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STUDIES ON THE QUANTITATIVE EVALUATION OF THE FUNCTION OF STOMACH AND DUODENUM

1. STATISTICAL EVALUATION OF EIGHT ITEMS ON X-RAY FIGURES

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Abstract

As a basic study for quantitative estimation of the function of the stomach and the duodenum, the following eight items on upright postero-anterior roentgenograms of the stomach of five groups were measured to perform a series of statistical analysis of relationships between the items in each group and of comparisons among the five groups, and the results were studied from a clinical point of view : 1) width of the gastric angle section (Ba), of the gastric body (Bc) and Ba/Bc ratio, 2) antrum lesser curvature length (L), greater curvature length(G) and G/L ratio, 3) middle zone thickness(MZ), 4) saw-toothed wave depth (Zhnlg), 5) antral peristalsis (AP), 6) antral spasm (AS), 7) duodenal loop length (L of D) and number of duodenal longitudinal folds (Lf).

The results of the statistical analysis revealed that large differences from the control group were found in the items, G/L, MZ, AP and Zhnlg, suggesting that these represent characteristic values as an index of quantitative diagnosis.

INTRODUCTION

Pathophysiology of the genesis of peptic ulcer is diverse, and it is extremely difficult to study them by a uniform procedure. This is because of the anatomical peculiarities of the stomach and the duodenum where peptic ulcer develops, but also because of a large number of factors in the genesis of the ulcer formation, which make practically very difficult to study by regulating these conditions. Now, one of the functions the stomach is destined to perform as its important roles is food reservoir. In view of the important physiological phenomenon of discharge of bile and pancreatic juice in the duodenum

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contiguous to the stomach, the importance of this purposeful function can be easily understood.

In this respect, it is quite significant to grasp the pathological conditions of the stomach and the duodenum through quantitative evaluation of their kinetic function by capturing and analyzing some of the physiological and pathophysiological phenomenon of the stomach and the duodenum.

Numerous studies have been published on gastric peristalsis, using diverse methods of observation including the abdominal window method, intragastric pressure curve method, electromyographic method, various radiological methods and so on. Of these methods, radiological ones have the advantage of permitting observation of peristaltic movements both in physiological conditions and with ease of comparison of the morphological conditions of between the stomach and the duodenum.

As a basic study of quantitative estimation of gastric and duodenal ulcer by means of x-ray films of the stomach, eight items regarding upright postero -anterior view of five groups were measured, the relationships between the items in the groups and comparison of the five groups were statisically analyzed, and the results were studied from a clinical point of view.

MATERIAL

114 cases of normal persons and 153 cases of peptic ulcer were studied (Table 1).

TABLE 1 No. of Cases and No. of Films Measured

Group	No. of cases	No. of examination
N	114	114
GU	47	49
GS	39	41
DU	39	43
DS	28	30
Total	267	277

N : normal
GU : gastric ulcer
GS : 〃 (scar stage)
DU : duodenal ulcer
DS : 〃 (scar stage)

The normal 114 cases were those who were admitted for a short period to undergo through physical checkup during 1975 through 1979, randomly sampled, having no ulcer in the past history and currently, and without any pathological change such as peptic ulcer or similar disease on upper GI examination.

The cases of peptic ulcer were studied on the pictures taken during the hospitalization of those who were admitted to the hospital during the period from 1975 to 1978. The pictures excluded from study included 1) cases in which it was difficult to make adjudgment on the site of the gastric angle because of too large gastric ulcer or the pathology of the peptic ulcer was considered likely to cause errors in measurements, 2) cases of linear ulcer, 3) cases of pyloric stenosis, 4) cases in which it was not possible to judge whether the ulcer is active one or a scar on radiographic pictures because endoscopic examination has not been made, and 5) cases in which the cause of abdominal pain was due to other than ulcer such as gallstone disease or pancreatitis.

Classification of Pathological Stages of Ulcer

Stages of ulcer were roughly divided into two stages according to the following findings by roentgenologic or endoscopic examination : the open stage in which tissue defect existed clearly in the ulcer bottom, and the scar stage in which there existed no tissue defect being accompanied by neither niche roentgenologically nor white moss in the center of ulcer endoscopically.

