

# Growth and Development:

*From Conception to Perception*



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By

Ghassan Hamdan Alnaami

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To my beloved parents,  
for their unwavering support, values, and the foundation they laid  
for my journey.

To my wife and children,  
for their endless patience, love, and the joy they bring to my life  
every day.

To my patients,  
whose courage, curiosity, and trust continue to inspire my  
commitment to learning, healing, and teaching.



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## ABOUT THE AUTHOR

**Dr. Ghassan Hamdan Alnaami** is a distinguished pediatrician with extensive training and board certification across multiple international medical boards. He earned his degree in Pediatrics in 2002 from both the **Jordanian Board of Pediatrics** and the **Arab Board of Pediatrics** and later obtained a third board certification from the **American Board of Pediatrics** in 2013. His career bridges both Eastern and Western medical traditions, granting him a comprehensive and nuanced understanding of pediatric care.



Dr. Alnaami also holds a degree in **Pediatric Cardiology** from Saudi Arabia and completed a subspecialty in **Pediatric Echocardiography** through training at the **University of Alberta in Edmonton, Canada**, and the **University of Colorado in Denver, USA**. He has contributed original research to several medical journals in the fields of pediatric cardiology and echocardiography.

In the past decade, he has focused increasingly on **general pediatrics** with a strong emphasis on **neurobehavioral medicine in children**, blending both generalist and specialist approaches to care. His clinical practice is well-regarded for its **comprehensive and holistic view of child health**, with a particular focus on **parental education** as a vital component of pediatric well-being.

Dr. Alnaami's dedication to accessible and high-quality care extends beyond borders, advocating for effective medical practices in both **developed** and **under-resourced** settings. He is the author of his first published book, "**Common Childhood Infections**", which reflects his commitment to educating both healthcare providers and parents in practical, evidence-based medicine.

## PREFACE

The journey of human development is a remarkable and intricate process, beginning long before birth and continuing through the formative years of life. As a pediatrician and educator, I have had the privilege of witnessing this journey unfold through the eyes of countless children, families, and healthcare professionals. *Growth and Development from Conception to Perception* was born from the need for a comprehensive yet practical resource that follows this journey step by step — from the earliest stages of fetal development to the dynamic period of adolescence.

This book was written with a dual purpose: to serve as a clinical guide for healthcare professionals involved in childcare and development, and as a source of clear, evidence-based information for families seeking to understand and support their child's growth. It presents a chronological framework that mirrors the stages of childhood — starting with conception and fetal life, progressing through infancy, toddlerhood, preschool, school-age years, and adolescence.

Each chapter integrates medical knowledge with developmental psychology, nutrition, behavioral science, and social determinants of health. I have aimed to include not only what to expect at each stage, but also how to identify, prevent, and manage common challenges. Clinical details are complemented by illustrations, tables, and growth charts to make the information more accessible and easier to apply in real-world settings.

Special care has been taken to include “Parents Sheets” in each chapter. These are written in plain language to empower families with practical strategies and guidance. The intent is to bridge the gap between clinical recommendations and day-to-day parenting, reinforcing the role of caregivers as active partners in promoting healthy development.

In writing this book, I have drawn upon the latest research, best practices, and my personal experiences in pediatric care. I hope it serves as a trusted companion to clinicians, students, and families alike — one that informs, reassures, and inspires confidence in the art and science of nurturing children.

With gratitude to the children and families who have taught me so much through their courage and resilience, I dedicate this book to their growth, potential, and future.

**Ghassan Hamdan Alnaami**

May, 2025

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# INTRODUCTION

*Growth and Development from Conception to Perception* is a comprehensive and practical resource that traces the journey of human development from the earliest stages in utero to adolescence. Designed for healthcare providers, educators, and caregivers, this book is structured chronologically, reflecting the natural progression of a child's physical, cognitive, emotional, and behavioral development.

The book opens with **Chapter 1: Fetal Growth**, exploring prenatal development and growth patterns. Detailed attention is given to fetal anthropometric measurements and the identification of growth abnormalities such as Small for Gestational Age (SGA) and Intrauterine Growth Restriction (IUGR). Tables and illustrations are used to clarify growth parameters and enhance clinical decision-making. A "Parents Sheet" concludes the chapter, simplifying key messages for expectant families.

