

Pathophysiological Studies of the Stomach and Duodenum

1. Duodenal Malrotation in Healthy Subjects

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ABSTRACT. A series of observation was preliminarily made on X-ray films of the stomach and duodenum of 94 healthy persons in order to determine what changes occur in regard to the motility function between these two organs in the case of peptic ulcer. The following results were obtained on the basis of whether or not there were running abnormalities of the duodenal loop, which abnormalities are noted rather frequently, as well as on the basis of statistical analysis :

- 1) Torsional anomaly of the duodenal loop (hereafter referred to as MD) was found in 18 of the 94 subjects (19.1%).
- 2) The maximum diameter of the duodenum in the MD group tended to be larger than that in the normal group.
- 3) The rate of onset of antral peristalsis, antral spasm, and duodenal longitudinal fold was higher in the MD group than in the normal group.
- 4) However, it was confirmed that the onset of these three symptoms was very rare.

For a long time much attention has been given to the movements of the digestive tract, in particular the linked movements of each part of the tract, and many reports have been made on the relationship between the stomach and duodenum in regard to the motility functions. More particularly, many controversies have arisen concerning the coordination of peristalsis from the stomach to the duodenum, which is a well-known fact. Such being the case, for a long time many reports have been made as to what characteristics are observed in regard to the movements between the stomach and duodenum in the case of gastroduodenal diseases, especially in the case of gastroduodenal ulcers. In view of the fact, however, that in recent years certain groups of researchers have been studying the problem of duodenal malrotation, which has a close relationship with the gastroduodenal movements, it may be worthwhile to reexamine this problem and related problems. Therefore when clinical examination of gastroduodenal movements was made from this viewpoint, the author aimed to determine the characteristics of the movements of the stomach and duodenum in the case of various diseases, especially in the case of gastroduodenal ulcers, using for analysis not only X-ray films of the stomach and duodenum but also video tapes from X-ray television. In the present study, the running

abnormalities of the gastroduodenal loop were examined as preliminary observations.

MATERIALS AND METHODS

Subjects : Ninety-four healthy persons were selected at random from among persons staying in our department for a short time for general health checkups, the so-called medical "dock" examination, during the period from April 1978 through December 1980. The following persons were judged as being healthy :

1. Those with no previous records of abdominal operations, liver, gall bladder, or pancreas diseases, or gastroduodenal diseases.
2. Those in whom no clear or presumed organic abnormalities were revealed by X-ray films of the upper digestive tract and in whom the duodenal loop was clearly depicted. Table 1 shows the ages and sex ratio of the healthy persons examined. They ranged in age from 23 to 61, and the mean was 49.1 years.

TABLE 1. Frequency of malrotation of the duodenum related to age

Age	Control Group			Malrotation of the duodenum
	No of cases			
	Male	Female	Total	
21 - 25	1	0	1	0
26 - 30	0	0	0	0
31 - 35	1	0	1	0
36 - 40	11	0	11	3 (27.2%)
41 - 45	12	0	12	0
46 - 50	20	0	20	6 (30.0%)
51 - 55	41	2	43	7 (16.3%)
56 - 60	5	0	5	2 (40.0%)
61 - 65	1	0	1	0
Total	92	2	94	18

Methods :

1. Conditions for taking X-ray films of the upper digestive tract
A contrast medium (200 ml) consisting of barium sulfate 100% suspended solution and foaming tablets (Gastroluft, 12 tablets), both commercially available, were administered early in the morning during fasting. Gastro-intestinal motility inhibitors were not administered prior to the X-ray examinations. The camera for X-ray television was Type DT-SK, and the X-ray films were taken at 200 mA, 0.25 sec., 90 KVA (PHOTO).
2. Measurements for X-ray films of the upper digestive tract X-ray films were taken from 4 directions : ventro-dorsally in both upright and supine positions and from the first oblique in both upright and supine positions.

The following 5 items on the X-ray films were examined and compared. The X-ray films after compression were excluded from examination.

- 2-1. Malrotation of the duodenum (MD) : As shown in Fig. 1, the normal shape of the duodenum is almost 3/4 of a circle. The initial region is called the duodenal cap and denotes a shape resembling an equilateral triangle. It runs obliquely from the pylorus towards the upper right back at the height of the 12th thoracic vertebra to the first lumbar vertebra on the right side of the spine. Beyond the cap it goes into the posterior peritoneal cavity, running in a C-shape, and transfers the jejunum passing through the Tritz ligament at the back of the stomach.