The gastric ulcer and duodenal ulcer at the open stage are respectively abbreviated to GU and DU, and these at the scar stage are respectively abbreviated to GS and DS. A normal case is abbreviated to N.

METHOD

Conditions of X-ray Examination of the Stomach

For x-ray examination, a contrast medium (200 to 250 ml) of 100% barium sulfate suspension on the market and a foaming agent (Gastroluft 12 tablets) were administered when the stomach was empty in the early morning. For photographing prior administration of any inhibitor of the movement of the digestive canal was prohibited.

Measuring Method of X-ray Figures

Upright postero-anterior views in fillings method taken at the time when barium reached the lower duodenal flexure were studied. Study was made by meticulous tracing in blue on a tracing paper of the stomach and in red of the duodenum. The duodenal loop in the duodenum was studied in particular, but when it was difficult to perform simultaneous tracing of the loop as a whole because of partial overlapping of the upright postero-anterior view with the antrum shadow, the loop trace in the upright posteroanterior view was judged upon preliminary observation of the loop run on a film of a supine position, and if it was still difficult to judge, the film was left out of study.

(1) Width of the gastric angle section (Ba), width of the gastric boody (Bc) and Ba/Bc ratio :

The width of the gastric angle section is denoted by (Ba), and the width

between the cardia and the gastric angle section by the gastric body width (Bc) and shown in mm (Fig. 1-a). The ratio of the width of the gastric angle section to the gastric body width, Ba/Bc, was calculated, to be used as an index to judge the extent of tension of the gastric wall components, mainly the proper muscular layer.

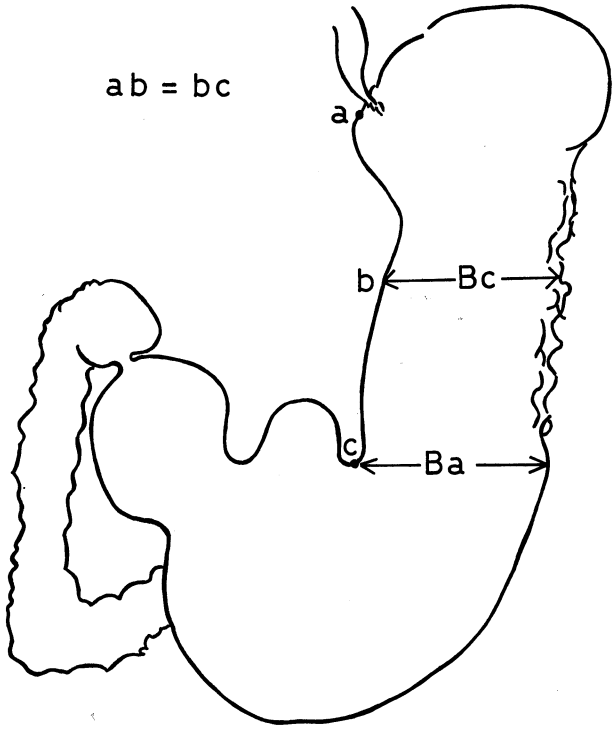

Fig. 1-a. Sites Measured by X-Ray Film of the Stomach

(2) Antrum lesser curvature length (L), antrum greater curvature length (G), and G/L ratio :

The contra-lateral point of the gastric angle, as shown in Fig. 1-b, was determined by using the horizontal line (Ba) in the gastric angle as reference, considering the line connecting the middle point of Ba with the middle point of Bc as the axis of the gastric boody, taking the angle by this gastric axis and the vertical line passing the middle point of Ba, plus 30°, in the clockwise direction from the gastric angle, and obtaining the intersection of this line with the gastric greater curvature as the contra-lateral point of the gastric angle.

The distance from the gastric angle to the pylorus and the distance from

the contra-lateral of the gastric angle are respectively termed the antrum lesser curvature length and the antrum greater curvature length, which are expressed in mm by measuring with a curvemeter on the trace. Contracting waves minutely seen in the gastric antrum, exceeding 5 mm in depth and estimated to be peristaltic waves, were measured faithfully following their movements, but those less than 5mm with a small width were measured in the width section. The ratio of the greater curvature length (G) to the lesser curvature length (L) is expressed in the greaterlesser curvature ratio (G/L ratio).

(3) Middle zone thickness (MZ) :

The thickness of the gastric juice layer seen on the upper part of the contrast medium in the upright x-ray film is termed the middle zone thickness and given in mm.

