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Transposed intrathoracic stomach: Functional evaluation

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ABSTRACT

Background: To study the functional aspects of the transposed stomach in the thoracic cavity and its effects on other organ systems. **Patients and Methods:** Children who had undergone gastric transposition more than 5 years ago were evaluated for symptoms, anthropometry, anaemia, duodenogastric reflux, pulmonary function, gastric emptying, gastric pH, gastroesophageal reflux and stricture, gastric motility, and gastritis and atrophy on histological examination of gastric mucosa. **Results:** Ten children were evaluated at a median follow-up of 90.5 months. On evaluation of symptoms, nine children were satisfied with the overall outcome. All patients had their weight and 7 patients had height less than 3rd percentile for their respective age. Anaemia was present in 7/10 children. On evaluation with hepatobiliary scintigraphy, duodenogastric reflux was present in only 1 patient. Mass contractions of the transposed stomach were present in two thirds of the children. The mean gastric emptying t1/2 was 39.1 minutes. Pulmonary function tests were suggestive of restrictive lung disease in all the patients. Forced vital capacity (FVC) and forced expiratory volume in 1 sec (FEV1) were worse in children who underwent transposition or diversion following oesophageal anastomotic leak. Acid secretion was preserved in most patients with episodes of high gastric pH during sleep in nearly half. Mild gastritis was present in all patients where as mild atrophy of the gastric mucosa was observed in only 1child. *Helicobacter pylori* were positive in 3/ 8 children. Barium swallow demonstrated reflux in 2 children. **Conclusions:** Most children with transposed stomach remain asymptomatic on follow up. However, subclinical abnormalities are detected on investigations, which need close observation as they can manifest later in life.

Key words: Gastric transposition, oesophageal replacement, long gap oesophageal atresia

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INTRODUCTION

The native oesophagus is the ideal conduit between the pharynx and the stomach. Although the acceptance of this fact has made oesophageal replacement a reserved procedure, it is still performed in the management of wide gap oesophageal atresia and extensive caustic or peptic oesophageal injuries. Kummell in 1922 made the first attempt at gastric transposition.[1] In 1981, Ahmed and Spitz, on reviewing their hospital data on colonic interposition, found significant morbidity and this prompted a change in their approach to gastric transposition.[2] The results reported by these authors were encouraging and gradually this procedure has gained acceptance amongst paediatric surgeons. Gupta *et al.* have shown gastric transposition to be feasible even in neonates with satisfactory early results.[3-7]

Physiological behaviour of the transposed stomach changes because of decreased blood supply, loss of innervation in addition to alteration in form due to stretching and intrathoracic location. The study of these changes assumes a greater importance in children as the transposed stomach needs to adapt with the growth of the child who has a longer life expectancy as compared to an adult. Thus, changes that may be tolerated in an adult may be detrimental in a child, requiring early detection and treatment.

MATERIALS AND METHODS

Children who had undergone gastric transposition between1993 and 2002 and had been operated by or under the supervision of the senior author were included in the study. Institutional Review Board approval was obtained. Records of these children were reviewed and the parents were contacted by survey post. These patients were in regular follow-up and there was gradual improvement in symptoms over time that settled after five years post surgery. Thus, this study was done in patients who had completed five years of regular follow-up. Informed parental consent was

obtained in all cases.

A questionnaire which comprised the aspects of eating, disease specific symptoms, and psychological, physical and social functioning was prepared. The questionnaire included 24 items of which 18 questions were adopted from GIQLI (Gastrointestinal quality of life index)[8] and the remaining 6 questions were specific for the patient population being evaluated. Each question had 5 options scored as 1 to 5 with a higher score indicating a more favourable response. The questionnaire was content validated by two senior paediatric surgeons.

The weight (in kilograms) and height (in centimeters) were recorded and WHO 2007 growth charts were referred to while expressing the results as percentile of respective age.[9]

Gastric emptying was evaluated using a radionuclide gastric emptying study using Tc99m labeled steamed rice cake. The data was analysed with the gastric emptying software (Seimens) and the results expressed as the emptying half time ($t_{1/2}$) in minutes.