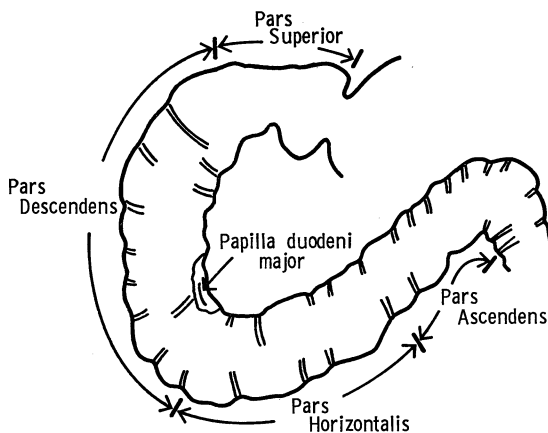


Fig. 1. Duodenum

The term malrotation used in the present paper does not refer to the term commonly used for malrotation at the embryonic stage. Rather, it means the kinking of the duodenum, or torsion abnormalities, i.e. torsional anomaly.

If MD exists, the lesion is detected as indentation findings (Fig. 2). In typical cases, it is observed in the upper part of the X-ray film as tursim of Kerckling's folds, generally hindering the passage of the contrast medium. In order to evaluate the clinical significance of MD, MD on X-ray films was classified into the following 3 grades according to Slavensky's method :

- a) Severe : MD was observed on all the X-ray films taken from all directions, and hindrance of the passage of the contrast medium and enlargement of the lesion or the luminal diameter of the terminal part of the duodenum were noted.
- b) Mild : MD was observed on X-ray films taken from more than 2 direction, but the passage of the contrast medium was not hindered.
- c) Normal variant : MD was suspected on an X-ray film taken from 1 direction only.

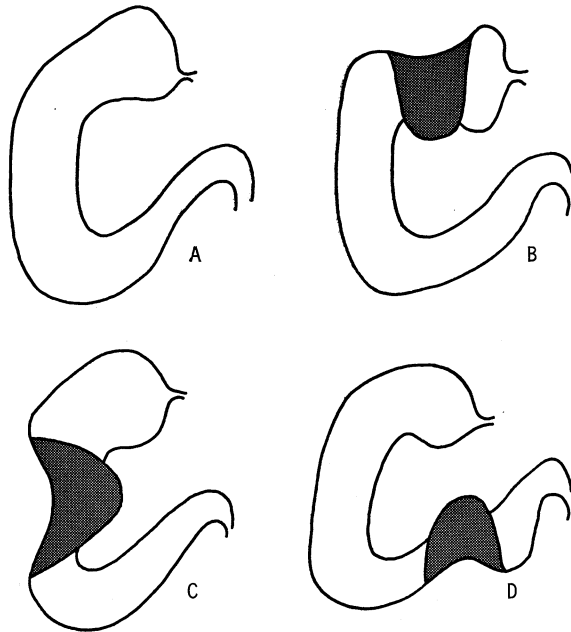


Fig. 2. Schematic illustrations of
 A : Normal duodenum
 B : Malrotation of the superior part of the duodenum
 C : Malrotation of the descending part of the duodenum
 D : Malrotation of the horizontal part of the duodenum

- 2-2. The largest luminal diameter of the duodenum : The widest region at the descending or horizontal part on the right side of the spine in the upper part of the X-ray films taken in the ventro-dorsal upright position was measured at a right angle to the vertical axis, denoted in mm.
- 2-3. Antral peristalsis (AP) : The contraction observed corresponding to the greater and lesser curvatures in the antrum was considered to be due to peristaltic movements, and it was examined.
- 2-4. Antral spasm (AS) : Spastic and contractile waves on the lesser curvature occurring persistently in the antrum were considered to be AS and were examined.
- 2-5. Duodenal longitudinal folds (Lf) : Duodenal longitudinal folds observed in parallel with the vertical axis in the X-ray films of the ventro-dorsal upright position were examined.

RESULTS

1. Frequency of malrotation

- 1-1. Frequency and sex ratio : MD was detected in 18 of the 94 subjects (19.1%). Differences between the male and female subjects could not be

compared since the majority of the participants in the present study were male (Table 2).