**Chapter 2** transitions to the **newborn period**, covering essential assessments such as the Apgar score and gestational age evaluation. This chapter delves into neurodevelopmental examination and introduces growth monitoring tools including the Fenton growth charts and INTERGROWTH-21st standards. These concepts are made accessible through summary charts and side-by-side comparisons.

In **Chapter 3**, the book provides a detailed **newborn physical examination**, guiding practitioners through evaluation of the skin, head, chest, abdomen, and extremities. The chapter is richly supported with clinical diagrams and reference tables to aid recognition of normal and abnormal findings.

**Chapter 4** addresses the **first month of life**, a period often filled with rapid changes and parental concerns. Topics such as feeding, jaundice, regurgitation, colic, and tongue-tie are discussed. Nutritional issues, including the role of probiotics and antireflux formulas, are also examined. A dedicated "Parents Sheet" offers strategies to support feeding and comfort during this transitional period.

**Chapters 5 and 6** follow the infant through **early (2–6 months)** and **late infancy (7–12 months)**. These chapters provide comprehensive guidance on nutrition, developmental milestones, sleep, food allergies, feeding

disorders, and conditions like failure to thrive and constipation. Issues such as gesture observation, sleep disturbances, and non-nutritive sucking are addressed using evidence-based strategies and behavior modification techniques. Diagrams and charts summarize normal development and red flags to monitor.

Moving into **toddlerhood, Chapters 7 and 8** address the periods of **13–18 months** and **19–35 months**, respectively. Feeding patterns, motor maturation, temper tantrums, breath-holding spells, and developmental screening are central themes. These chapters emphasize the importance of structured routines, consistent boundaries, and early identification of neurodevelopmental concerns. Tables and visual timelines help to map expected developmental trajectories.

**Chapter 9** explores the **preschool years (3–5 years)**, highlighting critical aspects of physical growth, social development, and behavioral challenges. Topics such as discipline strategies (including appropriate use of time-out) and non-nutritive sucking are presented with references to current research and professional guidelines. The accompanying "Parents Sheet" translates clinical content into actionable parenting techniques.

**Chapter 10** focuses on the **school-age years and preadolescence**, discussing nutrition, growth concerns such as stunting, and academic challenges, including learning disabilities and developmental coordination disorder. The chapter aims to support early school success through multidisciplinary intervention and home–school collaboration.

**Chapter 11** addresses **adolescence**, with an emphasis on pubertal growth, normal pubertal variants, and common issues like delayed or abnormal development. Visual aids provide clarity on pubertal staging, growth curves, and adolescent health milestones.

The book concludes with **Chapter 12: Issues in Development**, offering an in-depth look at complex developmental disorders including Autism Spectrum Disorders (ASD), Attention Deficit Hyperactivity Disorder (ADHD), Sensory Processing Disorder (SPD), language disorders, intellectual disabilities, fetal alcohol syndrome, and cerebral palsy. Each condition is presented with practical diagnostic criteria, management strategies, and resources for family support. An overview of complementary medicine in autism is also included, reflecting the diversity of care approaches parents may explore.

Throughout the book, **illustrations, summary tables, clinical flowcharts, and growth charts** are used to simplify and reinforce learning. Each chapter concludes with a "**Parents Sheet**", a plain-language summary designed to empower caregivers with the tools and knowledge needed to support their child's health and development.

By combining chronological clarity, scientific accuracy, and practical relevance, *Growth and Development from Conception to Perception* serves as both a clinical guide and a family resource, helping bridge the gap between medical expertise and everyday caregiving.

