

Obstetric Ultrasound

Principles, Clinical Practice and
Diagnostic Precision



SCANNING
TECHNIQUE



NORMAL
ANATOMY



ANOMALY
EVALUATION



GROWTH
ASSESSMENT

Obstetric Ultrasound:

Principles, Clinical Practice and Diagnostic Precision



**Font Fusions
Publication**

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Oral Sphere Journal of Dental and Health Sciences of the flagship initiatives under Font Fusions Publication is the Oral Sphere Journal of Dental and Health Sciences. This peer-reviewed, open-access journal provides a comprehensive resource for contemporary research in dentistry and related health disciplines. The journal encompasses a broad range of topics, including digital dentistry, artificial intelligence in diagnostics, oral manifestations of systemic diseases, and advancements in therapeutic modalities. Oral Sphere Journal of Dental and Health Sciences (OSJDHS) is indexed in the Directory of Open Access Journals (DOAJ) and Crossref, with its content discoverable through Google Scholar and ROAD (Directory of Open Access Scholarly Resources) (as of 2026).

Complementing this is another of the flagship initiatives under Font Fusions Publication, the **Bulletin of Health Sphere**. This peer-reviewed, open-access publication serves as a comprehensive resource for contemporary research across the health sciences, extending the publisher's reach beyond dentistry into the wider field of medical and allied health disciplines. The Bulletin encompasses a broad range of topics, including public and preventive health, clinical and translational medicine, digital health and health informatics, artificial intelligence in diagnostics and patient care, and advancements in therapeutic and rehabilitative modalities. Its commitment to quality is reflected in a rigorous editorial and peer-review process and in its inclusion in indexing platforms such as Crossref and Google Scholar (as of 2025), enhancing the visibility, accessibility, and scholarly impact of the research it disseminates.

BOOKS BY FONT FUSIONS PUBLICATION

Advancements Across Oral Sphere: Innovations Shaping Modern Dentistry:

Complementing the journal, Font Fusions Publication has also released a seminal book titled Advancements Across Oral Sphere: Innovations Shaping Modern Dentistry. Published on December 30, 2024, this book delves into cutting-edge developments in dental science and practice. Topics explored include digital dentistry, CAD/CAM technology, teledentistry, and the integration of artificial intelligence in clinical settings. The book aims to provide readers with insights into how these innovations are transforming patient care and clinical workflows. Authored by experts in the field, Advancements Across

Oral Sphere serves as both a scholarly reference and a practical guide for professionals seeking to stay abreast of technological advancements in dentistry.

Innovations in Oral Sphere: Ahead of the Curve: It is a comprehensive exploration of the latest advancements in oral health, offering a forward-looking perspective on the future of dental care and oral sciences. This meticulously curated volume brings together contributions from esteemed professionals in the field, providing readers with a detailed and up-to-date account of transformative progress in oral health. The book explores cutting-edge technologies, interdisciplinary research, and a deeper understanding of the complex relationships between oral health and overall well-being. It encompasses a broad range of topics, including regenerative treatments, digital dentistry, innovative diagnostic tools, and minimally invasive procedures. Each chapter presents insights into how these innovations are shaping the future of dental care, emphasizing the importance of integrating discoveries with ethical practices and patient-centered care. What sets this book apart is its forward-thinking approach. It not only examines the current state of oral health but also anticipates future developments, highlighting the growing importance of prevention, technology-driven solutions, and collaborative research in driving the future of oral health. This makes it an invaluable resource for students, practitioners, and researchers alike, serving as a guide to the ever-evolving world of oral health. Published by Font Fusions Publication Private Limited in May 2025, this book is priced at ₹270 and is available in India. It is printed and bound in Noida, India, and is available for purchase through Font Fusions Publication's website.

Cephalometrics for Orthognathic Surgery: Principles, Planning, and Precision: This essential text unravels the science and clinical relevance of cephalometry in orthognathic surgery. From foundational anatomical landmarks to advanced radiographic analyses, “Cephalometrics for Orthognathic Surgery” provides a structured and insightful approach to diagnosing dento-facial deformities and planning treatment.

Clinical Decision - Making & Case Management in Physiotherapy: This book provides a comprehensive guide to understanding the principles of clinical decision-making and the case management process in physiotherapy. It covers essential topics such as clinical reasoning models, including hypothetico-deductive, pattern recognition, and narrative reasoning, and emphasizes the importance of evidence-based practice. Key steps in clinical decision-making, from subjective and objective assessments to goal-setting, treatment planning, and outcome evaluation, are thoroughly explained. The book also explores case management, highlighting the role of physiotherapists in coordinating care, working with multidisciplinary teams, and ensuring patient-centered care across different stages, from acute to chronic conditions. Ethical and legal considerations, including informed consent, confidentiality, and professional boundaries, are discussed to help practitioners navigate complex clinical and ethical situations. Real-world case scenarios provide practical insights into applying these concepts in musculoskeletal, neurological, and geriatric care.

settings. Overall, the book serves as an invaluable resource for physiotherapists to enhance clinical decision-making and improve patient outcomes.

Evidence Based Dentistry: Dentistry is both an art and a science. This book explores the integration of scientific research and clinical expertise to provide the highest quality dental care. It defines evidence-based dentistry (EBD) as the judicious use of the best available clinical evidence combined with the dentist's experience and the patient's needs. The text covers the history and evolution of EBD, emphasizing its importance in the modern dental practice and the changing role of the patient in the decision-making process. From understanding the foundational principles to the step-by-step process of evidence-based learning, this book guides dental professionals through the process of applying evidence in clinical practice. It highlights the shift from tradition-based to evidence-based care, offering practical insights into improving clinical decision-making, enhancing patient care, and staying current with the latest research. A must-read for dental practitioners aiming to bridge the gap between scientific research and everyday clinical decisions.

The 10th Dentist: Innovations Transforming Modern Oral Care: This book offers a comprehensive and forward-looking account of the technological transformation reshaping contemporary dentistry, examining advances such as artificial intelligence, robotic and AI-guided surgery, regenerative medicine, tissue engineering, smart biomaterials, and 3D printing, and considering how each is redefining diagnostics, treatment planning, surgical precision, and patient outcomes. Across its chapters, the volume moves through imaging in oral cancer detection, clear-aligner orthodontics, periodontal regeneration, personalized prosthodontics, advanced regenerative strategies and material science, and the oral health needs of underserved populations, combining scientific depth with practical clinical relevance. Written in an accessible yet detailed style, and thoughtful in its treatment of the ethical questions and future challenges these innovations raise, *The 10th Dentist* serves as a valuable reference for dental professionals seeking to stay abreast of emerging trends and for readers with a broader interest in the future of oral healthcare.

Maneuvers in Basic Dental Implantology: A Step-by-Step Clinical Guide: Dental implantology has, within a single generation, moved from the margins of clinical practice to its centre. What was once the province of a few specialists is now an expectation of everyday patient care, and the replacement of missing teeth with osseointegrated implants has become one of the most predictable and rewarding treatments modern dentistry can offer. Yet every success of the discipline has created a new challenge: the growing distance between the confidence with which implants are marketed and the depth of understanding with which they should be placed. This book addresses that gap with admirable directness. Rather than overwhelming the reader with exhaustive theory, it returns to the fundamental maneuvers — the small, deliberate, repeatable acts of judgement and technique upon which every successful implant depends. From patient assessment and treatment planning, through the surgical placement of the fixture and the management of hard and soft tissue, to the prosthetic phase and the long years of maintenance that follow, the text follows the

natural arc of treatment as it unfolds in the clinic. Each step is explained in the order it is performed, and the reasoning behind each decision is made plain. The editors and contributing authors have drawn on wide clinical and academic experience to produce a guide that is at once rigorous and accessible. Students encountering implantology for the first time will find a clear and orderly path through a subject that can seem daunting; established practitioners will find a valuable reaffirmation of sound principle. It is a pleasure to commend this work to every clinician who wishes to place implants not merely competently, but well.

Commitment to Open Access and Global Collaboration: Font Fusions Publication's dedication to open access publishing ensures that knowledge is freely available to a global audience, breaking down barriers to information dissemination. By providing platforms like the Oral Sphere Journal and publishing comprehensive works such as *Advancements Across Oral Sphere*, the organization plays a pivotal role in advancing the fields of dental and health sciences. For researchers, clinicians, and academicians looking to contribute to or benefit from the latest developments in these fields, Font Fusions Publication offers valuable resources and opportunities for collaboration.

Books by Font Fusions Publication are now indexed in the **Directory of Open Access Books (DOAB)**, enhancing their global discoverability, accessibility, and visibility among researchers and academic readers.



FOREWORD

It gives me immense pleasure and a deep sense of pride to write the foreword for the book “Obstetric Ultrasound: Principles, Clinical Practice and Diagnostic Precision,” authored by Dr. Nishant Mishra and his team of contributing authors.



Obstetric ultrasonography has become an indispensable component of modern maternal and fetal healthcare. With continuous advancements in imaging technology, the importance of accurate diagnosis, systematic examination, and clinically meaningful interpretation has grown considerably. A comprehensive understanding of these principles is essential for radiologists, obstetricians, and postgraduate medical students.