(4) Saw-toothed wave depth (Zhnlg) :

Saw-toothed waves showing saw-tooth shadows on the greater curvature side of the gastric body are classified by depth as follows. Those exceeding 10 mm in depth are described with a mark $+++$, those less than 10 mm with $++$, and those less than 5 mm with $+$. For summarizing the extent of the saw-toothed waves and obtaining the average, these waves were counted with $+$ as 1.

(5) Antral peristalsis (AP) :

Contractions seen in correspondence to the greater and lesser curvatures of pyloric antrum were considered due to peristaltic movements. These are termed antral peristalsis (AP), and the number of peristaltic waves appeared is treated as the number of antral peristalsis. Moreover, "antral systole" termed by Golden[1] was measured as one of the AP.

(6) Antral spasm (AS) :

The concept of gastrospasms named by Věšín was introduced[2]. Namely spastic contraction waves on the lesser curvature side that occur continuously in the antrum were examined as antral spasms. The extent of antral spasms was marked with $+$ for single spasms, with $++$ for a few spasms, and with $+++$ for a cluster of spasms forming an irregular marginal figure, and invariably judged by upright postero-anterior views. When it was impossible to judge the extent of antral spasms because of overlapping of duodenal shadow over the antral shadow. The quantization of AS was made similarly to that of Zhnlg mentioned above.

(7) Duodenal loop length (L of D) :

The length of the pars descendens, i.e. from the upper duodenal flexure to the lower duodenal flexure, is termed duodenal loop length (Fig. 1-b), the middle point between the greater curvature side and the lesser curvature side

on the trace was measured with a curvemeter following the movement of the pars descendens, and shown in mm.

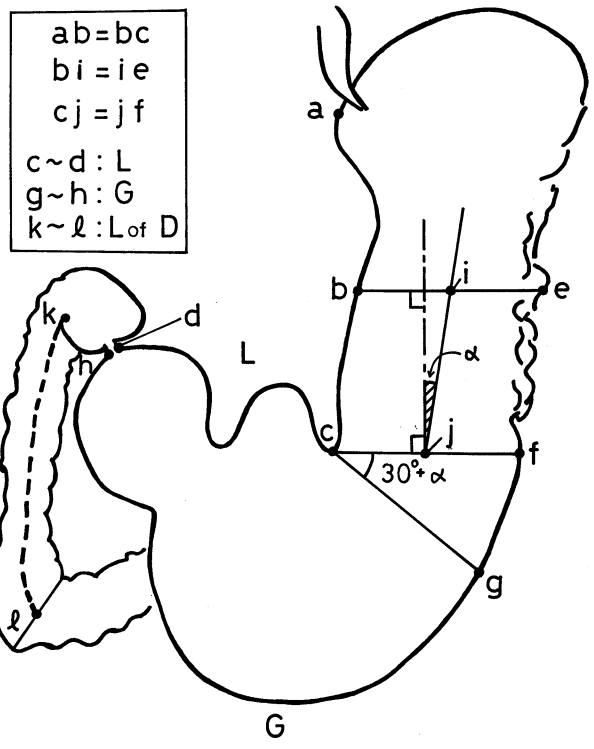

Fig. 1-b. Sites Measured by X-Ray Film of the Stomach

(8) Number of duodenal longitudinal folds (Lf) :

The number of duodenal folds appeared along the longitude seen in the pars descendens in the upright postero-anterior view, namely the number of duodenal longitudinal folds[1] was measured.

RESULTS

Regarding the eight items beginning with Ba/Bc, the following problems were taken up and statistically analyzed.

1) Distribution of the measured values of the items in the five groups, N, GU, GS, DU and DS.

2) Relationships and differences between the five groups regarding the eight items.