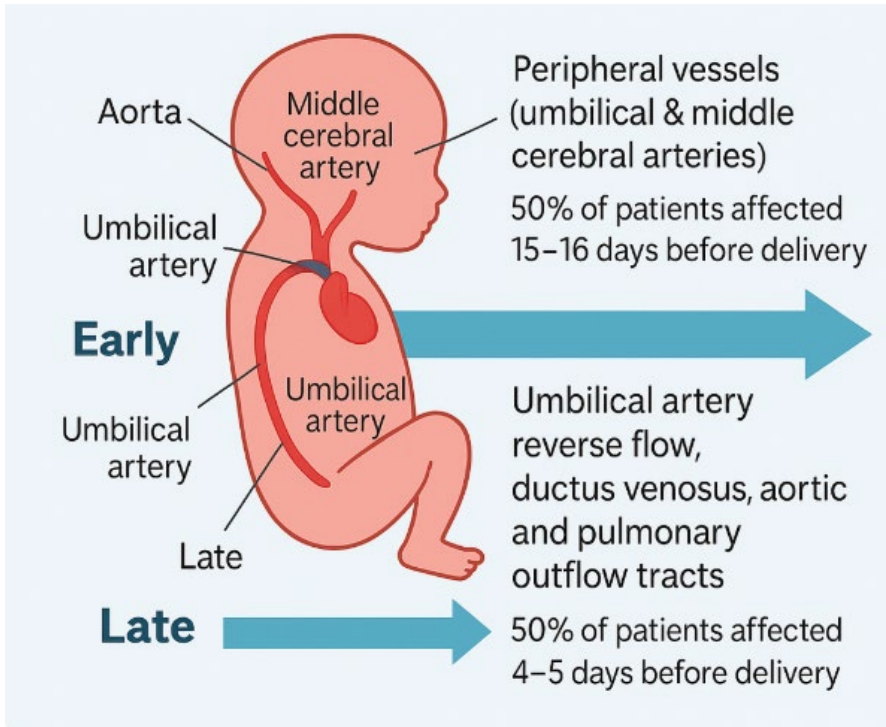


# CHAPTER 1

## FETAL GROWTH

### **Fetal Hemodynamics**

In the human fetus, blood flow has been estimated at approximately 600 mL/min in the pulmonary artery and 450 mL/min in the aorta, totaling around 1050 mL/min—or roughly 300 mL/min/kg. Today, advanced ultrasound techniques allow for the measurement of specific blood flows, including umbilical, cerebral, hepatic, and cardiac circulation. These methods enable early identification of abnormal flow patterns during the development of intrauterine growth restriction (IUGR). In cases of severe fetal growth restriction, Doppler studies often reveal a predictable sequence of abnormalities (Figure 1-1), categorized as "early" and "late" changes. Early Doppler changes typically appear in peripheral vessels such as the umbilical artery and middle cerebral artery—seen in 50% of affected fetuses approximately 15–16 days before delivery. Late changes, including reversed flow in the umbilical artery and abnormal waveforms in the ductus venosus, as well as the aortic and pulmonary outflow tracts, tend to emerge closer to delivery—about 4–5 days prior in 50% of cases.<sup>1</sup>



*Figure 1-1: Doppler changes in severely growth restricted fetuses*

### ***Fetal brain***

Fetal brain growth has been assessed using 3D ultrasound to measure brain volume, revealing that the median brain weight accounts for approximately 15% of total fetal weight. These sonographic assessments show that brain volume increases nearly tenfold during the second half of gestation. In conditions such as intrauterine growth restriction (IUGR), brain development is relatively preserved, even when umbilical blood flow is reduced. The decrease in brain volume is proportionally less severe compared to other organs, such as the liver.

Diffusion-weighted (DW) MRI has added valuable insights into normal brain development by measuring the apparent diffusion coefficient of water in fetal brain tissue. This technique allows visualization of both unmyelinated and myelinated fiber tracts during the second half of pregnancy. MRI

studies have shown the presence of migrating glial cells in the periventricular white matter beyond 20 weeks' gestation, after neuronal migration to the cortex is complete.

Despite advancements in imaging, fetal heart rate analysis remains the most reliable tool for assessing neurologic function in utero. Variability in fetal heart rate is more indicative of neurologic health than cardiac function. A mean variability of less than 1 beat per minute is a strong indicator of impaired autonomic control and suggests possible central nervous system damage.<sup>2</sup>

### *Fetal liver*

The fetal liver plays a central role in numerous metabolic functions and participates in both metabolic and endocrine interactions with the placenta. Three-dimensional ultrasonography demonstrates that fetal liver volume increases exponentially from the 18th week of gestation until term. Abnormal liver volumes have been documented in specific conditions: reduced volumes are observed in fetuses with intrauterine growth restriction (IUGR), while increased volumes are common in pregnancies complicated by insulin-dependent diabetes mellitus (IDDM).