This book brings together the fundamental principles and practical applications of obstetric ultrasound, covering early pregnancy assessment, fetal anatomy, congenital anomaly evaluation, fetal growth monitoring, Doppler studies, and various maternal and fetal complications. Its emphasis on structured reporting, diagnostic accuracy, and clinical applicability makes it a valuable educational resource.

Having been associated with Dr. Nishant Mishra during his postgraduate training in Radiodiagnosis at PGIMS, Rohtak, it is particularly gratifying to witness his progression from a postgraduate student to a radiologist, academician, and now a contributor to medical literature. As his teacher, I take special pleasure in seeing him undertake this academic initiative.

The publication of a medical textbook requires dedication, perseverance, and a commitment to sharing knowledge. I appreciate the efforts of Dr. Nishant Mishra and his fellow contributors in bringing together this work for the benefit of the medical fraternity.

I sincerely hope that this book will serve as a useful reference for postgraduate students, practicing radiologists, obstetricians, and all healthcare professionals involved in prenatal imaging.

I congratulate Dr. Nishant Mishra and the entire team of contributing authors on this academic milestone and extend my best wishes for the success of this publication and their future academic endeavours.

Warm Regards



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PREFACE

This book began with an observation shared across our reading rooms and labour wards: that obstetric ultrasound is, above everything else, a skill that is learned at the machine. The literature is rich with atlases and specialist monographs, but trainees repeatedly asked for a single, coherent text that would take them from the physics of the image to the wording of the final report, in the order in which questions actually arise during a scan. This volume is our answer to that request.

Our aim throughout has been practical. Each chapter is written to be used at the bedside as much as at the desk, and to explain not only what to look for but why, and what to do when the findings are uncertain. We have tried to keep the reasoning explicit, to state normal ranges and cut-offs clearly, and to flag the pitfalls and artefacts that most often lead the unwary astray.

The book is organised into ten chapters that follow the natural arc of a pregnancy. It opens with the foundations of ultrasound physics, instrumentation and scanning technique, then progresses through the clinical core of early pregnancy; the second-trimester anatomy survey; fetal growth assessment and Doppler surveillance; the placenta, cord and amniotic fluid; multiple pregnancy; the cervix, preterm birth and third-trimester complications; and a detailed, system-by-system account of fetal anomalies. The final chapters address obstetric ultrasound in special situations and the standards of reporting, quality assurance and medico-legal practice that underpin safe modern care.

This work is intended for radiology and obstetrics residents building their competence, for practising radiologists and obstetricians who want a concise and current reference, and for sonographers and fellows who wish to consolidate their technique. We have assumed familiarity with basic clinical medicine but not with the specifics of fetal imaging, and have written accordingly.

No text on a living, evolving field can be complete, and we are keenly aware that guidelines and technology continue to advance. We therefore welcome the comments and corrections of our readers, which will shape future editions. If this book helps even a little to make each scan more accurate, more reproducible and more useful to the women and families we serve, it will have achieved its purpose.

ACKNOWLEDGMENT

A book of this scope is never the work of its editors alone, and it is a genuine pleasure to record our gratitude to the many who made it possible.

We are indebted, first, to our teachers and mentors, whose patient guidance at the ultrasound machine shaped the way we see and the way we report. Much of what is worthwhile in these pages we owe to them.

We thank our residents, fellows and colleagues, whose questions sharpened our explanations and whose enthusiasm sustained the project through its many drafts. We are grateful, too, to the sonographers and technical staff of our departments, whose everyday skill is the quiet foundation of good obstetric imaging.

Our deepest debt is to the countless women and families who consented to their scans being used for teaching. Their trust is the reason this book exists, and we have tried to honour it by writing with care.

We acknowledge, with warm appreciation, Font Fusions Publication for their belief in this work and for their meticulous support through editing, design and production.

Finally, we thank our families, whose patience and encouragement carried us through the long evenings this volume demanded. Their support has been, throughout, our greatest resource.

The Editors

ABOUT THE EDITOR



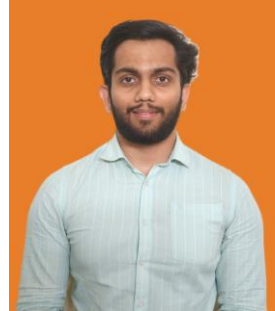
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The editors of this volume are radiologists, obstetricians and clinical teachers drawn from leading medical institutions across India. Together they bring complementary expertise in obstetric and interventional imaging to a shared commitment: making high-quality antenatal ultrasound accurate, reproducible and accessible.

		
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FOUNDATIONS

Obstetric ultrasound is the only imaging modality where the operator is the modality. CT and MRI images, however, require hardware, whereas all obstetric scans rely on the sonologist's mastery of three: the physics of sound in tissue, the controls of the machine to generate that sound, and the reproducible scanning protocol that appropriates it for clinical and medico-legal use.

BASIC ULTRASOUND PHYSICS FOR OBSTETRICS (WHAT MATTERS)

Diagnostic ultrasound uses sound waves of high frequency (1-20 MHz) that are produced by a piezoelectric transducer. A short pulse is then transmitted and the system waits for the echo from the reflector(s) to return; the depth of any reflector is calculated as described using the average tissue propagation speed of 1540 m/s [3]. This single assumption, that is, is the cause of all the artefacts described below in this chapter when fat (1450 m/s), bone (4080 m/s) or gas violate this assumption [4].

FREQUENCY, RESOLUTION, AND PENETRATION

The one most valuable trade-off to absorb is the relationship between frequency and penetration [5] – increased frequency results in reduced penetration, and vice versa. Higher frequencies (7-12 MHz transvaginal probes) give excellent axial resolution and penetration of only 6-8 cm which are ideal for first-trimester and cervical assessment. Lower frequencies (2–5 MHz curvilinear probes) penetrate the maternal abdomen 20–25 cm but with a sacrifice in resolution; this is good enough for third trimester biometry where structures are large enough to measure [6].

Table 1.1: Obstetric ultrasound probe types and their clinical applications

Probe Type	Frequency	Typical Penetration	Obstetric Use
Transvaginal (TVS)	5–9 MHz	6–8 cm	Early pregnancy, cervix, ectopic [6,7]
Curvilinear (TAS)	3.5–5 MHz	15–20 cm	Second/third trimester anatomy & growth
Sector / phased array	2–4 MHz	20–25 cm	Obese patients, fetal echo
Linear high-frequency	7–12 MHz	4–6 cm	Surface anomalies, NT in thin patients

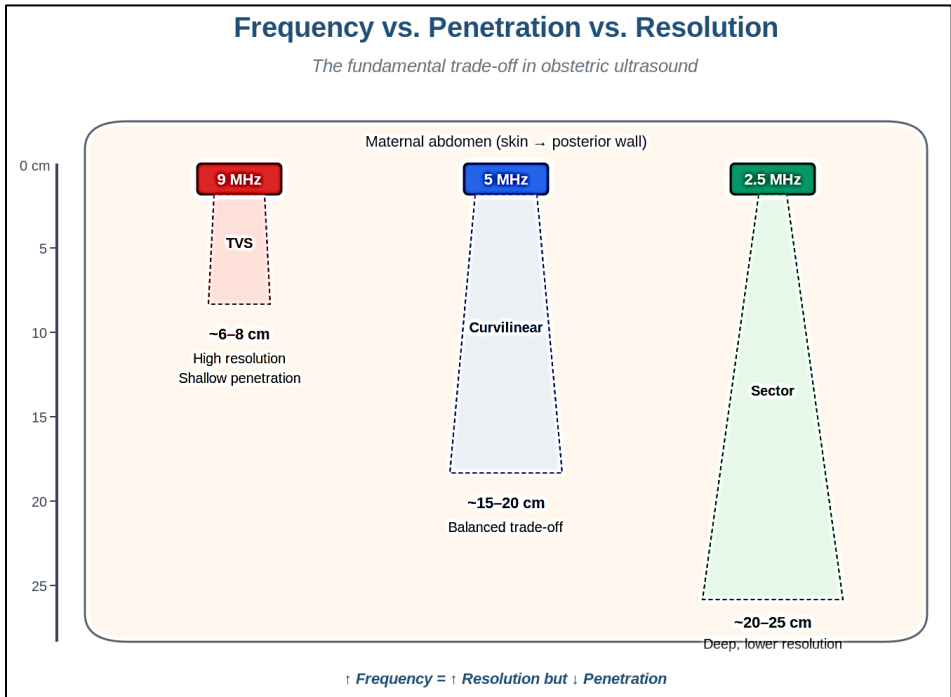


Figure 1.1: Inverse relationship between transducer frequency and tissue penetration. High-frequency transvaginal probes (9 MHz) offer excellent resolution but reach only 6–8 cm; mid-frequency curvilinear probes (5 MHz) balance resolution and depth; low-frequency sector probes (2.5 MHz) penetrate 20–25 cm at the cost of axial resolution

ACOUSTIC IMPEDANCE AND THE ORIGIN OF THE IMAGE

Each ultrasound image represents a map of the acoustic impedance mismatches [7]. When two tissues with wildly different impedances meet—soft tissue vs. bone, soft tissue vs. gas, etc.—nearly all of the sound is reflected, and the soft tissue–bone interface looks bright. When impedances are comparable (soft tissue–soft tissue), only a portion of the signal is reflected, creating the subtle grey-scale gradations that enable the differentiation of organs. This accounts for the shadowing of the structure’s posterior to it and for the fact that bowel gas can cover up an entire pelvic survey [8].