Regarding 1), the average value of each item, the 95% reliable section of the average value of SD and each item are shown in Table 2. A histogram

TABLE 2

Average Values and Standard Deviations of the 8 Items Measured

(n : no. of samples)

	Group	N	GU	GS	DU	DS
Ba/Bc	MEAN	1.05	1.16	1.15	1.07	1.12
	SD	0.26	0.28	0.24	0.29	0.28
	n	112	49	41	43	30
	confidence interval	1.00~1.10	1.08~1.24	1.07~1.22	0.99~1.16	1.02~1.22
G/L	MEAN	2.42	2.93	2.89	2.31	2.53
	SD	0.68	0.85	0.97	0.53	0.52
	n	112	48	40	41	30
	confidence interval	2.29~2.55	2.68~3.17	2.58~3.20	2.14~2.47	2.34~2.73
MZ	MEAN	9.50	7.94	12.68	14.28	17.10
	SD	15.89	12.14	22.45	19.33	26.99
	n	114	49	41	43	30
	confidence interval	6.55~12.45	4.47~11.41	5.60~19.76	8.38~20.17	7.03~27.17
Zhnlg	MEAN	1.43	1.44	1.37	1.26	1.28
	SD	0.69	0.68	0.49	0.49	0.46
	n	113	48	41	43	29
	confidence interval	1.30~1.55	1.24~1.63	1.21~1.52	1.11~1.41	1.10~1.45
AP	MEAN	0.63	0.89	0.88	1.41	1.24
	SD	0.59	0.67	0.56	0.59	0.58
	n	103	47	40	42	29
	confidence interval	0.52~0.75	0.70~1.09	0.70~1.06	1.22~1.59	1.02~1.46
AS	MEAN	0.67	0.47	0.45	0.69	0.31
	SD	0.81	0.89	0.80	0.89	0.47
	n	108	45	38	39	29
	confidence interval	0.51~0.82	0.20~0.73	0.19~0.71	0.40~0.98	0.13~0.49
L of D	MEAN	108.50	106.87	114.98	114.03	113.83
	SD	24.44	21.49	27.47	22.39	20.25
	n	100	39	40	38	30
	confidence interval	103.66~113.34	99.92~113.82	106.20~123.75	106.69~121.36	106.27~121.39
Lf	MEAN	0.48	0.29	0.33	0.47	0.57
	SD	0.58	0.51	0.62	0.65	0.88
	n	92	41	39	36	28
	confidence interval	0.36~0.60	0.13~0.45	0.13~0.53	0.25~0.69	0.23~0.91