As pregnancy progresses, the proportion of umbilical blood flow diverted through the ductus venosus declines significantly—from approximately 40% to 15%—while liver perfusion increases accordingly. Specifically, blood flow to the right hepatic lobe rises from 20% to 45%, whereas flow to the left lobe remains relatively stable at around 40%. This redistribution suggests that in late pregnancy, well-oxygenated blood is no longer preferentially directed toward the heart and brain.

In cases of severe IUGR, however, a greater proportion of umbilical blood—often exceeding the 90th percentile compared to control fetuses—is shunted through the ductus venosus. This adaptation preserves blood flow to the heart and brain at the expense of liver perfusion.

The brain-to-liver volume ratio normally decreases with gestational age but is significantly elevated in growth-restricted fetuses. This ratio serves as a useful prognostic marker in IUGR, with higher values correlating with poorer outcomes. An inverse relationship has also been identified between the brain/liver volume ratio and umbilical venous blood flow relative to fetal weight in small-for-gestational-age (SGA) fetuses.<sup>3</sup>

## Fetal anthropometric measurements

Fetal biometric measurements are essential tools in prenatal care, providing valuable insights into fetal growth, development, and gestational age (Table 1-1). Among these measurements, crown-heel length (CHL) and crown-rump length (CRL) are two key parameters frequently used during different stages of pregnancy. Each offers unique advantages depending on the timing and purpose of the assessment.

**Crown-heel length (CHL)**, also known as fetal height, refers to the measurement of an outstretched fetus from the top of the skull (crown) to the heel. It is analogous to standing height in older children and adults. Although fetal length increases with gestational age, growth velocity gradually declines throughout pregnancy, with a notable slowdown observed around 35 weeks of gestation.

**Crown-rump length (CRL)** measures the distance from the top of the fetal head (crown) to the bottom of the torso (rump or buttocks). It is the most reliable parameter for estimating gestational age during early pregnancy due to minimal biological variability at this stage.

Also, fetal growth can be predicted using other parameters like fetal height, weight (Figure 1-2), biparietal diameter, femur length and others (Figure 1-3).

Table 1-1: Fetal biometry<sup>4</sup>

Parameter	Equation
Fetal height (cm)	Male = $0.02 + \frac{66.74 \times FA^{2.32}}{23.0^{2.32} \times FA^{2.32}}$ Female = $0.02 + \frac{65.30 \times FA^{2.32}}{22.80^{2.32} \times FA^{2.32}}$
Fetal weight (g)	Male = $0.0001 + \frac{7347.2 \times FA^{4.23}}{38.26^{4.23} + FA^{4.23}}$ or $(0.1765 \times HT)^{3.7295}$ Female = $0.0001 + \frac{7001.8 \times FA^{4.29}}{38.10^{4.29} + FA^{4.29}}$ or $(0.167 \times HT)^{3.7295}$
Body surface area (BSA in cm <sup>2</sup> )	$0.2808 \times HT^{2.278 \log}$ Or $4.6677 \times WT^{0.7773}$ Or $0.01 + \frac{5464.2 \times FA^{2.79}}{42.36^{2.97} + FA^{2.79}}$
Crown-rump length (CRL in cm)	$\frac{54 \times FA^{2.0}}{27^{2.0} + FA^{2.0}}$
Head circumference (HC in cm)	$\frac{58 \times FA^{1.8}}{30^{1.8} + FA^{1.8}}$
FA: post-conceptual fetal age in weeks HT: fetal height, WT: fetal weight	