THE THREE MODES YOU WILL USE DAILY

1. **B-mode (brightness mode):** The standard two-dimensional grey-scale image. Acoustic output is low, and B-mode is considered safe at all gestational ages [9].
2. **M-mode (motion mode):** a single scan line plotted against time. Used almost exclusively for fetal cardiac rate and rhythm because acoustic output remains low,

making it the preferred technique for documenting embryonic cardiac activity in the first trimester [10].

3. **Doppler (colour, power, spectral):** uses the frequency shift of moving reflectors (red cells) to encode velocity. Spectral (pulsed-wave) Doppler delivers the highest acoustic intensity of any routine mode and is the principal reason the ALARA principle exists [11].

THE DOPPLER EQUATION IN ONE LINE

The Doppler shift $\Delta f = 2 \cdot f_0 \cdot v \cdot \cos \theta / c$, with v being the blood velocity, θ the insonation angle and c the sound speed [12]. There are two clinical implications to this. There are two clinical implications of this. This is the most common error with umbilical and uterine artery Doppler, and occurs as θ becomes close to 90° . If the spectral measurement is to be accurate, keep $\theta < 60^\circ$ and preferably $< 30^\circ$ [13]. Second, when absolute velocities are reported (such as MCA peak systolic velocity in fetal anaemia surveillance), this must always be corrected for angle, and this is not necessarily the case when using pulsatility indices [14].

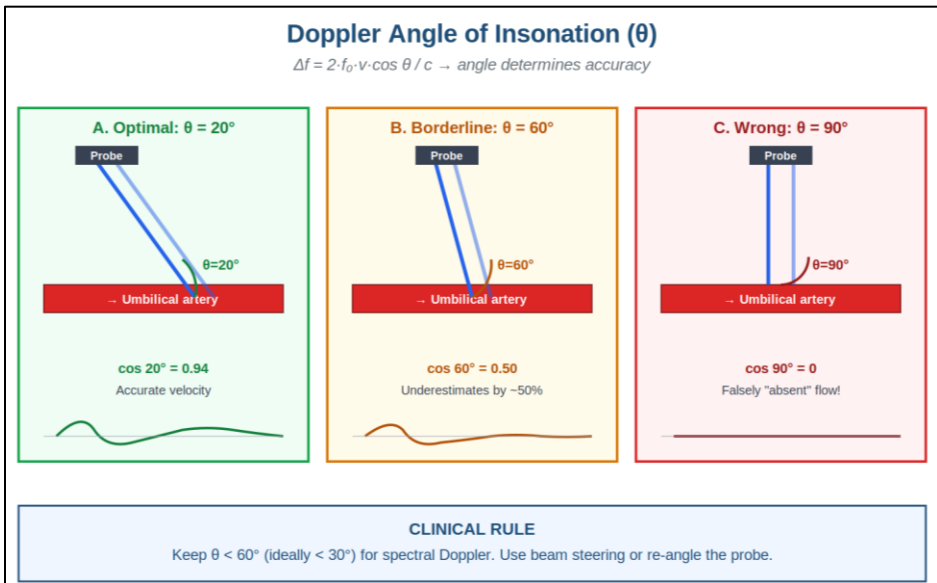


Figure 1.2: The Doppler angle of insonation determines measurement accuracy. (A) $\theta = 20^\circ$ gives $\cos \theta = 0.94$ accurate velocity. (B) $\theta = 60^\circ$ gives $\cos \theta = 0.50$ velocity underestimated by ~50%. (C) $\theta = 90^\circ$ gives $\cos \theta = 0$ falsely 'absent' flow despite normal vessel function

BIOEFFECTS, ALARA, AND THE TWO NUMBERS ON YOUR SCREEN

Ultrasound is a form of energy, and in principle, could produce non-thermal effects (acoustic cavitation) and thermal effects (tissue heating) [15] although there are no known adverse fetal effects at currently approved output levels. The US FDA has allowed obstetric machines to use intensities as high as 720 mW/cm², an approximately 8-fold higher limit than the pre-1992 level, where the responsibility for safe exposure would lie with the manufacturer and not the operator [16]. All modern machines then have two actual time indices, the Thermal Index (TI) and the Mechanical Index (MI), and it is expected that the operator will maintain them at the lowest level possible or As Low as Reasonably Achievable (ALARA) [17].

Table 1.2: Thermal and mechanical indices used in obstetric ultrasound and their clinical relevance

Index	What it estimates	Obstetric target	When it matters most
TIS (soft tissue)	Temperature rise in soft tissue with no bone in beam	< 1.0; start at 0.7	First trimester (no ossified bone)
TIB (bone)	Temperature rise where ossified bone is in focal zone	< 1.0	Second/third trimester; fetal head Doppler
MI	Non-thermal effects (cavitation, microstreaming)	< 1.0 obstetrically	Early gestation; contrast studies

Clinical Pearl First Trimester Doppler

- Routine spectral or colour Doppler interrogation of the embryo/fetus in the first trimester is NOT recommended for screening purposes.
- If Doppler is clinically indicated (e.g. ductus venosus assessment for aneuploidy screening), keep TI < 1.0, exposure time as short as possible, and document the indication.
- B-mode and M-mode (for fetal heart rate) are preferred for first-trimester viability and dating.

RESOLUTION: AXIAL, LATERAL, AND ELEVATIONAL

Axial resolution (parallel to the beam) will be the best resolution that the machine has and depends on pulse length – the shorter pulse = the better the axial resolution. The lateral resolution is along the beam and in the plane of interest, and is best achieved by adjusting the focal zone to lie at the depth of interest, where the beam width is optimised. The third factor, which is not commonly described, is elevational resolution (slice thickness) which is responsible for 'debris' falsely echoing in small cystic structures like early gestational

sac [18-20]. Understanding elevational artefact will avoid over calling intrasac echoes in early pregnancy.

Table 1.3: Common artefacts the obstetric sonologist must know

Artefact	Mechanism	Obstetric pitfall
Acoustic shadowing	High-impedance interface (bone, calcification)	Fetal spine/skull obscures brain & heart
Posterior enhancement	Sound passes through low-attenuation fluid	Confirms cystic gestational sac, bladder
Reverberation	Sound bounces between parallel reflectors	Anterior bladder wall mimics intracavitary debris
Mirror image	Strong reflector creates duplicate on deep side	May simulate second 'fetus' near diaphragm
Refraction (edge)	Beam bends at curved interface	Linear hypoechoic line behind sac edge → pseudo-duplication
Side lobe	Off-axis energy detects strong reflectors	Spurious 'debris' in sac, bladder

Shadowing and enhancement may not be a nuisance but it is a diagnostic ally. A shadow with no obvious reflector should raise suspicion for a calcification, stone or foreign body - posterior enhancement is one of the best ways to make a diagnosis of a structure containing fluid - and the gestational sac, ovarian cyst and full bladder can be confidently diagnosed.

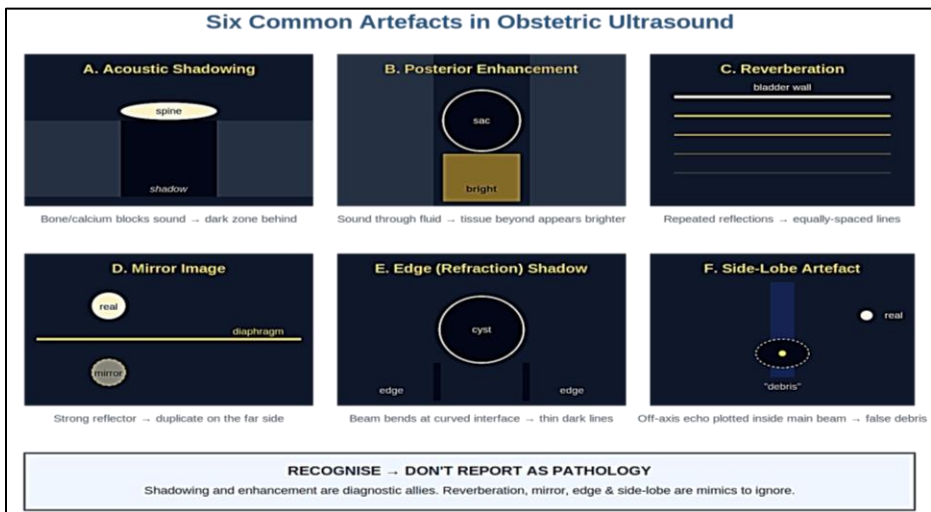


Figure 1.3: Six classical ultrasound artefacts. (A) Acoustic shadowing behind fetal spine. (B) Posterior enhancement deep to a fluid-filled gestational sac. (C) Reverberation echoes parallel to a strong reflector. (D) Mirror image creating a duplicate structure across the diaphragm. (E) Edge refraction shadows at the margins of a cyst. (F) Side-lobe echoes producing false intrasac 'debris'

ADVANCED IMAGE-PROCESSING MODES

There are three useful post-processing technologies offered by modern obstetric machines that can significantly enhance image quality, especially for difficult body habitus. The tissue harmonic imaging method (THI) is based on the fact that harmonics are only generated in the tissue as the ultrasound propagates through it; harmonics are suppressed in the near field, so there is less clutter in fundamental B mode images, as compared to conventional linear B mode imaging [22]. It has been demonstrated that THI enhances fetal structure visualisation during second trimester scanning in obese women [23]. Spatial compound imaging is an approach that compounds together multiple beam-steered frames to minimize speckle and enhance tissue contrast [20] while adaptive speckle reduction smoothes the image without compromising the true anatomical edges [21]. These modes can greatly improve diagnostic certainty, especially in challenging patients, when used together.