A 24-hour gastric pH measurement was performed using Gastrograph Mac 1 and a glass electrode (Medical Instruments Corporation, Switzerland). The probe was first calibrated and then passed 5 cm distal to the oesophago-gastric anastomosis. The parameters recorded were mean pH, median pH, percentage of time pH > 4 and notation was also made of the presence of spikes (periods of raised pH) during supine position or occurring 2 hrs after a meal.

Hepatobiliaryscintigraphy was performed after intravenous administration of 2-3 mCi (millicurie) of Tc99m-labeled mebrofinin. Duodenogastric reflux was said to be present if there was tracer activity documented in the thorax.

Barium swallow was performed under fluoroscopic guidance. Parameters evaluated during the study were stricture at oesophagogastric anastomoses, reflux across the anastomosis and gastric clearance in both supine position and erect positions.

Gastric manometry was performed using a catheter with three ports separated each by 3 cm with all ports placed in the stomach. The child was given at least 5 wet swallows (5-10 ml drinking water) and the response to the swallow was noted. The response was interpreted as no contraction if there was no elevation in basal pressure in any port, mass contraction if there was simultaneous rise in pressure in all ports or peristalsis if sequential increase in pressure in the ports was noted. Also the basal pressure and the peak pressure during contraction were also measured.

Upper gastrointestinal endoscopy was performed under sedation following an overnight fast. Mucosal biopsy was obtained from the corpora and the antrum of the stomach and submitted for histopathological examination. The parameters assessed were the appearance of gastric and oesophageal mucosa, stricture, distance of anastomosis from the incisors and presence of bile or residual food particles in stomach.

Pulmonary function tests were conducted and FVC, FEV, FEV1/FVC and peak expiratory flow rate (PEFR) were determined. The results were expressed as absolute value and the percentage of predicted value for the respective height. As reference values for Indian children were not available, 85% of the European standards were taken as reference range for a particular height in Pediatric Pulmonology unit of our institute.[10]

Hematological tests were performed after the child discontinued hematinics for at least 1 week and hemoglobin was measured. Serum iron studies were also performed and serum iron, percentage saturation of transferrin and serum ferritin were measured.

The gastric mucosal biopsy was taken from the corpora and antrum of the stomach during endoscopy and was submitted for histopathology for presence of mucosal atrophy and chronic gastritis. The sample was also stained with Giemsa stain and Methanamine silver to identify *Helicobacter pylori* in the biopsy specimen.

Statistical analysis was performed using Mann-Whitney and Chi squared tests.

RESULTS

Of 30 patients operated between 1993 and 2002, ten patients gave consent for participation in the study. Of the ten patients, two had oesophageal atresia type A and the rest had oesophageal atresia type C as per Gross classification.[11] The associated anomalies included atrial septal defect and patent foramen ovale in one patient each.

Five patients had been diverted (cervical oesophagostomy and gastrostomy / abdominal oesophagostomy) prior to surgery while the rest were not diverted. The details of patients are shown in Table 1. The route of gastric

transposition was posterior mediastinal in 7 patients and retrosternal in 3 patients and oesophagectomy was performed in all patients. All anastomosis were in the neck. A gastric drainage procedure was performed in all patients; pyloroplasty was performed in 1 patient, whereas pyloromyotomy was performed in the remaining patients. Post-operative leak was present in 3 patients, which resolved spontaneously after a mean duration of 15 days. Only 1 patient developed anastomotic stricture. This patient did not respond to multiple antegrade dilatations and ultimately required revision of cervical anastomosis. Two patients developed intestinal obstruction in the follow-up and underwent laparotomy.

These 10 children were evaluated at median (range) age of 90.5 months (range 63 months to 175 months) with median (range) follow-up of 90.5 months (60 to 170 months) following gastric transposition.

Three questionnaires were completed by the subjects with the assistance from the parents and the remaining 7 were completed by the parents alone. The mean score in the questionnaires was 101.8 (range 90 to 114). All parents except 1were satisfied with the eating habits of the child. Three children had restricted amount of intake at meals small frequent meals. Two children complained of recurrent cough, which was severe enough in only one patient to take time off school once a month. There was no case of dumping, heartburn, vomiting, halitosis, repeated respiratory tract infections and shortness of breathing at rest and exercise in this series when evaluated more than five years post operatively.