TABLE 2. The Frequency of Malrotation of the Duodenum

	Control Group		
	Male	Female	Total
No of cases	92	2	94
Normal duodenal configuration	74	2	76(80.9%)
Malrotation of the duodenum	18	0	18(19.1%)

1-2. Frequency of malrotation classified according to the region and the severity. Of 18 cases of MD, MD occurred the most frequently in the descending region. It was detected in the descending region in 11 cases (61.1%) and in the ascending region in 7 cases (38.9%). MD was not detected in the horizontal region.

A comparison of the severity of MD revealed that 8 of the 18 subjects (44.4%) had mild MD and that in 7 of the subjects (38.9%) MD was within the normal range. Three of the subjects (16.7%) had severe MD.

Table 3 shows a comparison of the regions of onset and the severity. It can be seen that mild MD (7 cases out of 8) and severe MD (all 3 cases) were mostly found in the descending regions while MD within the normal range was mostly in the ascending regions (6 cases out of 7).

TABLE 3. The Position and the Grade of Malrotation of the Duodenum

	Control Group			
	Severe	Mild	Normal Variant	Total
No of cases	3 (16.7%)	8 (44.4%)	7 (38.9%)	18(100.0%)
Pars Superior	0	1 (5.6%)	6 (33.3%)	7 (38.9%)
Pars Descendens	3 (16.7%)	7 (38.9%)	1 (5.6%)	11 (61.1%)
Pars Horizontalis	0	0	0	0

2. The largest luminal diameter of the duodenum Figure 3 shows histograms of the largest luminal diameters of the duodenum, in which a symmetric

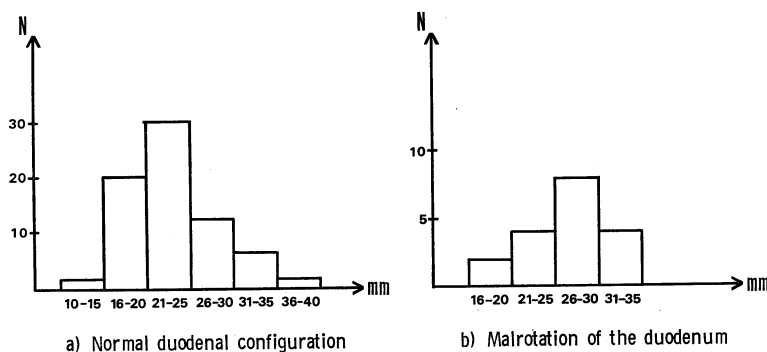


Fig. 3. Histogram showing the distribution of the lengths of the luminal diameters of the duodenum

binomial distribution is shown both in the normal and MD groups. However, a comparison of the mean values of the largest duodenal luminal diameters between the normal group and MD group revealed, since there were few female subjects, that the diameter in the MD group was enlarged to 27 ± 4.38 mm as compared with 24 ± 5.21 mm (shown in Table 4). This difference was statistically significant.

TABLE 4. The largest luminal diameter of the descending and horizontal parts of the duodenum to the right of the spinal column measured on anteroposterior radiographs taken in the erect position.

	Control Group					
	Male		Female		Total	
	n	Diameter (mm) Range Mean \pm SD	n	Diameter (mm) Range Mean \pm SD	n	Diameter (mm) Range Mean \pm SD
Normal duodenal configuration	74	15-37 24 ± 5.00	2	16-35 25 ± 9.50	76	15-37 24 ± 5.21
Malrotation of the duodenum	18	20-35 27 ± 4.26	0	0 0	18	20-35 27 ± 4.38

**... $P < 0.01$

3. Movements of the stomach and duodenum

The following results of AP, AS, and Lf as the factors showing the movements of the stomach and duodenum to some extent were obtained concerning the normal group and MD group (Table 5):

- 3-1. Appearance of peristaltic waves in the antrum: AP appeared in 21 of the 76 subjects in the normal group (27.6%) and in 6 of the 18 subjects in the MD group (33.3%).
- 3-2. Appearance of duodenal longitudinal folds: Lf was noted in 15 of the

TABLE 5. Gastroduodenal Movement (1)

	Normal duodenal configuration			Malrotation of the duodenum			Total		
	M	F	T	M	F	T	M	F	T
No of cases	74	2	76	18	0	18	92	2	94(100.0%)
Antral Peristalsis (AP)	20	1	21 (27.6%)	6	0	6 (33.3%)	26	1	27 (28.7%)
Duodenal longitudinal fold (Lf)	14	1	15 (19.7%)	5	0	5 (27.8%)	19	1	20 (21.3%)
Antral Spasm (AS)	4	0	4 (5.2%)	2	0	2 (11.1%)*	6	0	6 (6.4%)

*.....P<0.05

76 subjects in the normal group (19.7%) and in 5 of the 18 subjects the MD group (27.8%).