Machine Settings & Optimization

A diagnostic image is not the machine's default image. Every probe-on-patient encounter should begin with a deliberate sequence of optimisations preset, depth, focus, gain, then frequency/harmonics. The order matters: there is no point setting gain on an image of the wrong depth.

The Optimisation Sequence (do it every patient)

1. **Select the correct preset:** Obstetric presets pre-load appropriate frequency, dynamic range, persistence, and critically output limits that keep TI/MI in obstetric range. Do not scan a pregnant patient on an 'abdomen' or 'small parts' preset.
2. **Set depth:** The structure of interest should occupy roughly two-thirds of the screen. Excess depth wastes pixels; insufficient depth crops the posterior placenta or the posterior uterine wall.
3. **Position the focal zone:** Place the focal marker at the depth of the structure being measured. Lateral resolution is optimal only at the focal zone; off-focus, beam width widens and small structures blur [25].
4. **Adjust overall gain and TGC:** Amniotic fluid should appear anechoic (jet black), not grey. If fluid is grey, gain is too high and small intrasac echoes will be falsely created. The Time-Gain Compensation (TGC) sliders correct for normal attenuation with depth; a poorly set TGC produces horizontal bands of over- or under-gain.
5. **Frequency, harmonics, compounding:** Drop frequency in obese patients to gain penetration; raise frequency in thin patients for resolution. Tissue harmonic imaging reduces near-field clutter and is particularly useful in difficult body habitus [26].

Checklist 30-Second Pre-Scan Optimisation

- Obstetric preset selected
- Depth adjusted so structure of interest fills $\frac{2}{3}$ of screen
- Focal zone placed at structure of interest
- Amniotic fluid is anechoic (not grey)
- TGC sliders show a smooth vertical curve
- $TI < 1.0$ and $MI < 1.0$ visible on screen
- Harmonics on if body habitus is challenging

Table 1.4: Common gain and depth errors

Error	What you see	Clinical consequence
Gain too high	Grey amniotic fluid; speckle in cysts; loss of contrast	False intrasac echoes; over-call of subchorionic bleed
Gain too low	Anechoic 'holes' in placenta and tissues	Missed solid lesions; under-call of placental abruption
Depth too shallow	Posterior wall / placenta cropped	Posterior placenta praevia missed; incomplete uterine assessment
Depth too deep	Image of interest small, low effective resolution	Inaccurate biometry; missed soft markers
Focal zone wrong depth	Lateral blur off-focus	Mismeasurement of NT, BPD; missed thin septa in multiples [3,23]

Doppler-Specific Errors

Doppler is where physics most often defeats the operator. The four classical errors are angle, gate, gain, and filter.

1. **Angle error:** $\theta > 60^\circ$ produces unreliable velocities. Re-angle the probe or use beam steering before accepting a measurement.
2. **Sample gate size:** the gate should cover roughly half the vessel diameter and sit in the centre of the lumen. Too small misses peak velocity; too large picks up wall motion and contaminates the spectrum.
3. **Doppler gain:** increase until background noise just appears, then back off. Excess gain widens the spectral envelope and falsely lowers the pulsatility index.
4. **Wall filter:** set low (50–100 Hz) for low-velocity fetal vessels (umbilical artery end-diastolic flow, ductus venosus). A high wall filter will erase true end-diastolic flow and create a false absent-end-diastolic-flow report a potentially catastrophic error.

5. **Pulse repetition frequency (PRF)/scale:** if too high, the spectrum is small and low-velocity flow is missed; if too low, aliasing wraps the waveform around the baseline [27].

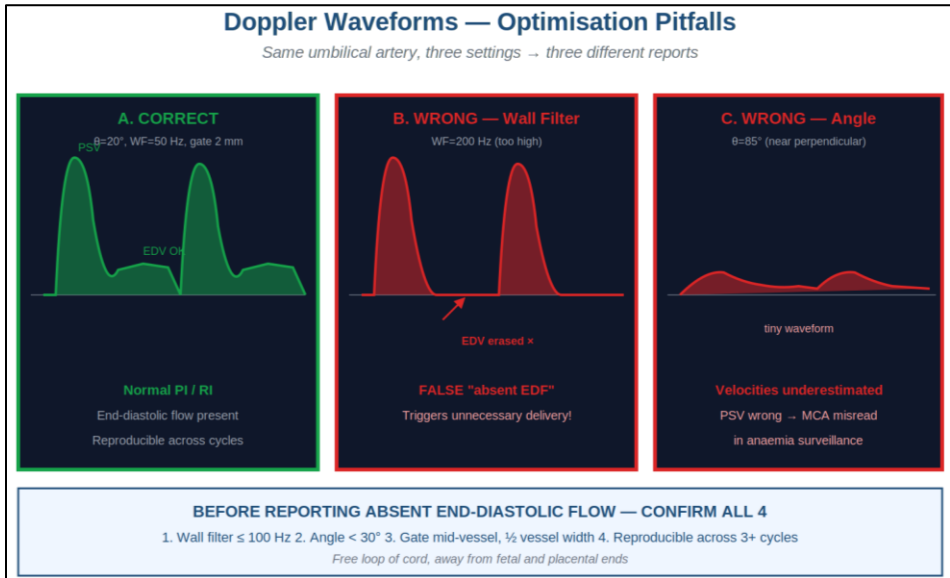


Figure 1.4: Umbilical artery Doppler three settings, three different reports. (A): Correctly optimised waveform with low wall filter, small angle, and appropriate gate; end-diastolic flow clearly present. (B): Wall filter set too high erases end-diastolic flow and produces a falsely 'absent EDF' report a potentially catastrophic error. (C): Angle 85° produces tiny waveforms with grossly underestimated velocities

MEDICO-LEGAL PEARL The 'Absent End-Diastolic Flow' Trap

Before reporting absent or reversed end-diastolic flow in the umbilical artery a finding that may trigger delivery confirm all four:

- Wall filter ≤ 100 Hz
- Angle of insonation < 30°
- Gate in mid-vessel, sized to ½ vessel diameter
- Reproducible on at least 3 consecutive waveforms in a free loop of cord, away from the fetal and placental ends

Document the waveform image with these parameters visible on screen [13,24].

Standard Planes & Image Acquisition (Exam-Proof and Medico-Legal)

Reproducibility is the foundation of obstetric ultrasound's medico-legal defensibility. A scan that cannot be reproduced cannot be defended in court, and a measurement made off-

plane cannot be defended scientifically. International Society of Ultrasound in Obstetrics and Gynecology (ISUOG) and AIUM practice guidelines define standard planes for every routine obstetric scan; departures from these planes should be deliberate, documented, and justified [28].

Why Standard Planes Exist

Standard planes serve three functions simultaneously: (1) they ensure biometric measurements are reproducible between operators and across visits; (2) they guarantee a minimum anatomical survey, so that anomalies are not missed simply because the operator never looked in the right place; and (3) they create a stored image archive that proves what was and was not visible at the time of the scan. The last function is the medico-legal core of practice.

Table 1.5: Standard planes by scan type

Scan / Gestation	Mandatory standard planes	Key measurement
Early pregnancy (TVS)	Mid-sagittal uterus; coronal sac; both adnexa	MSD, CRL, yolk sac, both ovaries [6,7]
First trimester (11–14 wk)	Mid-sagittal fetus (neutral position, $\frac{2}{3}$ of screen)	CRL, NT, nasal bone, ductus venosus [10,15]
Level 1 (18–22 wk)	BPD/HC transthalamic; AC transgastric; FL diaphyseal; 4CH heart; placenta; AFI	BPD, HC, AC, FL, placenta, liquor [14,26]
Anomaly scan (Level 2)	Level 1 + transventricular & transcerebellar; face profile; spine sag + axial; outflow tracts; kidneys; bladder	Systematic anatomical survey [14,27]
Growth scan (3rd tri)	BPD/HC; AC; FL; AFI/SDP; placenta	EFW, percentile, liquor, placenta [26]
Doppler	Free loop umbilical cord; MCA axial brain; uterine arteries at internal os	PI, RI, PSV with angle correction [12,13]

The Three Cardinal Biometric Planes

Three planes underpin almost every biometric measurement and are the most common source of reporting error when taken incorrectly [29].

1. **Transthalamic plane (for BPD and HC):** symmetrical, axial section of the fetal head showing the midline falx, cavum septi pellucidi anteriorly, and paired thalami with the third ventricle between them. The cerebellum should NOT be visible if it is, the plane is too low [30].