All patients had weight below the 3rd percentile of their respective weight for age values. In seven patients, the height was below the 3rd percentile for their respective height for age values. The mean haemoglobin was 11.4 gm/dl (range 8.3 to 12.3 gm/dl). Seven patients were anaemic as per WHO definition.[12] Serum iron and the percentage saturation of transferrin were decreased in all patients with mean ± standard deviation values of 41 ± 7 μg/dl and 11.8 ± 2%, respectively. Serum ferritin was decreased in 7 patients and was below 10 ng/ml in 2 children.

Duodenogastric reflux was observed during hepatobiliary scintigraphy in only 1 patient.

Pulmonary function tests could be performed in 9 patients. In all patients, the pattern was that of a restrictive lung disease. The mean of the percentages of the predicted value for FVC was 46.6 ± 7.2% (range 34% to 55%). The mean of the percentages of the predicted value for FEV1 was 51 ± 7.8%.The mean of the FEV1/FVC ratio was 96.6 ± 4% (range 91 to 100%). The peak expiratory flow rate was mean 1.45 ± 0.4 liters/. It was also noted children who underwent diversion or gastric transposition primarily (Group I) had significantly higher percentages of predicted FVC and FEV1when compared with children who underwent diversion or gastric transposition after anastomotic leak (Group II) [Table 2].

The mean of gastric emptying t1/2 was 39.1 minutes (range 20 to 58 minutes). Only in 9 patients, 24 hour gastric pH monitoring could be performed. The median (range) of the recorded mean pH and median pH were 1.7 (1.0- 3.9) and 1.4 (0.9- 3.7), respectively. All patients except one had a low pH in stomach (pH < 2.5). All patients were on anti-acids for the first year following surgery. Four patients showed evidence of episodes of raised pH during sleep. The median value of the duration the pH > 4 was 4.5% (1.0- 45.8%). The patterns noticed were variable - five patients maintained acidity of the stomach with rise in the pH related only to the ingestion of food [Figure 1a]. Three patients maintained

Table 1: Patient characteristics

	Indication	Diversion duration (months)	Age at surgery	Weight at surgery (kg)	Percentage of 50th percentile
Patient 1	Pure EA	5.0	5.0 months	8.0	109.0
Patient 2	EA TEF, long gap	5.5	5.5 months	5.0	82.0
Patient 3	EA TEF, long gap	14.0	14 months	6.2	57.4
Patient 4	EA TEF post repair leak	16.0	16.5 months	7.7	72.0
Patient 5	EA TEF post repair leak	3.0	3.0 months	4.0	74.0
Patient 6	EA TEF post repair leak	-	6 days	2.2	56.0
Patient 7	EA TEF post repair leak	-	9 days	2.6	71.0
Patient 8	EA TEF post repair stricture	-	120 days	2.0	32.0
Patient 9	EA TEF post repair leak	-	9 days	2.4	63.0
Patient 10	Pure EA	-	3 days	2.2	81.0

EA- oesophageal atresia, TEF – tracheooesophageal fistula

acidity of the stomach with multiple episodes of increase in pH [Figure 1b]. One patient (11.1%) demonstrated a relatively higher pH in the stomach with multiple episodes of increase in pH [Figure 1c].

Gastric manometry was performed in 9 patients. Mass contractions were documented in 6 patients, while in 3 patients no response to swallow was detected. There were no propulsive and peristaltic waves. The resting median gastric pressure was 6 cm H_2O (range 3 to 15 cm H_2O), while the median peak pressure was 14 cm H2O (range 8 to 30 cm H_2O).

Barium swallow revealed no stricture or hold up at the oesophagogastric anastomosis. Reflux across the cervical anastomosis was seen in 2 patients. In almost all patients, it was seen that gastric emptying markedly increased in erect position as compared to supine [Figure 2].

