

Gestational Age-Related Morphological and Morphometric Changes in the Human Foetal Stomach: An Anatomical Study

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Abstract

Background: The human foetal stomach undergoes significant growth and structural remodelling throughout intrauterine life. Accurate morphometric data describing these developmental changes are essential for understanding normal foetal gastrointestinal development and for providing baseline reference values for foetal anatomy, prenatal imaging, and congenital anomaly assessment. However, comprehensive gestational age-specific morphometric data on the foetal stomach remain limited, particularly across the entire span of gestation.

Objective: To evaluate the morphometric and morphological changes in the human foetal stomach at different gestational ages.

Materials & Methods: This cross-sectional observational study was conducted on spontaneously aborted and medically terminated human foetal specimens from 10 weeks onwards available in the museum of the Department of Anatomy, FMHS, SGTMU, after approval of the institutional ethical committee. Gestational age was determined using crown-rump length and available obstetric records. Foetuses were categorized into 3 groups according to gestational age for analysis. Morphometric parameters of the stomach including maximum length, maximum breadth, thickness, length of greater and lesser curvature, and width of cardiac and pyloric ends were measured. Some gross morphological features of the stomach were also recorded.

Results: All measured morphometric parameters demonstrated a progressive increase with advancing gestational age, which strongly suggests a positive correlation. Growth was relatively rapid during the second trimester, followed by a steady increase in the third trimester.

Conclusion: The human foetal stomach exhibits predictable and progressive morphometric growth throughout gestation. The normative data generated in this study contribute to the understanding of foetal gastric development and may serve as valuable reference standards for anatomists, embryologists, foetal medicine specialists, radiologists, and paediatric surgeons in the evaluation of normal and abnormal foetal gastrointestinal development.

Keywords: Foetus; Foetal stomach; Morphometry; Gestational age; Gastric development.

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Introduction

Stomach is the widest part of the alimentary tract and appears as a fusiform dilatation of the foregut in the fourth week of development.¹ It begins its development at the 3rd to 5th cervical vertebral level. Because of the marked cephalic growth of the foregut, descent of the stomach occurs so that its eventual final location is in the region between the 10th thoracic and 3rd lumbar vertebral level.² It plays a fundamental role in digestion, storage, and regulated emptying of ingested contents.

The stomach undergoes a complex and multifactorial rotation. This process occurs mainly due to the differential growth of the gastric wall, particularly on the left side, and the increased gastric motility resulting from earlier mesenteric expansion. The direction of this rotation is influenced by the mechanical forces exerted on the stomach and its mesenteries by neighbouring organs.³ Normal growth of the foetal stomach is essential for the coordinated development of the gastrointestinal tract and serves as an important indicator of foetal maturity and wellbeing. This J-shaped enlargement

of the alimentary canal is continuous with the oesophagus at its proximal end and the duodenum at its distal end. It appears as a spindle-shaped dilation of the foregut during the 4th week of intrauterine life.⁴

As it descends, it undergoes changes in shape, size, and orientation. By the 7th and 8th weeks, it rotates around a craniocaudal axis, positioning the greater curvature to the left and the lesser curvature to the right.⁵ With further development, it rotates around an anteroposterior axis, causing the caudal (pyloric) part to move upward and to the right, while the cephalic (cardiac) part shifts slightly downward and to the left. Ultimately, the stomach attains its final position with its axis extending from the upper left to the lower right.¹

Congenital gastric anomalies, including hypertrophic pyloric stenosis and thoracic stomach, may occur in newborns, while rarer conditions such as gastric duplication, diverticula, and hypoplasia have also been described.

Understanding the normal morphological development of the foetal stomach is essential for recognizing deviations from normal anatomy and may contribute to the diagnosis and management of congenital gastric abnormalities. The present study aimed to assess gestational age-related changes in the shape, location, appearance of rugae and development of cardiac incisura and pyloric sphincter, along with its morphometric parameters like length, breadth, and lengths of the greater and lesser curvatures of the stomach in human foetuses. In the human embryo, the stomach starts developing as a fusiform dilatation at the 4th week of gestational age⁶ and thereafter undergoes several morphological and microscopic changes during the process of development. The mucosal epithelium differentiates from the endodermal lining, and the mesodermal coating gives rise to the submucosal connective tissue and smooth muscle layer.⁷ The submucosa consists of a thick layer of dense connective tissue containing collagen fibers, elastic fibers, arterioles, venous plexus, lymphatics, and nervous plexus.⁸ The muscularis mucosa of the stomach is thin and composed of two layers, whereas the muscularis externa has three layers from inside out — oblique, circular, and longitudinal — but unevenly located in various parts of the stomach. The circular layer is thickened at the distal pyloric antrum, whereas the longitudinal layer and oblique layer are most pronounced in the upper two-thirds and lower half, respectively.⁹

Materials and Methods

This observational study was conducted on 30 spontaneously aborted or medically terminated human foetuses of both sexes, aged 10 weeks onwards, obtained from the Department of Anatomy, Faculty of Medicine and Health Sciences, SGT University, Gurugram, Haryana. The study was

conducted after approval from the Institutional Ethics Committee. Gestational age was determined from the medical records available in the departmental museum.