3-3. Appearance of antral spasm : AS was noted in 4 of the 76 subjects in the normal group (5.2%) and in 2 of the 18 subjects in the MD group (11.1%).

3-4. Relationship between AP, Lf, and AS : Table 6 shows the mutual relationship between AP, Lf, and AS.

i) There were no cases in which both Lf and AS were noted in both groups.

TABLE 6. Gastroduodenal Movement (2)

		Lf(+) AS(+)	Lf(+) AS(-)	Lf(-) AS(+)	Lf(-) AS(-)
Normal duodenal configuration (n=76)	AP(+)	0	4/76 (5.3%)	0	17/76(22.4%)
	AP(-)	0	11/76(14.5%)	4/76 (5.3%)	40/76(52.6%)
Malrotation of the duodenum (n=18)	AP(+)	0	1/18 (5.6%)	0	5/18(27.8%)
	AP(-)	0	4/18(22.2%)*	1/18 (5.6%)	7/18(38.8%)

*.....P<0.05

AP : Antral Peristalsis
Lf : Duodenal longitudinal fold
AS : Antral Spasm

ii) There were no cases in which both AS and AP were noted in both groups.

iii) However, both Lf and AP were observed in 4 of the 76 subjects in the

normal group (5.3%) and in 1 of the 18 subjects in the MD group (5.6%).

- iv) Lf was observed, but AS and AP were not, in 11 of the 76 subjects in the normal group (14.5%) and in 4 of the 18 subjects in the MD group (22.2%). The difference was statistically significant.

DISCUSSION

The correlation of the movements between the stomach and duodenum has long been studied by many researchers, and, particularly, the motility has attracted much attention. In the present study, preliminary observation were made, centering on MD, in order to determine, on the basis of the results, how the correlation of the movements between the antrum of the stomach and the duodenum can be interpreted when gastroduodenal ulcers are detected on X-ray films.

The onset of MD, a morphological anomaly in the duodenum, may be understood to be due to incomplete rotation at the embryonic stage from embryologic and pathoanatomical points of view^{1,2,3}.

The duodenal loop beginning with the bulbus duodeni and reaching the flexura duodenojejunalis is apt to develop torsional anomaly over the entire area at a high frequency. Especially during two decades, the rate of appearance is as high as 60%. However, when he is 35 or over, the rate sharply declines to 25%, according to a report⁴. This development has been attributed to the fact that the disposition and fixation of the duodenum are completed by the age of 30 or so^{4,5}.

If age greatly affects the onset of MD, MD examinations must be carried out in consideration of the age and sex ratio. However, the present study was made using normal subjects who visited our department for general health checkups. A simple comparison of our results with those obtained in Western countries should not be refrained from, but the fact remains that MD was detected in 19.1% of our healthy subjects.

Further research is necessary before it can be ascertained that the regions of onset of MD are mostly in the descending regions and not in the horizontal regions. It is unnecessary to argue that the descending regions of the duodenal loop are regions where the most complicated functions occur from anatomical and physiological viewpoints. On the other hand, however, there is the opinion that the curve formed by the loop itself, including this part, is narrow and upright in a person with a slim physique while it is low and broad in a person with a heavily-build physique so that there is a negative correlation between the loop width and loop height. Yet another opinion⁶ is that such a negative correlation has not been recognized and that instead in men there has been a markedly significant correlation between the loop area formed between the loop and the median line of the backbone and the body weight or between the loop area and the true body surface areas, thereby attempting to introduce

morphological findings into clinical studies.

Therefore in consideration of the fact that MD is observed in the loop with a certain frequency and that the existence of MD shows a delay of dilatation and gastric emptying of the duodenum in a significant correlation^{4,5,7}, morphological examination of the duodenal loop may have some significance.

More particularly, our finding that the largest luminal diameter was significantly enlarged as compared with that in the normal group correlated well with the results^{4,5,7} obtained by the group of Danish authors. Further examination of this significance might reveal additional important findings.

So far several methods for the examination of gastroduodenal movements have been introduced, including the abdominal fenestration method, the balloon method, and the electromyogram method, but X-ray examinations still play an important role. The first study of the movements in the digestive tract was made by Cannon⁸ and was reported in May 1897. Since the normal movements of the digestive tract include the transfer of the contents, observation of the movements must be macroscopic, supplemented and fundamentalized by electrophysiologic and other examinations. In this sense, macroscopic observations by means of the abdominal fenestration method and roentgenography are very important and cannot be ignored.