2. **Transabdominal (transgastric) plane (for AC):** axial section of the fetal abdomen with the stomach bubble on the left, a short segment of intrahepatic umbilical vein equidistant from each lateral abdominal wall, and the spine posteriorly. The kidneys should NOT be visible (too low) and the heart should NOT be visible (too high) [31].
3. **Femoral diaphysis plane (for FL):** the femur is imaged with both ends clearly defined, the bone perpendicular to the beam, and measurement taken from one end of the ossified diaphysis to the other not including the cartilaginous femoral head or distal epiphysis [32].

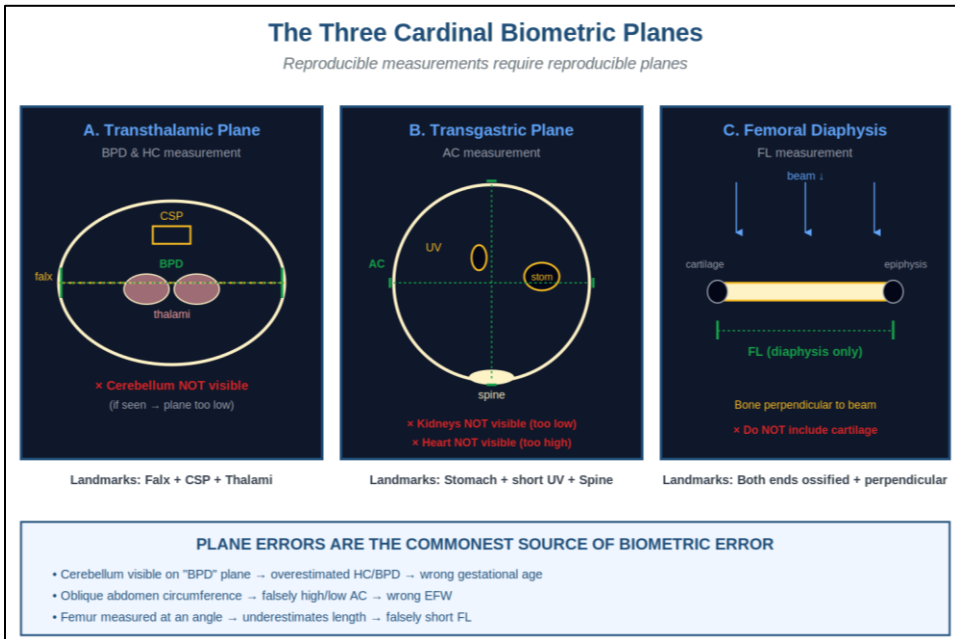


Figure 1.5: The three cardinal biometric planes. (A) Transthalamic plane: falx, cavum septi pellucidi (CSP), and thalami visible; cerebellum NOT visible. (B) Transgastric plane: stomach bubble, short intrahepatic umbilical vein (UV), and spine visible; kidneys and heart NOT visible. (C) Femoral diaphysis: bone perpendicular to beam, both ossified ends defined, cartilaginous epiphyses excluded from measurement

Nuchal Translucency a Special Case in Plane and Calliper Discipline

Nuchal translucency (NT) measurement, detailed in Chapter 4, is a good example of the importance of plane discipline even for a sub-millimetre measurement. NT is reproducible by trained operators within ~0.3 mm but it fails to be reproducible if the operator is inexperienced or the plane is not chosen well [29,30]. The result of measured NT varies by

up to 0.4 mm between machine–probe combinations, which is sufficient to change a Down-syndrome risk assessment clinically in phantom studies. The bottom line: a measurement is as good as the plane it was measured from and audit of stored NT images based on objective scoring is now a common quality-control measure [33].

Image Acquisition: The Image Itself is Evidence

All measurements reported must have an attached image. The information to be displayed for each stored image is: patient identifiers, date and time, gestational age, calliper placement, and Doppler (angle, gate, wall filter, PRF). It is impossible to audit an image that has no dimension and has no callipers and it is impossible to attach an image that has no identifier to a patient. When systematic standard-plane images are not included in the archive, the two most common medico-legal claims in obstetric ultrasound, missed fetal anomaly [34] and incorrect dating [35] are significantly more difficult to defend.

MEDICO-LEGAL Minimum Image Documentation Standard

For EVERY obstetric scan, store images that show, with on-screen annotations:

- Patient identifiers (name/ID), date, gestational age
- Each measurement WITH callipers in place (not just the number in a report)
- The standard plane for each biometric (transthalamic, transgastric, femoral)
- The placenta in two orthogonal planes, including its relationship to the internal os
- For Doppler: waveform with angle, gate, wall filter and PRF visible
- A 'normal study' image set is as important as a positive finding it proves what was looked at.

Table 1.6: Common acquisition mistakes that generate complaints

Mistake	Consequence	Fix
Off-axis transthalamic plane (cerebellum visible)	Overestimated BPD/HC → wrong gestational age	Re-acquire pure axial plane; cerebellum must disappear [26]
Oblique AC plane	Falsely elevated or reduced AC → wrong EFW	Demand circular outline + stomach + UV + spine [26]
FL measured at an angle	Underestimates femur length	Bone must be perpendicular to beam, both ends defined [26]
No image of internal os in 3rd trimester	Praevia missed; indefensible	Always document os in mid-sagittal plane; TVS if low-lying
No stored 'normal anatomy' images	Cannot prove anomaly was looked for	Capture full ISUOG Level 2 image set [14]
Doppler reported without angle/filter visible	Indefensible if waveform challenged	Always store waveform with parameters on screen [13]

The Operator-Dependence Problem

Obstetric ultrasound is the most operator dependent imaging technique in routine clinical practice. Two operators can scan the same patient within an hour on the same machine, and obtain different EFWs and different NTs and different anatomy surveys. The countermeasures are not technical, but behavioural: rigid adherence to standard planes, audit of image quality, continuous training and critically 'reporting suboptimal study, recommend re-scan' instead of committing to an off-plane measurement. It is an honest reporting protocol that is not only good medicine, but also good medico-legal protection [35].

Key Takeaways
<ul style="list-style-type: none">• Higher frequency = better resolution but shallower penetration; choose the probe for the gestation.• Keep Doppler angle $< 60^\circ$ (ideally $< 30^\circ$) and wall filter low for fetal vessels; these two settings cause more reporting errors than any others.• ALARA is non-negotiable: $TI < 1.0$, $MI < 1.0$, minimum exposure time, no routine first-trimester spectral Doppler.• Optimise in this order every patient: preset $\rightarrow$ depth $\rightarrow$ focus $\rightarrow$ gain $\rightarrow$ frequency/harmonics.• Standard planes are not pedantry they are the basis of both reproducibility and medico-legal defensibility.• The stored image is the evidence; if it is not captured, it did not happen.

EARLY PREGNANCY (CLINICAL CORE)

All other obstetrician care is built on the first trimester. A well-structured and progressive way over the early pregnancy scan makes it a technically demanding, but reproducible and defensible clinical examination. This chapter deals with the normal first trimester evaluation, the criteria for the determination of viability and gestational age, the evidence-based algorithm used in managing pregnancies of unknown location (PUL), sonographic diagnosis of early pregnancy failure and ectopic pregnancy, and the sonographic reporting templates used to meet clinical and medico-legal requirements [1,2].

NORMAL EARLY PREGNANCY - STEPWISE EVALUATION

All early pregnancy scans followed a specific order and this is not dependent on the clinical situation. This sequence puts the operator at ease that a critical finding (most importantly a live ectopic) is not missed due to speed of pass from the operator to the uterus [3,4]. The following six-step process should be followed to avoid making this mistake.

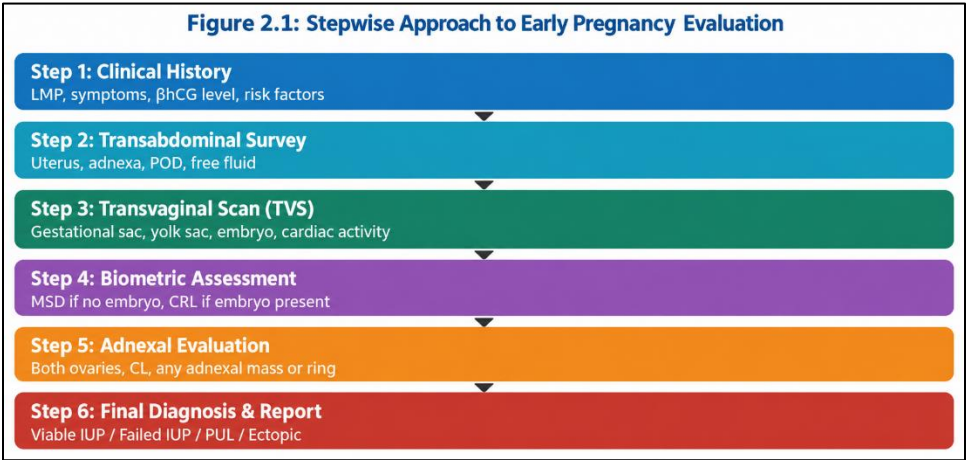


Figure 2.1: Stepwise approach to the early pregnancy evaluation. Each step must be completed before advancing to the next; jumping directly to uterine assessment without adnexal survey is the most common cause of delayed ectopic diagnosis [6,7].