Grouping of specimens

The foetuses were categorized according to gestational age into:

- Group I: 10–15 weeks
- Group II: 16–24 weeks
- Group III: ≥ 25 weeks

Inclusion criteria

- Spontaneously aborted or medically terminated foetuses aged ≥ 10 weeks.
- Foetuses of either sex.

Exclusion criteria

- Foetuses with gross congenital anomalies.
- Foetuses aged < 10 weeks.

Study method — Foetal parameters

- Crown-rump length (CRL): the measurement of the length of the human abortus from the vertex to the bottom of the buttocks (rump). It was measured using thread and scale in centimeters.
- The weight of the abortus was measured in grams using a digital weighing machine.
- Foot length was measured from the posterior tip of the foot to the end of the longest toe using Vernier calipers.



Fig. 1 Measurement of Crown-Rump Length



Fig. 2 Measurement of Foot Length

Dissection and examination

After recording these external parameters, the foetuses were preserved in 10% formalin. The abdominal cavity was exposed through a subcostal incision with extensions along the inguinal folds. The dissection followed the guidelines outlined in “Cunningham's Manual of Practical Anatomy, 15th edition”.¹⁰

The anterior abdominal wall and part of the left lobe of the liver were removed to expose the stomach. The stomach was examined macroscopically for its morphology, position, and relations with surrounding viscera, and representative specimens were photographed. Subsequently, the stomach was carefully removed, and its height, width, and lengths of the greater and lesser curvatures were measured.



Fig. 3: Foetal stomach in situ

Morphological parameters of stomach

Morphological features of the stomach were assessed, including location and shape, rugae, cardiac incisura, and pyloric sphincter development, by visual inspection.

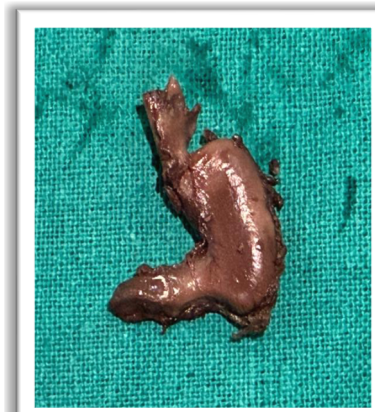
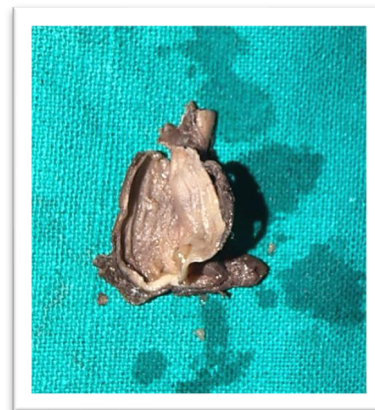
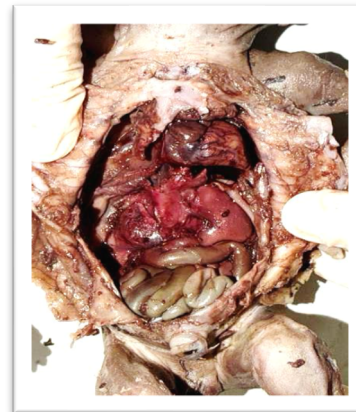


Fig. 4 Location, shape, rugae, cardiac incisura and pyloric sphincter

Morphometric parameters of stomach

Maximum length of stomach — the length of the stomach was taken from the highest point of the fundus to the point on the line joining the incisura angularis and greater curvature.

Maximum breadth of stomach — the width was measured from the highest point of the body to the lesser curvature.

Maximum length of greater curvature — taken from the cardiac orifice along the left border to the pyloric orifice.

Maximum length of lesser curvature — taken from the cardiac orifice along the right border to the pyloric orifice.



Fig. 5 Measurement of maximum length, breadth, greater curvature and lesser curvature of stomach

Results

A total of 30 foetal stomach specimens from different gestational age groups were analysed to evaluate changes in weight and morphometric parameters. Progressive increases were observed in all measurements with advancing gestational age, indicating continuous growth and development of the foetal stomach.