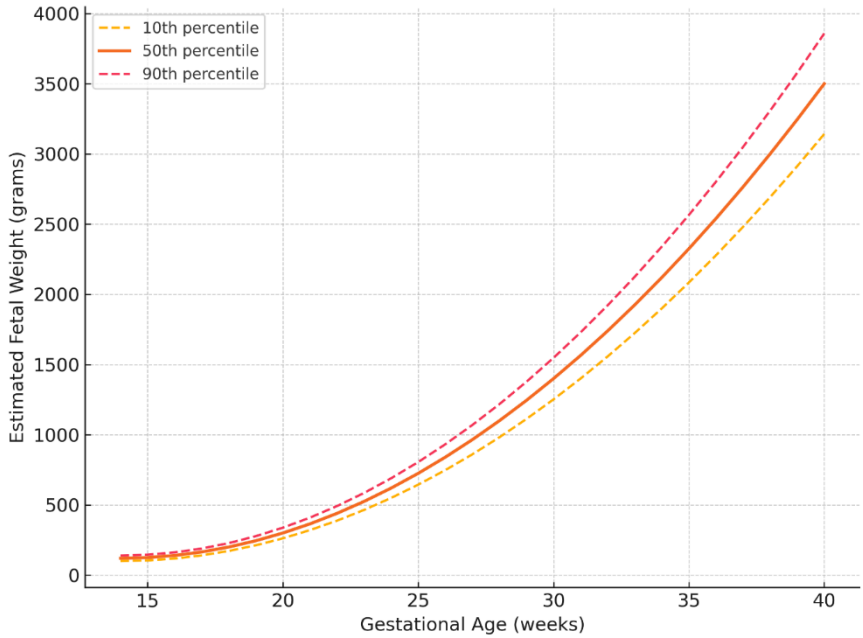


Figure 1-2: Estimated fetal weight (EFW) percentiles by gestational age for male and female fetuses. Redrawn by the author using publicly available data from the World Health Organization (WHO) and NICHD fetal growth standards.<sup>5</sup>

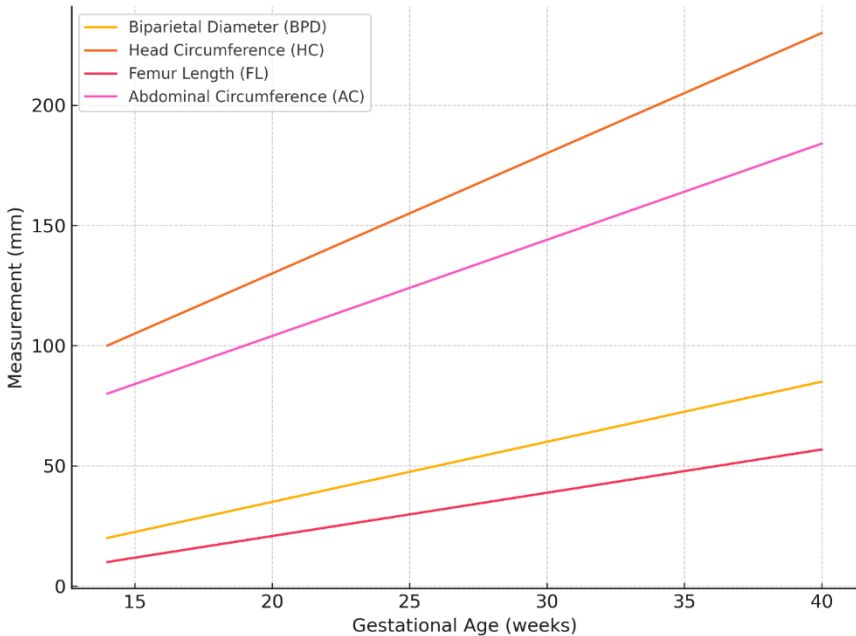


Figure 1-3 Growth trajectories of key fetal biometric parameters including BPD, HC, FL, and AC across gestation. Redrawn by the author from open-access fetal biometry datasets (e.g., WHO, NICHD).<sup>6</sup>

## Small for gestational age (SGA) and IUGR

**Intrauterine Growth Restriction (IUGR)** is a significant and often silent contributor to fetal and neonatal morbidity and mortality. It is defined as a fetal growth rate that is below the expected potential for a specific infant, taking into account factors such as race and gender. While the terms *IUGR* and *Small for Gestational Age (SGA)* are frequently used interchangeably, they are not synonymous.