Step 1 — Clinical Orientation

The sonologist should be familiar with the last menstrual period (LMP), serum beta-hCG level and trend, current symptoms (pain, bleeding, etc., passage of tissue), and obstetric history, and should be aware of any risk factors for ectopic pregnancy such as a previous ectopic, tubal surgery, assisted reproduction, and an intrauterine device in situ [5,6]. All

subsequent findings are put into perspective by this information: If a patient has risk factors, and the beta-hCG levels are discordantly low, this is not a normal gestational sac until proven otherwise [7].

Step 2 — Transabdominal Survey

Start with the full bladder sagittal and coronal views of the entire uterus, both adnexa, the pouch of Douglas (POD) and the paracolic gutters. The transabdominal scan will reveal gross abnormalities, such as a large adnexal mass, large amounts of haemoperitoneum or multiple gestations that will guide the subsequent transvaginal evaluation [8].

Step 3 — Transvaginal Scan (TVS)

For the assessment of early pregnancy, transvaginal is a requirement. The TVS probe (5-9 MHz) gives spatial resolution an order of magnitude better than the transabdominal approach in structures < 3cm. The probe is introduced into the uterus gently and the uterus is then viewed in mid-sagittal and coronal planes and each adnexa is then systematically examined. The POD will be again evaluated under TVS for free fluid [9].

Table 2.1: Normal first-trimester milestones on transvaginal ultrasound. Absence of expected findings at stated MSD thresholds defines developmental failure [2,21].

Gestational Age (LMP)	Mean Sac Diameter	Expected Sonographic Finding	References
4 + 3 wk	2-3 mm	Intracardiac sign; no yolk sac yet [22]	[3,22]
5 wk	6-8 mm	Double decidual sac sign; no embryo [21]	[21]
5 + 3 wk	10-12 mm	Yolk sac (2-6 mm) within sac [18]	[18]
6 wk	15-18 mm	Embryo ≥ 2 mm with cardiac activity [26]	[26]
7 wk	≥ 20 mm	CRL measurable; rhombencephalon visible [2]	[2]
9-10 wk	—	Amnion visible; yolk sac degenerating [3]	[3]

Steps 4-6: Biometry, Adnexal Evaluation, and Diagnosis

Biometry is carried out after assessment of the uterine cavity (Section 5 below). The whole of each ovary is then examined. The corpus luteum (CL) is not an ectopic and will have a thick echogenic wall, peripheral vascularity on colour Doppler ('ring of fire') and is located within the ovarian stroma [10]. The final diagnosis combines all the findings into one of four possibilities: viable intrauterine pregnancy (IUP), non-viable intrauterine pregnancy (IUP), PUL, and ectopic. Each scan should have one of these four conclusions recorded in the scan report [11].

VIABILITY ASSESSMENT & DATING — CRL VERSUS MSD PITFALLS

First trimester dating is of critical clinical and medico-legally importance. A miscalculation of 3-5 days in GA later can lead to over- or under-diagnosis of intrauterine growth restriction and misinterpretation of the serum screening cut-offs as well as disagreements

regarding the indication for delivery. The two measurements used for dating pregnancies in the first trimester are crown-rump length (CRL) for an embryo and mean sac diameter (MSD) if an embryo is not seen [12].

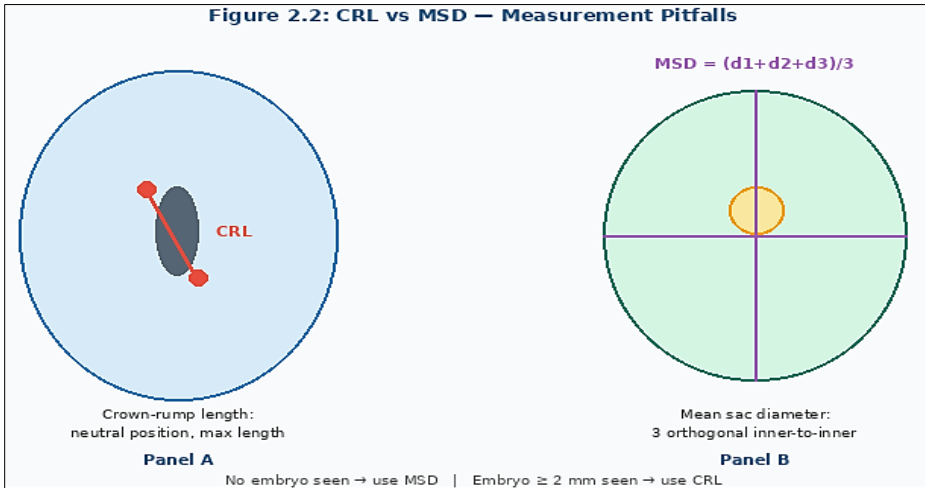


Figure 2.2: CRL versus MSD. Panel A: Crown-rump length (CRL) — embryo in neutral position, calliper from crown to rump, excluding yolk sac. Panel B: Mean sac diameter (MSD) — three orthogonal inner-to-inner measurements averaged. Use MSD when no embryo is visible; switch to CRL the moment a definite embryo ≥ 2 mm is identified

Crown-Rump Length (CRL): Technique and Pitfalls

An embryo is considered visible when it has an average diameter of ≥ 2 mm, at which point the measurement of CRL should be taken. Embryo should be in neutral position — neither hyperflexed nor hyperextended — as hyperflexed will mean a reduction in CRL up to 2 mm (several days under-estimation of GA) [13]. The calliper is applied along the outside of the crown to the outside of the rump, not including the yolk sac. At least three measurements are taken and the greatest is used as the measurement is more important to be underestimated [14]. The CRL is a reliable date only up to 84 mm (about 13+6 weeks), after which BPD and HC are used as the reference measurements [15].

Clinical Pearl — CRL: The Three Deadly Pitfalls

- Hyperflexion: embryo curled — CRL underestimated — gestational age underestimated — later wrongly labelled 'growth-restricted'.
- Yolk sac included: falsely elongated CRL — gestational age over-estimated — screening cut-offs shifted.
- Measuring below 84 mm threshold with suboptimal plane: always use the largest of three frozen measurements on a neutral-position embryo [2,24].

Mean Sac Diameter (MSD): When and How

If there is no embryo visible, MSD is used. It is the average of the three diameters measured across the inner-to-inner sac perpendicular to the middle axis of the sac, two diameters in the sagittal plane and one in the coronal plane, on TVS [16]. The most critical drawback is measuring the outer to the outer instead of inner to inner, which will overestimate MSD by 2-4 mm, and can cause a sac to fail too early [17]. MSD should not be used for dating after embryo is seen as the range of variation (+/-14 days at 95% CI) is too wide to be clinically reliable [18].

Viability Thresholds: The 2013 NEJM Criteria and Subsequent Validation

In 2013, Doubilet and colleagues conducted a landmark study for the diagnosis of miscarriage without the risk of misclassifying a viable pregnancy [19].

Table 2.2: Evidence-based criteria for diagnosing miscarriage in the first trimester. Each criterion applies when findings are unequivocal on TVS by an experienced operator; a second examiner is recommended if doubt exists

Measurement	Diagnostic Criterion for Miscarriage
CRL	CRL ≥ 7 mm with no cardiac activity
MSD	MSD ≥ 25 mm with no embryo
MSD (no yolk sac)	MSD ≥ 16 mm with no yolk sac (single operator)
Embryonic HR	HR < 90 bpm at 6-7 wk: poor prognosis; not diagnostic alone
Medico-Legal Pearl — Never Diagnose Miscarriage Below These Thresholds	
<ul style="list-style-type: none"> CRL 5-6.9 mm with no cardiac activity: equivocal — not diagnostic. Rescan in 7 days. MSD 16-24.9 mm with no embryo: equivocal. Rescan in 7-10 days. A single examiner's subjective impression of 'no heartbeat' is NOT a diagnosis of miscarriage if thresholds are not met. Premature diagnosis has led to termination of viable pregnancies. 	

Pregnancy of Unknown Location (PUL) — Approach & Algorithm

A pregnancy of unknown location (PUL) means that a positive serum beta-hCG is present without any intrauterine or extrauterine pregnancy is seen on TVS. PUL is not a diagnosis, but a management category. About 8-10% of all women who present to an early pregnancy unit will have PUL on their initial scan and of these, about 6-20% will ultimately be confirmed as ectopic [20]. The clinical challenge is to efficiently risk stratify PUL with minimal unnecessary intervention in the majority who have failing intrauterine gestations [21].