Table 1: Morphological parameters of stomach at various gestational groups

Morphological Parameter	Group-I (10–15 Weeks)	Group-II (16–24 Weeks)	Group-III (≥25 Weeks)
Location of stomach	Predominantly in the left	Mainly in the left hypochondrium	Definitively in the left

Morphological Parameter	Group-I (10–15 Weeks)	Group-II (16–24 Weeks)	Group-III (≥25 Weeks)
	hypochondrium with a relatively high	drium and epigastrium	hypochondrium extending into the epigastrium

Morphological Parameter	Group-I (10–15 Weeks)	Group-II (16–24 Weeks)	Group-III (≥25 Weeks)
	position beneath the developing liver		m, resembling the adult position
Shape of stomach	Fusiform to developing J-shaped	Predominantly J-shaped	Well-defined J-shaped stomach
Gastric rugae	Absent or poorly developed	Present	Well-developed
Cardiac incisura	Absent or indistinct	Present but shallow	Well-defined
Pyloric sphincter	Not identifiable	Developing	Well-developed

Table 2: Morphometric parameters of stomach at various gestational groups

Morphometric Parameter	Group-I 10–15 wk (Mean ± SD)	Group-II 16–24 wk (Mean ± SD)	Group-III ≥25 wk (Mean ± SD)
Weight (g)	0.186 ± 0.0886	1.042 ± 0.4999	7.569 ± 3.061
Maximum length (mm)	9.365 ± 1.6102	18.23 ± 3.601	45.88 ± 10.2927
Maximum breadth (mm)	5.912 ± 1.0592	11.49 ± 2.271	28.96 ± 6.4849
Thickness (mm)	1.972 ± 0.3968	3.77 ± 0.6664	7.96 ± 1.5100
Greater curvature length (mm)	14.217 ± 2.5782	27.97 ± 5.602	70.02 ± 15.5313
Lesser curvature length (mm)	8.509 ± 1.5523	16.69 ± 3.348	42.10 ± 9.369
Cardia width (mm)	2.193 ± 0.4136	3.84 ± 0.8049	9.16 ± 1.894
Pylorus width (mm)	1.881 ± 0.386	3.587 ± 0.7343	8.41 ± 1.859

Discussion

The present study demonstrated progressive morphological maturation of the foetal stomach with advancing gestational age. The stomach changed from a high left hypochondrial, fusiform structure at 10–15 weeks to a predominantly J-shaped configuration at 16–24 weeks and a well-developed J-shaped, adult-like morphology after 25 weeks. Rugae and the pyloric sphincter developed progressively from absent or poorly defined structures to well-developed features. These findings are consistent with Roy and Roy (2013), Jaipal et al. (2016), and Gworys et al. (2012), who reported progressive changes in gastric position, shape and maturation with gestational age. Overall, the findings indicate that foetal gastric development involves progressive positional, morphological and structural maturation towards the adult configuration.

Table 3: Comparison of morphological features of the foetal stomach across different gestational ages

Author & year	Gestational age	Location	Shape	Rugae	Pyloric sphincter	Other important morphological findings
Gworys et al., 2012 ¹	12–40 wk.	Progressive positional development; mature position by term	Final stomach shape developed progressively	Not reported	Progressive increase in cardiac and pyloric widths	Rapid/intensive growth up to ~22 wk.; harmonic growth from ~30 wk. to birth
Roy &	15–40 wk.	≤16 wk. epigastr	~16 wk. tubul	~19 wk. indi	≤16 wk. indi	36 wk. lower

Gestational Age-Related Morphological and Morphometric Changes in the Human Foetal Stomach: An Anatomical Study

Au tho r & yea r	Gest atio nal age	Locatio n	Shap e	Ru gae	Pylo ric sph incte r	Othe r impo rtant morp holog ical findi ngs
Ro y, 20 13¹ 2		ic/umbilical; ~28 wk. adult-like	ar/C-shape d; ~28 wk. J-shape d	stin ct; ~23 wk. well - dev elop ed	stinc t; 18 wk. midl ine; ~23 wk. well - deve lope d	stoma ch at umbil ical level; 37 wk. partia lly uncov ered by liver
Jai pal et al., 20 16¹ 3	13– 37 wk.	13–25 wk. upper abdomi nal; 26– 37 wk. upper R/L quadrants	13– 25 wk. crescent; 26– 37 wk. typical shape	Not repor ted	Not repor ted	2nd trime ster: obtus e- angle d; 3rd trime ster: acute- angle d
Ra hm an et al., 20 17¹ 4	12– 36 wk.	Not reporte d	Not repor ted	Not repor ted	Pylo ric width incr ease d: 2.15 , 4.06 & 4.93 mm	Pylori c width increa sed: 2.15, 4.06 & 4.93 mm
Ba diu et al., 20 19¹ 5	13– 40 wk.	Not assesse d	Not asses sed	Not repor ted	Not repor ted	Longi tudin al, transv erse & sagitt al