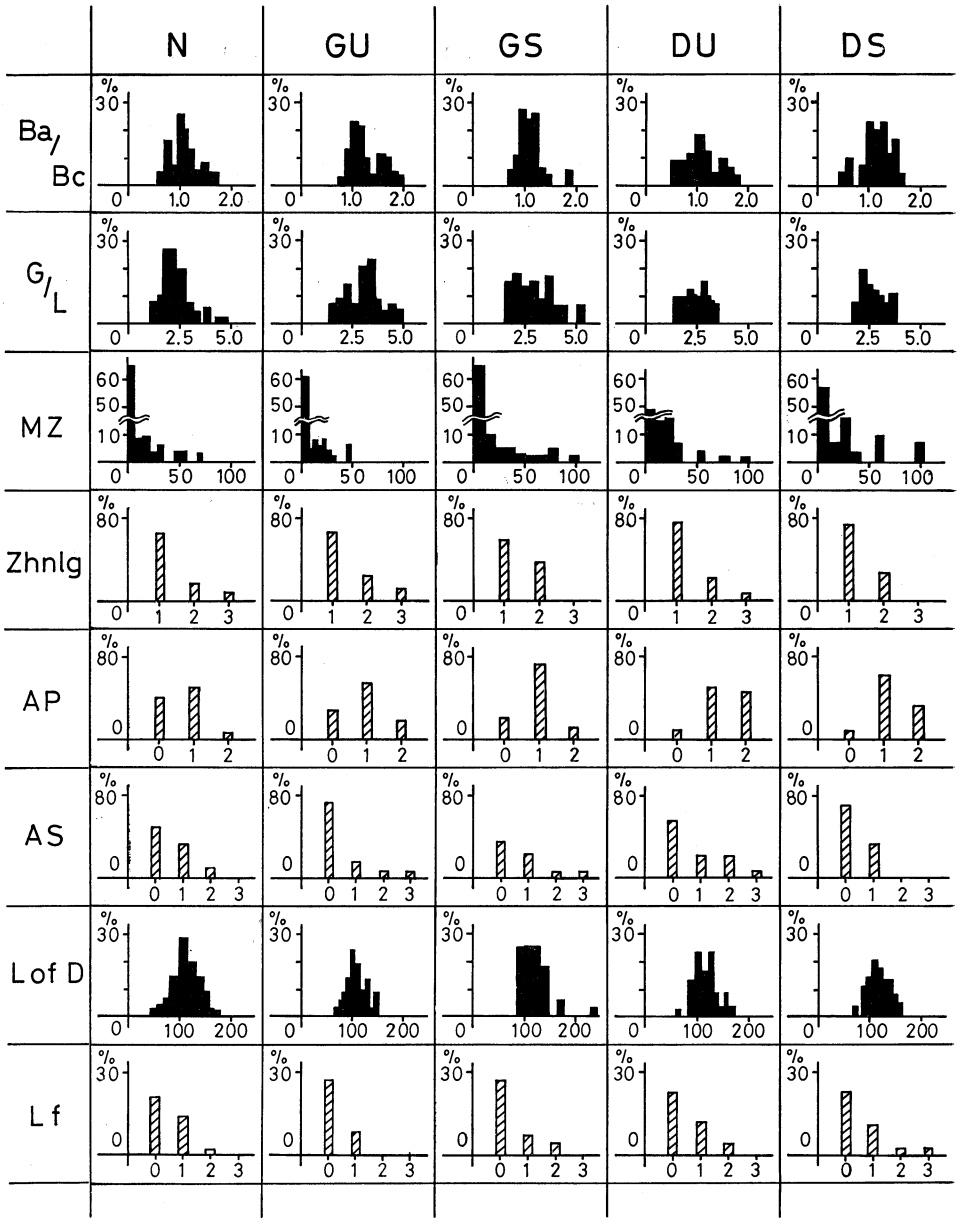

Fig. 2. Histrograms by the Groups Regarding the 8 Items

was obtained by making incidence distribution table of each item (Fig. 2). Regarding MZ, addition was made beginning with those with no MZ observed and shown in per cent. Regarding 2), a significance test of the average value among the five groups on seven items, Ba/Bc, G/L, MZ, AS, and Zhnlg was performed. For this test, the F test, t test and Welch's test were used and the results obtained are shown in Table 3. The code **,*, and + in Table 3 respectively mean a significant difference in the average value found with a significant level of 0.01, 0.05, 0.10.

TABLE 3

Test of Differences in Average Value among the Groups on 7 Variables

(significant level: XX ····· 0.01, X ····· 0.05, + ····· 0.10)

Ba/Bc, G/L	N	GU	GS	DU	DS
	F t w	F t w	F t w	F t w	F t w
N		X	X		
GU	X XX XX				
GS	XX XX XX				
DU		XX XX XX	XX XX XX		
DS		XX X X	XX + +	+	

Zhnlg, AP	N	GU	GS	DU	DS
	F t w	F t w	F t w	F t w	F t w
N			X	XX +	X
GU	X		X	X	X
GS	X				
DU	XX	XX	XX		
DS	XX	X	XX		

MZ, AS	N	GU	GS	DU	DS
	F t w	F t w	F t w	F t w	F t w
N		X	XX		XX X
GU			XX	XX + +	XX X +
GS		∽			
DU					X
DS	XX X XX	XX	XX	XX X X	

Lf	N	GU	GS	DU	DS
	F t w	F t w	F t w	F t w	F t w
N					
GU	+				
GS					
DU					
DS	XX	XX +	X		

From the table it will be seen that there was a significant difference in the average value in item G/L between GU and GS groups in the N group, while in both GU and GS groups had a significant difference between the DU and DS groups. No significant difference was observed among the rest of the groups.

The measurements of each item are divided into three or four groups, and number of instances of measurements and percentage of each of the N, GU, GS, DU, and DS groups, are shown in Table 4.