Incidentally, the normal movement of the stomach is only one kind of movement, i.e. so-called peristalsis. The initial point of peristaltic waves is a segment in the cardia, but small waves generated in the cardia are hardly discernible. They can only be recognized in the lower part of the stomach as clear contractile waves⁹. When the contraction of the stomach begins, the contents in the stomach are pushed to the front of the contractile waves and are transported from the antrum to the pylorus. When the waves draw near the pylorus, part of the contents of the stomach are sent to the duodenum.

However, peristaltic waves are more rapid than the movement of the contents of the stomach so that when the waves moving at a faster speed catch up with the contents, the majority of the contents are pushed back towards the antrum again, and the so-called retropulsion phenomenon occurs¹⁰. In these series of movements, if excretion of the contents of the stomach is delayed by torsional anomaly in the duodenum, which receives the contents, it is easily understood that its clinical significance is not so small. In this sense, it may be said that the enlargement of the luminal diameter of the duodenum in the MD group is significant.

Before concluding this chapter, mention should be made of the fact that AP, Lf, and AS were not observed in counted 52.6% of the subjects in the normal group and in 38.8% in the MD group. If this phenomenon is considered centering on the appearance of Lf, it may be interpreted that it is rare for both AP and AS, or either of them, to appear together with Lf. Although this finding tallies well with other results^{11,12,13} in which the movements in the upper part of the duodenum are inhibited at the contractile phase of the antrum pyloricum, it may be said that the inhibitory phenomenon reported by Joseph

et al. can be observed here.

SUMMARY

Of a total of 94 subjects, malrotation of the duodenum was detected on X-ray films of the stomach and duodenum in 18 healthy persons (19.1%). The largest luminal duodenal diameter showed a tendency toward becoming larger in the MD group than in the normal group. Antral peristalsis, antral spasm, and duodenal longitudinal folds appeared more frequently in the MD group than in the normal group. However, the rate of appearance of all 3 symptoms, or of 2 of them, was very low.

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REFERENCES

- 1) Slavensky, Edith J. : Developmental anomalies of the duodenal loop. Thesis. Munksgaard, Copenhagen, 1969
- 2) Gravgaard, E. pp. 112-128 in Lauge-Hansen, N. (ed.) Developmental anomalies of the gastrointestinal tract due to malrotation. Munksgaard, Copenhagen, 1974
- 3) Lauge-Hansen, N. : Developmental anatomy of the human gastro-Intestinal tract. Munksgaard, Copenhagen, 1973
- 4) Gravgaard, E., Holm Möller, S. and Andersen, D. : Malrotation of the duodenum. frequency in a radiographic control group. *Scand. J. Gastroent.* **12** : 585-588, 1977
- 5) Gravgaard, E., Holm Möller, S. and Andersen, D. : Malrotation of the duodenum and Duodenal Ulcer. *Scand. J. Gastroent* **12** : 589-592, 1977
- 6) Owen J, P. and Keir, M. J. : Correlations between duodenal loop size and external body measurements. *Clin. Radiol.* **29** : 523-527, 1978
- 7) Tommesen, P., Fisker, P., Löugreen N. A., Brandsborg, M. X. and Brandsborg, O. : The influence of an abnormal duodenal loop on basal and food-stimulated serum gastrin concentrations. *Scand. J. Gastroent.* **13** : 979-981, 1978
- 8) Bowditch, H. P. : Movements of the alimentary canal. *Science (New Series)* **5** : 901-902, 1897
- 9) Fukuhara, T. : Mechanism of gastrointestinal movement. Bunkodo, Tokyo, 1973 (in Japanese)
- 10) Johnson, L. R. : Gastrointestinal physiology. Mosby, Saint Louis, 1977
- 11) Joseph, D. R., and Meltzer, S. J. : Inhibition of the duodenum coincident with the movements of the pyloric part of the stomach. *Amer. J. Physiol.* **27** : Proc. XXXI-XXXII, 1910
- 12) Bass, P. : The electric and mechanical activity of the gastroduodenal junction. *Jap. J. Smooth Muscle Res.* **6** : 93-95, 1970
- 13) Adachi, I. : The intrinsic reflexes in the stomach and the duodenum adjacent to the pylorus. *Jap. J. Physiol.* **21** : 1099-1104, 1959 (in Japanese)