Figure 2.3: PUL Algorithm – Decision Tree

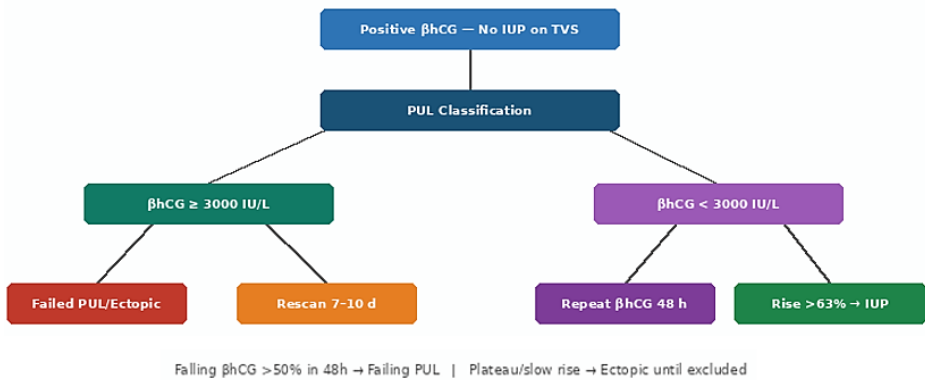


Figure 2.3: PUL management algorithm. The discriminatory zone ($\text{beta-hCG} \geq 3000 \text{ IU/L}$) divides cases into those where a normal IUP should be visible on TVS and those below it where expectant management and serial beta-hCG monitoring are appropriate. A rise of $\geq 63\%$ in 48 hours predicts viable IUP; a fall of $\geq 50\%$ predicts failing PUL [9,28]

The beta-hCG Discriminatory Zone

If the serum beta-hCG is above the discriminatory zone (typically 1000-2000 IU/L (Third International Standard), but increased to 3000 IU/L at many centres to minimise the number of false-positive ectopic pregnancies, particularly in women with an anteverted uterus [22]. If there is no IUP, then ectopic pregnancy must be ruled out above the discriminatory zone. Serial measurement of beta-hCG , 48 hours apart, is the main management tool below that [23].

Serial beta-hCG Interpretation Rules

The doubling time concept, first described as 66% over 48 hours for viable IUP, was refined by Barnhart and colleagues who showed that 53% over 48 hours is the minimum increase expected for viable IUP, and that a threshold of 63% rise (99th centile) decreases the number of false-positive ectopic pregnancy diagnoses. On the other hand, a decline of $\geq 50\%$ in 48 hours is reliable for identification of a failed gestation (either failed IUP or complete miscarriage). This is the most critical scenario in the context of PUL – a plateau or slow rise ($< 63\%$) – and should prompt a clinical assessment that is done in a hurry [24].

Checklist — PUL Management Protocol

- Document: beta-hCG level, date/time, TVS findings, symptoms, haemodynamic status.
- Above discriminatory zone + no IUP on TVS: treat as ectopic until proven otherwise. Refer to gynaecologist immediately.

Checklist — PUL Management Protocol: Continued...

- Below discriminatory zone: repeat beta-hCG at 48 h. Calculate percentage change.
- Rise $\geq 63\%$: rescan TVS at 7-10 days (likely viable IUP, too early to see).
- Fall $\geq 50\%$: monitor to <5 IU/L (failing PUL, likely complete miscarriage).
- Rise $<63\%$ or plateau: urgent TVS and gynaecology review (ectopic cannot be excluded) [9,28].

Role of Serum Progesterone in PUL Triage

A single progesterone <5 nmol/L has a sensitivity of 90-96% for non-viable pregnancy. While not diagnostic of ectopic, a very low progesterone in the context of PUL supports a failing gestation and may justify accelerated management. Progesterone >25 nmol/L is strongly associated with viable IUP but cannot exclude ectopic pregnancy in all cases [25]. Most protocols now combine progesterone with beta-hCG ratio and clinical context for triage.

Ectopic Pregnancy — Diagnosis & Reporting

The sensitivity of progesterone <5 nmol/L for non-viable pregnancy is 90–96%. A very low progesterone level in the context of PUL is not diagnostic of ectopic, but may warrant an accelerated approach to management. In a minority of women, progesterone levels >25 nmol/L will not rule out an ectopic pregnancy, but will strongly suggest it if levels are high. Most protocols now use the combination of progesterone, beta-hCG ratio and clinical context for triage [26].

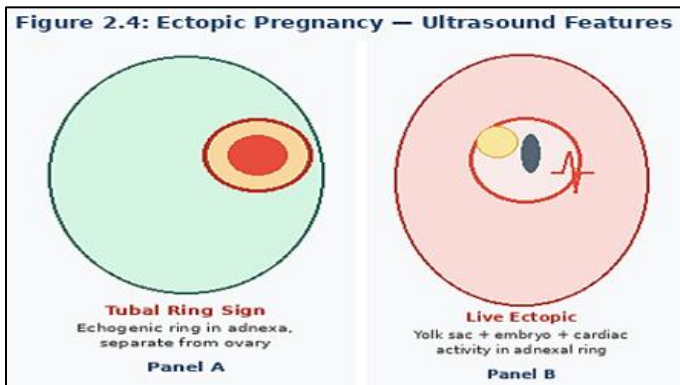


Figure 2.4: Ectopic pregnancy ultrasound spectrum. Panel A: Tubal ring sign — an echogenic ring separate from the ovary representing trophoblastic tissue surrounding the ectopic sac; the central area is the ectopic gestation. Panel B: Live ectopic — an adnexal ring containing a yolk sac and embryo with detectable cardiac activity; this finding is unequivocal and mandates immediate intervention

Sonographic Features of Ectopic Pregnancy

Ectopic pregnancy (EP) affects around 1-2% of all pregnancies and is a common cause of first trimester death of the mother [5]. The diagnosis by ultrasound is most important in order to prevent rupture. Up to 90% of ectopics can be identified on index TVS by a trained operator. The sonographer's role is not only to confirm the diagnosis, but also to characterize the ectopic completely, including location, size, viability, and haemoperitoneum, which will influence how the ectopic will be managed (expectant, medical [methotrexate] or surgical) [27].

Table 2.3: Sonographic features of ectopic pregnancy and their diagnostic weight on TVS. 'Ring of fire' on colour Doppler increases specificity but should not be used as the sole criterion for diagnosis [5,6].

Sonographic Finding	Description	Diagnostic Weight
Live ectopic	Embryo + cardiac activity outside uterus [6,11]	Pathognomonic — immediate intervention
Tubal ring sign	Echogenic ring separate from ovary [11]	Very high (PPV 95-97%) [11]
Heterogeneous adnexal mass	Complex mass in adnexa, no ring [6]	High; include in differential [6]
Echogenic free fluid in POD	Haemoperitoneum — volume matters [7]	Suspicious if no IUP [7]
Corpus luteum only	Cyst within ovarian stroma — 'ring of fire' [23]	Normal — confirm it is WITHIN ovary
No adnexal finding	PUL — manage per algorithm [28]	6-20% chance of ectopic [10,28]

Site-Specific Ectopics: Rare but Dangerous

Ninety-five percent of ectopic pregnancies are tubal. The remaining 5% include cornual/interstitial (mortality rate 2-2.5% vs 0.14% for tubal), cervical, caesarean-scar, ovarian, and abdominal implantations [28]. Interstitial ectopics are notoriously difficult to diagnose because they may appear to be within the uterine cavity on superficial inspection; the key sign is the 'interstitial line' — an echogenic line extending from the uterine cavity to the ectopic sac — and a myometrial mantle of <5 mm around the ectopic sac [29].

Caesarean Scar Ectopic: A Growing Emergency

Caesarean scar ectopic (CSE) occurs when the gestation implants in the fibrous scar of a previous lower-segment caesarean. Its incidence is rising with increasing caesarean rates. The sonographic criteria are: gestational sac in the lower uterine segment, absent or thin (<5 mm) myometrium between sac and bladder, continuous decidual flow around the sac on Doppler, and empty uterine cavity and cervical canal [30]. Early diagnosis is critical because expectant management carries a risk of life-threatening haemorrhage.

Clinical Pearl — Caesarean Scar Ectopic: All 4 Criteria Required

- Gestational sac in the anterior lower uterine segment at the site of the caesarean scar.
- Myometrial mantle between sac and bladder serosa <5 mm on TVS.
- Empty uterine cavity and endocervical canal above the sac.
- Rich pericystic blood flow on colour Doppler [5,7]. Report immediately and refer without delay.

Reporting an Ectopic Pregnancy: Mandatory Elements

The key elements of an ectopic report are: (1) uterine cavity status (empty, decidual reaction or pseudogestational sac); (2) adnexal finding with precise location, size (in 2 and 3 dimensions) and internal characteristics; (3) presence or absence of free fluid with estimated volume and echogenicity (anechoic vs echogenic, this latter constituting a sign of haemoperitoneum); (4) the identity of the ovary (confirming the adnexal mass is separate from the ovary); and (5) a clear diagnostic statement with urgency flag, as appropriate [31].

Early Pregnancy Complications

Figure 2.5: Spectrum of early pregnancy complications. Panel A: Subchorionic haematoma — a hypoechoic crescent between the gestational sac and the endometrium; the embryo and yolk sac are intact. Panel B: Blighted ovum (anembryonic pregnancy) — MSD ≥ 25 mm without a yolk sac or embryo. Panel C: Missed abortion — embryo with CRL ≥ 7 mm and absent cardiac activity confirmed on M-mode

Subchorionic Haematoma (SCH)

The most frequent sonographic finding of the first trimester is between 18% of women with symptoms of an early pregnancy [32]. Acutely, SCH presents as a hyperechoic crescent, but becomes hypoechoic and anechoic as it liquefies over days to weeks, avoiding

the potential for overdiagnosis of hypoechoic rim alone. Retrochorionic haematoma (between chorion and decidua basalis) has a more adverse prognosis than subamniotic haematoma [33].

Prognostic classification by volume: Small SCH (<25% of sac volume), moderate (25-50%), and large (>50%) correlate with increasing risk of adverse outcome. Large SCH is associated with a two-fold increased risk of miscarriage and a three-fold increased risk of placental abruption in the second trimester [34].