Regarding the date on item AP, which are dispersive type as 0, 1, 2, •••, division tables were made by taking two groups at a time from the five groups, and chisquare (χ^2) test was performed also for testing similarities between the division tables were made by taking two groups at a time from the five groups, and chisquare (χ^2) test was performed also for testing similarities between the

TABLE 4

No. of Instances of Measurement of Variables by Classes

( ) : Percentage

	Group	N	G U	G S	D U	D S
Ba/Bc	1.20 ～	25 (22.3)	15 (30.6)	15 (36.6)	11 (25.6)	10 (33.3)
	1.00～1.19	40 (35.7)	21 (42.9)	19 (46.3)	17 (39.5)	9 (30.0)
	～ 0.99	47 (42.0)	13 (26.5)	7 (17.1)	15 (34.9)	11 (36.7)
	Total	112 (100)	49 (100)	41 (100)	43 (100)	30 (100)
G/L	2.40 ～	51 (45.5)	33 (68.8)	26 (65.0)	18 (43.9)	15 (50.0)
	1.90～2.39	42 (37.5)	9 (18.7)	8 (20.0)	12 (29.3)	12 (40.0)
	～ 1.89	19 (17.0)	6 (12.5)	6 (15.0)	11 (26.8)	3 (10.0)
	Total	112 (100)	48 (100)	40 (100)	41 (100)	30 (100)
MZ	25 ～	19 (16.7)	5 (10.2)	8 (19.5)	9 (20.9)	8 (26.7)
	10 ～ 24	18 (15.8)	12 (24.5)	6 (14.6)	13 (30.2)	5 (16.6)
	～ 9	77 (67.5)	32 (65.3)	27 (65.9)	21 (48.9)	17 (56.7)
	Total	114 (100)	49 (100)	41 (100)	43 (100)	30 (100)
Zhnlg	1	78 (69.0)	32 (66.7)	26 (63.4)	33 (76.8)	21 (72.4)
	2	22 (19.5)	11 (22.9)	15 (36.6)	9 (20.9)	8 (27.6)
	3	13 (11.5)	5 (10.4)	0 (0.0)	1 (2.3)	0 (0.0)
	Total	113 (100)	48 (100)	41 (100)	43 (100)	29 (100)
AP	0	44 (42.7)	13 (27.7)	9 (22.5)	2 (4.8)	2 (6.9)
	1	53 (51.5)	26 (55.3)	27 (67.5)	21 (50.0)	18 (62.1)
	2	6 (5.8)	8 (17.0)	4 (10.0)	19 (45.2)	9 (31.0)
	Total	103 (100)	47 (100)	40 (100)	42 (100)	29 (100)
AS	0	55 (50.9)	33 (73.3)	26 (68.4)	22 (56.4)	20 (69.0)
	1	38 (35.2)	6 (13.3)	9 (23.7)	8 (20.5)	9 (31.0)
	2	11 (10.2)	3 (6.7)	1 (2 6)	8 (20.5)	0 (0.0)
	3	4 (3.7)	3 (6.7)	2 (5.3)	1 (2.6)	0 (0.0)
	Total	108 (100)	45 (100)	38 (100)	39 (100)	29 (100)
Lf	0	52 (56.5)	30 (73.2)	29 (74.4)	22 (61.1)	17 (60.7)
	1	36 (39.1)	10 (24.4)	7 (17.9)	11 (30.6)	8 (28.6)
	2	4 (4.4)	1 (2.4)	3 (7.7)	3 (8.3)	1 (3.6)
	3	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (7.1)
	Total	92 (100)	41 (100)	39 (100)	36 (100)	28 (100)