Gastroscopy was performed in 8 children. The oesophageal stump was normal in all except 1 in which it was mildly inflamed. The gastric mucosa was pink and rugosities were maintained in all patients. Bile or residual food particles were not noticed in any of the patients.

Histopathological examination of gastric mucosa biopsy was performed for only 8 patients and revealed mild gastritis in all patients except 1. Mild atrophy was seen in only 1 patient. *H. pylori* was identified in 3 out of the 8 biopsy specimens [Figures 3 and 4]. There was no appreciable difference in the degree of atrophic or inflammatory changes in the corporal and antral biopsies.

DISCUSSION

Kummell in 1922, made the first attempt at gastric transposition through the mediastinal route.[1] Spitz reintroduced gastric transposition in children and reported good early results[13] and these techniques are now being commonly used for oesophageal replacement in children.

Three of the patients restricted the amount of food but not the type of food. This finding can be explained by the loss of reservoir function of the stomach. Most of the children and parents claimed to be satisfied, only on detailed questioning these symptoms were brought out. Davenport *et al*. also noted that although a high proportion of patients in their study were

Table 2: Comparison of pulmonary functions tests in between the group I (Primary diversion or gastric transposition) and group II (Previous complicated thoracic surgery)

	FVC	FVC (% predicted)	FEV1	FEV1 (% predicted)	FEV1/FVC	FEV1/ FVC (% predicted)	PEFR	PEFR (% predicted)
Group I (n = 3)	0.94	53.33	0.92	58.0	97.0	106.67	1.61	65.86
Group II (n = 6)	0.57	43.33	0.55	47.5	96.5	104.00	1.38	69.66
P value	0.020	0.040	0.022	0.049	0.878	0.738	0.508	0.753

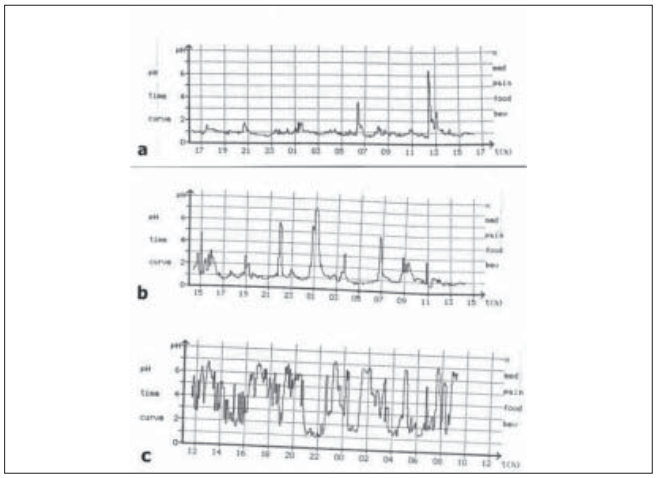


Figure 1: Total of 24 hr pH monitoring showing (a) Low pH, no high pH peaks during night (the peaks seen are at the time of meals and are normal) (b) Low pH, high pH peaks during night (c) Relatively high pH, high pH peaks throughout the day

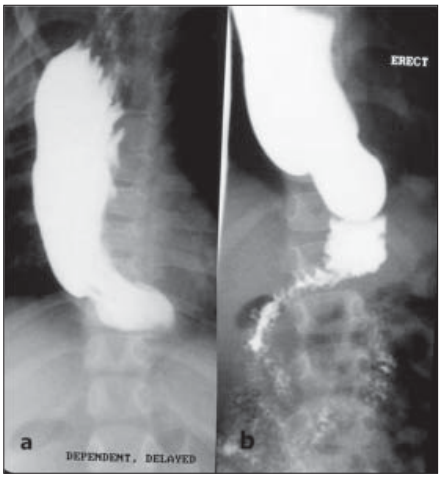


Figure 2: Barium swallow showing clearance of contrast in different posture. (a) In the supine position there was little clearance noted even 5 minutes after administration of contrast, (b) In the erect position prompt clearance of contrast is noted