Au tho r & yea r	Gest atio nal age	Locatio n	Shap e	Ru gae	Pylo ric sph incte r	Othe r impo rtant morp holog ical findi ngs
						diame ters increa sed progr essive ly with GA
Ka rnul & Murt hy, 20 22¹ 6	16– 40 wk.	No position al variatio n observe d	No variatio n repor ted	Foe tal- spe cific data not repor ted	Foet al- spec ific data not repor ted	GC and LC increa sed with GA; linear growt h obser ved
Pr ese nt stu dy, 20 26	10 wks onw ards	10–15 wk. high left hypoch ondriu m; 16– 24 wk. left hypoch ondriu m; >25 wk. left hypoch ondriu m → epigast rium, adult- like position	10– 15 wk. fusif orm; 16– 24 wk. predo mina ntly J-sha pe d; >25 wk. well- devel oped J-sha pe d	10– 15 wk. abs ent; 16– 24 wk. poo rly deve lop ed; >25 wk. well - deve lop ed	10– 15 wk. not iden tifi able; 16– 24 wk. deve lopi ng; >25 wk. well - deve lop ed	All para meter s increa sed progr essive ly with gestat ional age

The present study demonstrated progressive morphological maturation of the foetal stomach with advancing gestational age, changing from a high left hypochondrial, fusiform structure at 10–15 weeks to

a predominantly J-shaped configuration at 16–24 weeks, and a well-developed, adult-like J-shaped morphology after 25 weeks.

Table 4: Comparison of foetal stomach morphometric parameters across different studies

Auth or and year	Sam ple size	GA rang e	Metho d	Major morpho metric paramet ers	Major finding s
Gwo rys et al., 2012	225	12–40 wk.	Post-morte m	Stomach length, GC, LC, cardia/pylorus width, wall thickness, mass	Rapid growth up to ~22 wk., followed by slower growth; length: 9.64–26.8 mm; GC: 17.6–62.1 mm; LC: 8–21 mm; cardia width: 1.7–3.94 mm; pyloric width: 1.68–5.24 mm; no significant sex differences.
Roy & Roy, 2013	50	15–40 wk.	Post-morte m	Height, width, GC, LC, capacity	Progres sive increase in dimensi ons and capacity .
Jaip al et al., 2016	52	13–37 wk.	Anato mical	Position and shape	Progres sive changes in

Auth or and year	Sam ple size	GA rang e	Metho d	Major morpho metric paramet ers	Major finding s
					stomach position , orientati on and morpho logy with advanci ng gestatio n.
Rah man et al., 2017	30	12–36 wk.	Post-morte m	Length, weight, GC, LC, cardia and pylorus width	All paramet ers increase d with GA; stomach length: 14.36–24.38 mm across three age groups.
Badi u et al., 2019	135	13–40 wk.	Ultras ound	Longitud inal, transvers e and sagittal diameter s	Linear increase in all three dimensi ons; signific ant associat ion with GA and foetal biometr ic paramet ers.
Kar nul & Mur thy, 2022	20	16–40 wk.	Post-morte m	GC, LC, volume	Strong positive correlati ons with GA: GC r =

Author and year	Sample size	GA range	Method	Major morphometric parameters	Major findings
					0.991, LC r = 0.975 and volume r = 0.971; p < 0.001.
Present	30	10 wks	Medically termin	Longitudinal, transvers	All measured

The present study demonstrated a progressive gestational-age-related increase in all assessed morphometric parameters of the foetal stomach. Stomach weight, length, breadth and thickness increased from 0.186–7.569 g, 9.365–45.88 mm, 5.912–28.96 mm and 1.972–7.96 mm, respectively. Greater and lesser curvature lengths increased from 14.217–70.02 mm and 8.509–42.10 mm, while cardiac and pyloric widths increased from 2.193–9.16 mm and 1.881–8.41 mm, respectively. These findings are consistent with previous observations by Gworys et al., Roy and Roy, and Rahman et al., who reported progressive enlargement of foetal stomach dimensions with advancing gestation. The findings also correspond with Badiu et al., who demonstrated increasing gastric diameters on ultrasonography, and Karnul and Murthy, who reported strong positive correlations between gestational age and gastric curvature lengths and volume. Overall, the present findings support a continuous and measurable growth pattern of the foetal stomach throughout gestation.

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Author and year	Sample size	GA range	Method	Major morphometric parameters	Major findings
study		onwards	ated or aborted	e and sagittal diameters	morphometric parameters increased progressively with gestational age.

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Gestational Age-Related Morphological and Morphometric Changes in the Human Foetal Stomach: An
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