**SGA** refers to infants whose birth weight is below the 10th percentile for their gestational age based on population growth charts, without necessarily considering in utero growth patterns. SGA is further classified as:

- **Moderate SGA:** Birth weight between the 3rd and 10th percentiles.
- **Severe SGA:** Birth weight below the 3rd percentile.

In contrast, **IUGR** is a clinical diagnosis indicating that a fetus has experienced restricted growth due to pathological factors such as placental insufficiency or perinatal insults. Importantly, a neonate may be classified as SGA without being IUGR, and vice versa—a baby with a birth weight above the 10th percentile could still meet criteria for IUGR if there is evidence of in utero growth deceleration and malnutrition.

While SGA is a statistical assessment of size, IUGR reflects compromised intrauterine growth and often indicates fetal stress. Although SGA may result from milder or late-acting forms of IUGR, it can also arise from other antenatal environmental influences. Therefore, SGA should not automatically be assumed to be benign.

IUGR is classified into stages based on biometric and Doppler ultrasound findings, which help assess the severity and guide clinical management (Table 1-2). In the early stages, ultrasound may show a reduced abdominal circumference (AC) with preserved head growth, indicating asymmetric IUGR. As the condition progresses, biometric ratios such as head-to-abdomen circumference (HC/AC) may increase, and estimated fetal weight (EFW) falls below the 10th percentile. In advanced stages, abnormal Doppler findings in the umbilical artery, middle cerebral artery, or ductus venosus suggest worsening placental insufficiency and fetal compromise, necessitating close monitoring or delivery.

**Types of IUGR:** (Table 1-3, and Table 1-4)

1. **Asymmetrical IUGR (Type I):**
  - Represents 70–80% of cases.
  - Characterized by "head sparing" where head growth is preserved while body growth is restricted (Figure 1-4).
  - Typically arises in the third trimester, often due to uteroplacental insufficiency.
  - These fetuses usually exhibit normal early growth, followed by poor weight gain later in pregnancy.
2. **Symmetrical IUGR (Type II):**
  - Accounts for 20–30% of cases.
  - Growth restriction occurs early in gestation, affecting all body parts equally.
  - Common causes include chromosomal abnormalities, congenital infections, or intrinsic fetal anomalies.
  - Associated with a reduction in both cell number and size.

Table 1-2: Stages of IUGR based on ultrasound biometry

Stages	EFW	AC	Doppler cardiovascular changes
Stage 0	<10 percentile	<10 percentile	Normal UA and MCA
Stage I	<10 percentile	<10 percentile	Abnormal UA or MCA
Stage II	<10 percentile	<10 percentile	Absent or reversed Doppler flow of the UA
Stage III	<10 percentile	<10 percentile	Absent or reversed Doppler flow of the DV
<p><b>Based on the amniotic fluid index (AFI), each IUGR fetus will be either A (AFI &lt;5 cm) or B (AFI ≥5 cm).                      EFW; Expected fetal weight, AC; Abdominal circumference                      UA; umbilical artery, MCA; middle cerebral artery, DV; ductus venosus</b></p>			

Fetal Malnutrition Markers

1. Ponderal Index (PI)
  - Formula:
 
$$PI = \frac{([Weight (g)] \times 100)}{Length (cm)^3}$$
  - Interpretation:
    - PI < 10th percentile: Suggestive of fetal malnutrition
    - PI < 3rd percentile: Indicates severe fetal wasting
2. Mid-Arm Circumference to Head Circumference Ratio (MAC/HC)
  - Also known as Kanawati and McLaren’s Index
  - Normal range: 0.32–0.33
  - MAC/HC < 0.27 is indicative of malnutrition

Newborn Malnutrition Markers

1. Clinical Assessment of Nutrition (CAN) Score
  - Evaluates 9 physical parameters:
    - Hair, cheeks, neck and chin, arms, legs, back, buttocks, chest, and abdomen
  - Scoring:
    - Each parameter is scored 1 (malnourished) to 4 (normal)
    - Maximum score: 36

- Minimum score: 9
  - CAN score < 25 suggests neonatal malnutrition
2. Cephalization Index (CI)
- Formula:

$$CI = \frac{\text{Head Circumference (HC)}}{\text{Body Weight}}$$

Interpretation:

- A high CI (increased brain-to-body ratio) indicates more severe IUGR
- Correlates with greater risk of brain vulnerability, cerebral palsy, and severe psychomotor delay

*Table 1-3: Ultrasound parameters differentiating types of IUGR*

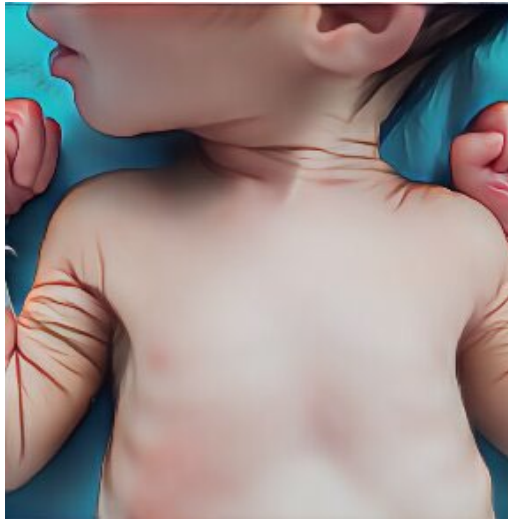
IUGR type	Abdominal circumference	Biparietal diameter	Head circumference	Femur length
Asymmetrical	Decreased	Normal	Normal	Normal
Symmetrical	Decreased	Decreased	Decreased	Decreased

*Table 1-4: Difference of symmetrical and asymmetrical IUGR<sup>7</sup>*

Characteristics	Symmetrical IUGR	Asymmetrical IUGR
Period of insult	Earlier gestation	Later gestation
% total IUGR cases	20–30%	70–80%
Cell number	Reduced	Normal
Cell size	Normal	Reduced
Ponderal Index	Normal (more than 2)	Low (less than 2)
Postnatal anthropometry	Reductions in all parameters	Reduction in weight length and head circumference-normal (brain sparing growth)
Difference between head and chest circumference in term IUGR	Less than 3 cm	More than 3 cm

Features of malnutrition	Less pronounced	More pronounced
Prognosis	Poor	Good

*Figure 1-4: Asymmetrical IUGR. Note the loss of fat whole over the body, visible rib cage, excessive skin fold whole over the body and relatively large heads compared with rest of the body*



Intrauterine growth restriction (IUGR) arises from a complex interplay of maternal, placental, and fetal factors (Table 1-5). Maternal contributors

include chronic conditions such as hypertension, diabetes, renal disease, autoimmune disorders, malnutrition, smoking, substance abuse, and infections like TORCH and malaria. Placental causes encompass abnormalities like infarctions, vascular insufficiency, and infections. Fetal factors involve chromosomal anomalies, congenital malformations, and multiple gestations.

Neonates with IUGR face immediate challenges, including hypoglycemia, hypothermia, respiratory distress, coagulation disorders, and increased susceptibility to infections (Figure 1-5). They also have a heightened risk of perinatal mortality and complications associated with prematurity, such as necrotizing enterocolitis and chronic lung disease.

Long-term sequelae of IUGR are significant (Figure 1-6, and Table 1-6). Affected individuals are predisposed to short stature, cognitive impairments, and neurological disorders like cerebral palsy. Furthermore, IUGR is linked to the development of metabolic syndrome in adulthood, characterized by obesity, type 2 diabetes, hypertension, and cardiovascular diseases. These outcomes are thought to result from fetal adaptations to nutrient and oxygen deprivation, leading to lasting structural and functional changes in organs.

Early detection and management of IUGR are crucial to mitigate both immediate and long-term adverse outcomes. Regular prenatal monitoring, addressing maternal health issues, and timely delivery decisions play pivotal roles in improving the prognosis for affected infants.

*Table 1-5: Causes for intrauterine growth restriction<sup>8</sup>*

<b><i>Maternal</i></b>
Maternal age
Altitude
Socioeconomic status
Ethnicity or race
Maternal substance abuse
Maternal medication
Maternal height and weight
Parity
Inter pregnancy interval
Previous delivery of a SGA newborn
Assisted reproductive technologies
Failure to obtain normal medical care during pregnancy
Severe maternal starvation during pregnancy
Poor weight gain