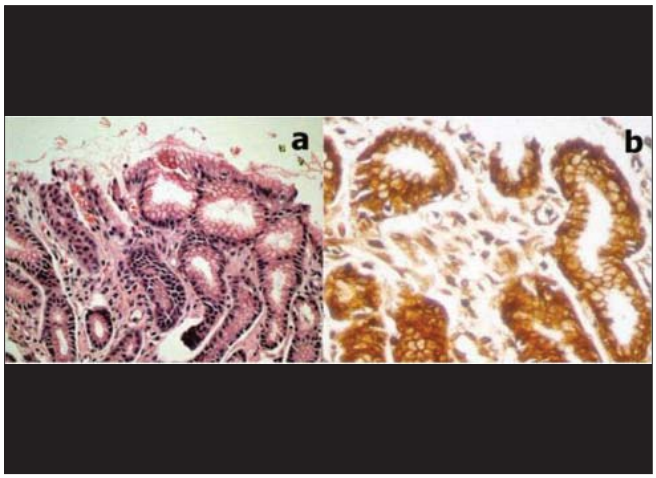


Figure 3: (a) Hematoxylin and Eosin staining of gastric mucosa at 200× showing minimal gastritis with no metaplasia and no atrophy, (b) Methanamine silver stain of gastric mucosal biopsy at 400× revealing no *H. pylori* like organisms

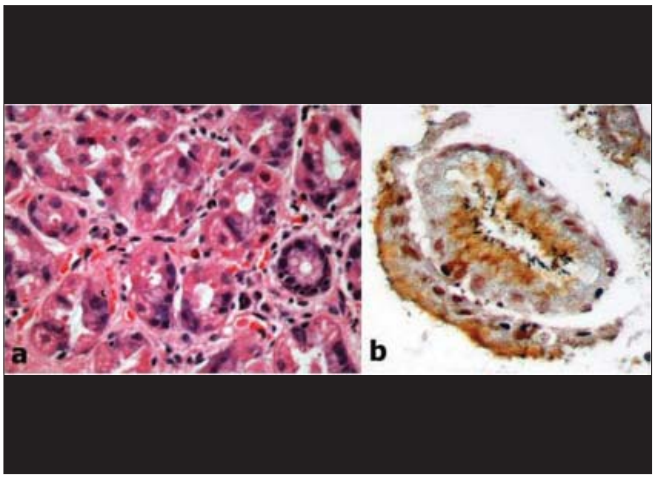


Figure 4: (a) Hematoxylin and Eosin staining of gastric mucosa at 200× showing mild chronic gastritis with mild atrophy but no metaplasia, (b) Methanamine silver stain of gastric mucosal biopsy revealing numerous *H. pylori* like organisms abutting the mucosal surface of the gastric gland

symptomatic, most parents were satisfied with the results of the surgery.[14] The symptoms in these patients cannot be totally attributed to the procedure of gastric transposition as a significant number of patients with oesophageal atresia who had undergone successful primary repair also have similar symptoms.[15-17] These studies have found that even on long-term follow-up of children successfully operated for oesophageal atresia, 35-50% had difficulty in swallowing, while 25% had respiratory symptoms.

The weight of all children in this study was less than 3rd percentile of their respective weight for age. The height was less than 3rd percentile of respective height for age in 7 children. Although total calorie intake in a day was not calculated for these children, most parents reported that the intake of the patients was comparable to their peers. Significant number of children in other series of gastric transposition also had poor growth.[14,18] Davenport noticed that 76% of their patients were between 3rd and 97th percentile for height while 65% were between 3rd and 97th percentile for weight.[14] Hirschi *et al.* on evaluating children who had undergone gastric transposition noted that 40% of their patients were below the 5th percentile of weight for age.[18] A higher prevalence of poor growth noticed in our study can in part explained by higher prevalence of malnutrition, in our region.

