and 30 min represent mean of 20, 23, 21, 19, 12 and 10 meals, respectively.

In the present study emptying and absorption of 6% ethanol by the stomach were measured simultaneously at 5-min intervals up to 30 min. Emptying of 6% ethanol from the stomach was exponential in rate (Fig 2) and did not differ significantly from that of water (Fig 1). About 85% of an ethanol meal and 90% of a water meal had left the stomach by 30 min (Fig 1). Hunt (9) has provided evidence that the emptying of carbohydrates, fats and acids is controlled by receptors in the duodenum. Ethanol is lipid soluble as well as water soluble so that it would pass into these receptors without difficulty and would not be expected to activate them. Thus the findings in these experiments agree with these theoretical considerations.

The amount of ethanol absorbed was related directly to the time present in the stomach (Fig 3). A total of 21.09 g of ethanol or about 27 ml of absolute ethanol

Table 1. Absorption Coefficient (k) of Ethanol at Different Times

Time (min)	Mean ± SE				No. of meals
	Contents recovered (ml)	Original meal recovered (ml)	Ethanol in contents (mg/ml)	k (ml/min)	
0- 5	266.5 ± 14.9	238.3 ± 13.5	50.4 ± 0.6	4.53 ± 0.52	20
0-10	234.1 ± 13.5	200.7 ± 12.5	43.7 ± 1.0	4.24 ± 0.46	23
0-15	180.0 ± 17.9	140.6 ± 14.8	36.2 ± 1.6	5.25 ± 0.42	21
0-20	129.1 ± 18.8	103.6 ± 15.9	31.8 ± 2.3	4.53 ± 0.32	19
0-25	88.0 ± 22.4	65.8 ± 17.1	24.7 ± 1.5	5.20 ± 0.45	12
0-30	74.0 ± 18.5	54.1 ± 14.1	21.3 ± 2.2	4.64 ± 0.51	10

Table 2. Acid Output in Response to Ethanol and Water Test Meals

Time (min)	Acid output: Ethanol (Mean mEq ± SE)	Ethanol (No. of test meals)	Water (Mean mEq ± SE)	Water (No. of test meals)
0- 5	0.74 ± 0.13	20	1.16 ± 0.48	19
0-10	2.58 ± 0.36	23	2.02 ± 0.23	23
0-15	4.30 ± 0.58	21	3.42 ± 0.57	20
0-20	4.11 ± 0.48	19	4.43 ± 0.58	15
0-25	6.09 ± 0.58	12	5.34 ± 0.64	11
0-30	5.28 ± 1.05	10	5.85 ± 0.69	7

(99.5% w/v ethanol, sg = 0.789) was added to the water and phenol red mixture to give a final volume of 350 ml and an ethanol concentration of 60.26 mg/ml. At 30 min, 6.42 g, or about 8 ml of absolute ethanol was absorbed and less than 3 ml was left in the stomach. In this period about 16 ml of absolute ethanol had emptied from the stomach. Thus under these conditions, the amount of ethanol emptied from the stomach was about twice that absorbed. The findings of this study in conjunction with those of a previous study (1), suggest that similar amounts of ethanol can be absorbed by the stomach within 30 min whether emptying is delayed or allowed to proceed normally. Both studies indicate that the stomach is an important site of ethanol absorption.

It was of interest that the absorption coefficient (k) was about 4.7 ml/min (Table 1), a value that was similar to that found previously (1). This finding indicates that the rate of absorption of ethanol is constant despite variation in concentration of test meals as found in the previous study (1) or in volume left in the stomach as found in the present study.

Ethanol has been found to stimulate acid output by a variety of mechanisms. It stimulates acid output by direct application to fundic glandular mucosa (10), by perfusion of denervated transplanted antral pouches (11, 12) and by intravenous infusion (11). In the present study, acid output in response to 6% ethanol was not different from that in response to water alone (Table 2), and confirms the finding of a previous study (1). These findings suggest that either distention alone (350 ml) is sufficient stimulus for acid output and that under these conditions ethanol does not have any further effect or that ethanol, in concentrations up to 6% (w/v), is not a stimulus for acid secretion in man.

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