TABLE 5
Test of Differences among the Groups Regarding the AP Number

significant level ** ----0.01
* ----0.05
+ ----0.10

	N	GU	GS	DU	DS
N		*	+	**	**
GU				**	+
GS				**	*
DU					
DS					

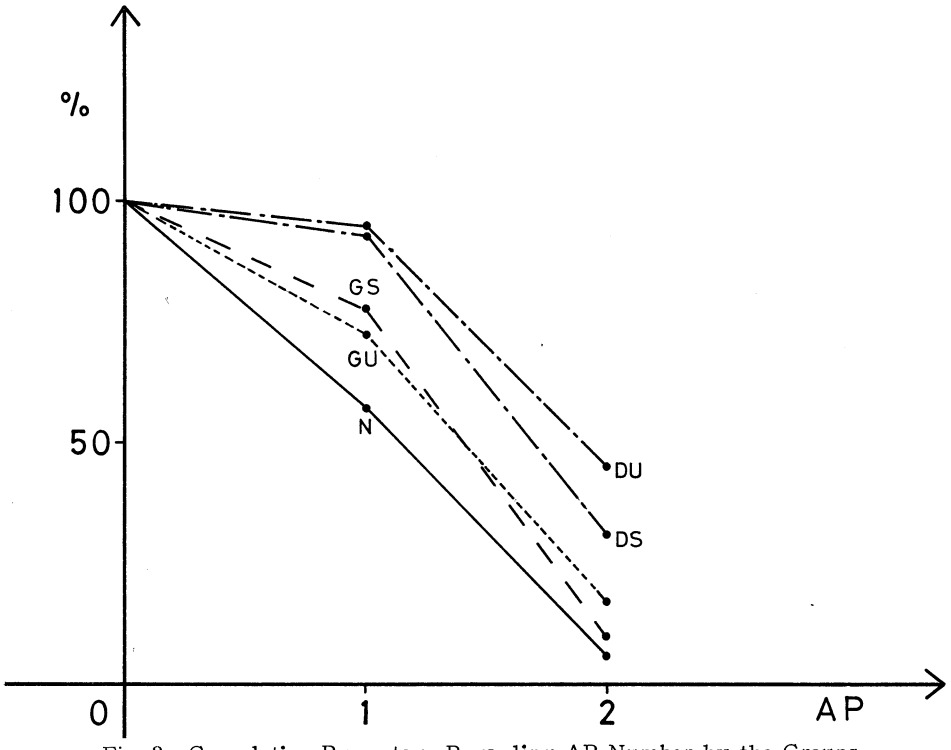

Fig. 3. Cumulative Percentage Regarding AP Number by the Groups

two groups, and the results obtained are shown in Table 5. The number of cases on AP were added up as 2, 1, 0, and shown in percentage in Fig. 3.

DISCUSSION

With due attention paid to the differences among the five groups, the results of statistical analysis of each item are discussed from a clinical viewpoint.

(1) Ba/Bc :

In the average values, the GU and GS groups have higher values than the N group, a significant difference between the N group and the GU as well as the GS groups being revealed in at t test with a significant level at 0.05. When Ba/Bc data are roughly divided into the group of 0.99 and less, the group from 1.00 to 1.19, and the group of 1.20 and over, the duodenal ulcer groups DU and DS have a higher rate of the group of 0.99 and less in Ba/Bc than the gastric ulcer groups GU and GS. The N group shows a high percentage of 42.0% for the group of 0.99 and less in Ba/Bc, showing low values like the DU and DS groups. This appears due to high values in Ba/Bc in the gastric ulcer groups GU and GS with the tonus decline in the gastric wall, while no difference was caused in tonus or extensibility of the gastric muscles in the duodenal ulcer groups.

(2) G/L :

Differences are seen in standard deviation between the GU and GS groups and the DU and DS groups. In the t test and Welch's t test (Table 3), no significant difference was seen between the N group and the DU and DS groups, while a significant difference was observed between the N group and the GU and GS groups. Significant differences clearly appeared between the gastric ulcer groups and the duodenal ulcer groups.

When the G/L data are roughly divided into the group of 1.89 and less, the group from 1.90 to 2.39, and the group of 2.40 and over, the GU and GS groups show a tendency to be in the group of 2.40 and over in G/L. Examination of the incidence distribution reveals that the GU and GS groups tend to show multiple peaks compared to the N group. Like Ba/Bc, G/L data show significant differences between the GU and GS groups and the N group, revealing a tonus decline in the gastric wall, particularly in the pyloric antrum in the gastric ulcer groups. Nonetheless, no finding was obtained to show an increase in the tonus of the gastric wall in the duodenal ulcer groups compared with the N group. In this respect, the G/L data seem to reveal similar findings to those of the Ba/Bc data.

(3) MZ :

In the average values, all groups except the GU group show higher values than the N group. In the F test, significant differences are seen with a

significant level of 0.01 between the GS and DS groups and the N group, while the significant level is 0.01 for the GS, DU and DS groups are higher than the GU group. A significant difference is seen between the DS group and the DU group with a significant level at 0.05, and the values are high in the scar stage for both gastric and duodenal ulcers. When the MZ data are divided into the group of 9 and less, the group form 10 to 24, and the group of 25 and over, the rate of the group of 25 and over in MZ is increased in the GS and DS. Hitherto MZ has been considered to indicate the volume of gastric juice, which seems to vary somewhat due to the volume of barium, reverse flow of bile, etc. apart form the gastric discharge function.