Haematological studies revealed anaemia in 7 patients with decreased serum iron in all suggestive of iron deficiency anaemia. Similar findings were also noted in another study in which median haemoglobin was 12.3 gm/dl and the changes were attributed to iron deficiency due to defective iron absorption secondary to decreased acid production in the transposed stomach.[14] The support for this theory came from high incidence of atrophic gastritis and hypochlorhydria noticed after gastric transposition studies in adults.[19] A recent study found a prevalence of anaemia among normal school going children in our region to be 66.4%.[20] Due to high prevalence of anaemia in our region, with the prevalent vegetarian diet and low socioeconomic status, it is difficult to correlate the occurrence of the anaemia to the procedure performed. The maintained gastric pH in these patients suggests that the function of stomach remained intact. However, the increased gastric emptying time in supine position may attribute to less absorption of iron contributing to anaemia.

Duodenogastric reflux when evaluated by hepatobiliary scintigraphy was detected in only one of our patients. However, we found no concordance among the findings of 24 hr pH monitoring and scintigraphy in relation to detection of duodenogastric reflux. This can be explained as radionuclide scintigraphy detects reflux of biliary secretion while 24 hr pH monitoring detects reflux of alkaline duodenal juice which is contributed by pancreatic secretion. Therefore, a different composition of duodenal juice may cause discordance between the results of these two investigations. The presence of this phenomenon was confirmed previously.[21,22] Gupta *et al.* reported that the prevalence of duodenogastric reflux in patients following gastric transposition to be 60% at 3 months, 50% at 6 months and 40% at 1 year post procedure.[7] This demonstrates a clear trend in fall in prevalence of duodenogastric reflux as the duration following the surgery increases. In this study, as the patients were evaluated at a mean follow-up of 91.3 months, it may account for the low prevalence of

duodenogastric reflux.

Pulmonary function tests revealed abnormalities in all patients in this series with restrictive pattern with near normal ratio of FEV1/ FVC but decreased FEV1 and FVC, but it did not manifest as respiratory symptoms. Davenport *et al.* reported that amongst the 16 children who had undergone gastric transposition previously, all except one revealed lung function values below the predicted values for height.[14] Similar derangements are also seen following successful repair of oesophageal atresia also show abnormal values.[23-25]

The gastric pH monitoring in our patients has shown conclusively that stomach retains its acid-producing capacity even in the long term, with median pH < 2.0 in all our patients except one. Also in all our patients except one child, the percentage duration of study with pH < 4.0 was less than 20% of the total duration of study. This is below the upper limit of physiological duodenogastric reflux described in studies, i.e. 27-28%.[22,26] Our findings are in contrast to studies performed in adults, which have demonstrated poor acid secretion in a significant number of patients (30-50%).[19,20] The controversy whether the transposed stomach acts as a conduit[27] or retains its contractility[15,28,29] remains unresolved. No peristaltic activity was observed in any patient. These findings firmly establish that the stomach retains some contractility after it is transposed in the thorax but even in the long-term studies these mass contractions fail to evolve into peristaltic contractions.

Gastroscopy in our patients revealed no pathology apart from mild oesophagitis seen in one patient. The data regarding gastroscopy findings following gastric transposition is scarce, with a few studies performed only in adults with non-consistent results varying from normal findings in all[28,30] to abnormal findings in all[28-30] The relevant data in children is unavailable. In contrast to other studies,[29,30] in the present study, food particles in the thoracic stomach or any bile reflux across pylorus were not noticed in any patient during gastroscopy.

Gastric biopsy was performed in 8 patients. Mild chronic gastritis was present in all patients except one. Atrophy was seen in only 1 patient where there was mild atrophy of the glands. This patient also had numerous *H. pylori*, which may have contributed to presence of atrophy. *H. pylori* were seen in 3 of the 8 biopsies examined. No metaplasia was observed in any of the biopsies. Other authors have also reported presence of chronic gastritis in all or most of their patients.[29,31] The aetiology of this chronic gastritis can be multifactorial, namely, duodenogastric reflux, retained food particles and *H. pylori*. However, these factors were not present in the 3 patients with gastritis in this study. Routine follow of these patients is recommended as intestinal metaplasia has been reported by some authors.[29]

CONCLUSION

The study establishes gastric transposition as a safe option for oesophageal replacement but still cautions the paediatric surgeon to keep the patient in follow-up to determine if these derangements become symptomatic later in life or not.

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