(4) Zhnlg :

The extent of Zhnlg tends to be higher in the GU and GS groups than in the DU and DS groups. In the F test, comparison with the N group revealed that the DU group showed low values, indicating a significant difference with a significant level of 0.01. The results of the chisquare (χ^2) test by dividing the Zhnlg data into the group of less than 5 mm, the group less than 10 mm, and the group of 10 mm and over show a difference with a significant level of 0.05 between the N group on one hand, and the GS and GU groups, but no significant difference between the N group and the DU and DS groups. The Zhnlg are considered to be composed of the mucus of relatively higher viscosity covering the mucous membrane different from the genesis of MZ and the height of folds of the greater curvature. It is difficult to set the conditions for measuring Zhnlg and MZ, and these may not be completely analyzed by routine x-ray tests.

(5) AP :

The results of the test reveal significant differences with 0.01 or 0.05 in the level of significance between the N group and the GU, GS, DU and DS groups respectively. Nonetheless, the results of the F test, t test or chisquare (χ^2) test with AP number divided into 0 to 2 groups (Table 5) reveal no difference between the GU group and the GS group and between the DU group and the DS group. The results of the t test reveal a difference with a level of significance at 0.01 between the GU group and the DU group, and with a level of significance at 0.05 between the GS group and the DS group.

Examination of the extent of AP in the groups reveals that the N group has a high percentage of showing 0 or 1 in the AP number, that the GU and GS groups have a higher percentage of showing 1 or 2 in the AP number than the N group, and a lower percentage of showing 0 in the AP number.

On the other hand, the DU and DS groups have an increased percentage of showing 2 in the AP number, while the percentage of showing 0 in the AP

number is decreased. Various different views have been published on the distinction between the peristaltic wave and peristole regarding the peristalsis in the antral portion of the gastric pylorus. In the present study, peristole was measured as one of the peristaltic waves according to the view that peristaltic wave and peristole are qualitatively identical and the difference is merely quantitative, as Maki et al. have described[3].

It is in fact difficult to distinguish between peristaltic wave and peristole regarding peristaltic waves near the pyloric ring. Absence of significant differece between the GU group and the GS group as well as between the DU group and the DS group may perhaps be due to movements not different from those in the open stage, because relatively early cases were measured with ulcer scars in both the GS and DS groups. Nonetheless, movements even in the scar stage may actually show similar movements in the open stage. This has to be investigated in further studies.

(6) AS :

The DS group shows in the results of the F test a significant difference with a significant level at 0.01 from all of the rest of the groups. Regarding spasms, the sites to be noted in routine x-ray films of the stomach are often confined to the pyloric antrum. The definition of these spasms leaves problems pending. It requires further study to determine whether these spasms are abnormal phenomena caused by contraction of the muscularis mucosal, or also by the proper muscular layer.

(7) L of D, Lf :

Regarding the duodenal loop, which makes a meandering run, which may be considered to make measurements of its projection on a film meaningless, but we took it up in connection with the longitudinal folds.

Although it is not possible to distinguish on a single x-ray film whether duodenal longitudinal folds are Borgström's[4] propulsive wave, retrograde wave or static wave, it is worth examining them in view of the fact that the pattern of movement of the duodenum considerably varies between gastric ulcer and duodenal ulcer[5]. At any rate, the contracting cycles in the duodenum are considered far more numerous than in the stomach[6]. It is noteworthy that the incidence of observing duodenal longitudinal folds completed in the pars descendens of the duodenum in the x-ray films is very low as shown in Table 2.

SUMMARY

1. In a total of five groups including peptic ulcer groups of GU, GS, DU and DS and the normal group, eight items were measured and statistically

analyzed.

2. It has been revealed that marked differences between the GU, GS, DU and DS groups and the normal group appeared in the results of the statistical analysis in G/L, MZ, AP, and Zhnlg. Consequently the results seem to suggest that G/L, MZ, AP and Zhnlg are characteristic values as an index for quantitative estimation. Moreover, this method of study seems to be significant as an approach for the roentgenologic diagnosis of the stomach.

3. The eight items dealt with have been studied independently, but these eight items seem to be mutually related. The analysis of multiple variables of these eight items is now underway.

Acknowledgment

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