CHECKLIST — SCH Reporting Elements

- Location: anterior, posterior, fundal, retrochorionic, or subamniotic.
- Dimensions: three planes (length x height x width in cm).
- Volume as percentage of gestational sac volume (ellipsoid formula: $\pi/6 \times L \times H \times W$ for sac and haematoma separately).
- Echogenicity: hyperechoic (acute) — hypoechoic — anechoic (resolving).
- Viability confirmation: embryo CRL, cardiac activity on M-mode documented separately [14,15].

Blighted Ovum (Anembryonic Pregnancy)

The blighted ovum is an anembryonic pregnancy as it is when a gestational sac contains no embryo or yolk sac but is larger than it should be. The diagnosis is made if the MSD is ≥ 25 mm (no embryo or yolk sac) or ≥ 16 mm (no yolk sac) when the diagnosis is made by one operator [35]. These thresholds have been adjusted from earlier thresholds (20 mm and 13 mm, respectively) with a specific focus on avoiding the possibility of misdiagnosis.

The gestational sac of a blighted ovum may appear deformed, irregularly shaped, or positioned low in the uterine cavity. Absent or minimal trophoblastic flow on Doppler supports the diagnosis but should never substitute for the size-based criteria [36]. When MSD is below threshold but no embryo is seen, the correct report is: 'Gestational sac with no embryo visible at this gestation — follow-up TVS in 7-10 days to reassess' [37].

Missed Abortion (Early Embryonic/Fetal Demise)

Missed abortion is the death of the embryo or fetus before birth, but it does not lead to an abortion. According to the sonographic definition, the condition of the fetus is $CRL \geq 7$ mm and there is no cardiac activity as the definitive criterion [38]. Prior to confirming embryonic death, M-mode (not colour or spectral Doppler, which have higher TI in the first trimester) must be used to document lack of cardiac motion and delayed imaging should be performed by a second operator or a repeat scan [39].

Slow heart-rate (<90 beats per minute at 6-7 weeks, <100 beats per minute at 7-8 weeks) has a poor prognosis and the subsequent risk of miscarriage is around 80%, but slow heart rate alone is not indicative of a missed abortion [40]. Such patients should be re-imaged in 7 days, with close clinical monitoring.

Table 2.4: Diagnostic thresholds for early pregnancy complications. The threshold is required — never diagnose below it. A second examiner or rescan is mandatory when findings are equivocal [2,24].

Complication	Key Sonographic Criterion	Threshold	References
Blighted ovum	No embryo in sac ≥ 25 mm MSD	MSD ≥ 25 mm	[2,24,27]
Missed abortion	No cardiac activity, CRL ≥ 7 mm	CRL ≥ 7 mm	[2,10]
SCH — large	$>50\%$ of sac volume [15]	Volume ratio	[14,15]
Slow embryonic HR	<90 bpm at 6-7 wk [26]	Poor prognosis; rescan in 7 d	[26]

Reporting Templates: Early Pregnancy

A structured report prevents omission of critical elements and creates a medico-legally auditable record. The following templates reflect current ISUOG and AIUM reporting standards [10,28] and should be adapted to local institutional requirements. The report format mirrors the format established in Chapter 1 for all obstetric scanning documentation.

Template A: Viable Intrauterine Pregnancy

Field	Content
Clinical indication	Confirmed pregnancy; first-trimester viability assessment. LMP: [date]. beta-hCG: [value] IU/L.
Technique	Transabdominal (TAS) + transvaginal (TVS) sonography.
Uterus	Anteverted/retroverted; myometrium homogeneous. Single live intrauterine gestation confirmed.
Gestational sac	MSD: [X] mm, sited in the [anterior/posterior] uterine body. Regular margins, posterior enhancement.
Yolk sac	[Present/absent]. Diameter: [X] mm (normal 2-6 mm).
Embryo/Fetus	CRL: [X] mm. Cardiac activity: present on M-mode. HR: [X] bpm.
Gestational age	[X wk + Y days] by CRL (Robinson/ISUOG chart). Estimated due date (EDD): [date].
Adnexa	Right ovary: [dimensions], corpus luteum present/absent. Left ovary: [dimensions]. No adnexal mass.
Free fluid	None. / Small volume physiological fluid in POD.
Conclusion	Single viable intrauterine pregnancy. CRL [X] mm = [X wk + Y d]. Cardiac activity present. Next scan recommended at [date/gestation].

Template B: Ectopic Pregnancy Suspected

Field	Content
Clinical indication	Pelvic pain/vaginal bleeding. LMP [date]. beta-hCG [value] IU/L. History of [risk factors].
Uterine cavity	Empty. [Thick decidual reaction / pseudogestational sac — no yolk sac seen — cannot confirm IUP].
Adnexal finding	[Right/left] adnexal mass: [X x Y x Z] mm. Appearance: [tubal ring / heterogeneous / live ectopic — embryo CRL X mm, cardiac activity present]. Separate from ipsilateral ovary confirmed.
Ovaries	Right ovary: [dimensions]. Left ovary: [dimensions]. Corpus luteum: [side, size].
Free fluid	[None / moderate / large] free fluid in [POD / paracolic gutters]. Echogenic (haemoperitoneum suspected) / anechoic.
Colour Doppler	Pericystic flow: [present — ring of fire pattern / absent].
URGENT conclusion	Findings consistent with [right/left] ectopic pregnancy. [Live / non-live.] Haemoperitoneum [absent/present — estimated volume]. Immediate gynaecological review advised.

Template C: Pregnancy of Unknown Location (PUL)

Field	Content
Uterine cavity	Empty. No gestational sac, yolk sac, or embryo identified. Endometrial thickness: [X] mm.
Adnexa	No adnexal ring, mass, or free fluid identified. Corpus luteum: [present on right/left / absent].
beta-hCG	[X] IU/L ([above/below] discriminatory zone of 3000 IU/L at this institution).
Conclusion	Pregnancy of Unknown Location (PUL). No IUP or ectopic identified on TVS. Serial beta-hCG at 48 h and clinical review recommended. Ectopic pregnancy NOT excluded [10,28].

Template D: Early Pregnancy Failure

Field	Content
Gestational sac	MSD [X] mm. [Irregular outline / low in cavity / normal outline]. No embryo [if anembryonic].
Yolk sac	[Present: [X] mm / absent — abnormal if MSD >8 mm].
Embryo (if present)	CRL [X] mm. Cardiac activity: absent on M-mode, confirmed by [second operator name / repeat scan at X date].

Template D: Early Pregnancy Failure: Continued...

Diagnostic statement	[Missed abortion (CRL [X] mm, no cardiac activity) / Blighted ovum (MSD [X] mm, no embryo or yolk sac)] — meets NEJM 2013 diagnostic criteria [2].
Recommendation	Findings discussed with [clinician/patient]. Management options (expectant, medical, surgical) to be offered by gynaecologist.

Key Takeaways

1. Always complete the six-step protocol (history — TAS — TVS — biometry — adnexa — diagnosis) before formulating a report; ectopics are missed when the adnexa are not formally surveyed [6,7].
2. Use CRL for dating once an embryo ≥ 2 mm is visible; measure in neutral position; use the largest of three callipers; exclude the yolk sac. CRL is valid up to 84 mm only [2].
3. Do not diagnose miscarriage below threshold: CRL ≥ 7 mm with no cardiac activity OR MSD ≥ 25 mm with no embryo. Below these thresholds, rescan in 7-10 days [2,24].
4. PUL is a management category, not a diagnosis. A beta-hCG above the discriminatory zone (3000 IU/L) with no IUP on TVS must be managed as ectopic until excluded [9,28].
5. A rise of $<63\%$ in 48 hours in PUL is the danger zone — do not wait for a routine appointment; arrange urgent clinical review [9].
6. Up to 90% of ectopics are visible on index TVS; always formally evaluate the adnexa in both planes and confirm the adnexal mass is separate from the ovarian stroma [6,11].
7. Subchorionic haematoma $>50\%$ of sac volume carries substantially elevated risk of miscarriage and later abruption — report the volume ratio, not just a qualitative size [15].
8. Confirm embryonic death by M-mode and document second-operator or rescan confirmation before any patient is counselled about pregnancy failure [2,24].

SECOND-TRIMESTER ANATOMY SURVEY (THE ANOMALY SCAN)

The second trimester anomaly scan is one of the most significant interactions in obstetric imaging. It should be carried out between 18 and 22 completed weeks, and must simultaneously rule out major structural abnormalities, establish or confirm biometric dating, determine placental position and fetal number, and produce a report which is clinically, ethically and medico-legally complete. The ultrasound exam is more comprehensive than any other. This chapter outlines the systematic protocol, standard planes, biometric rules, soft-marker framework, and structured reporting templates for conducting and documenting an anomaly scan according to international standards [1].

THE ANOMALY SCAN — RATIONALE, TIMING & LEGAL FRAMEWORK

Why 18–22 Weeks?

The 18–22-week window is selected because organs are well developed and can be seen in the anatomy survey at ultrasound resolution, but the fetus is still small enough to allow such a survey in a single session [2]. Anomalies that only become apparent as normal organ development occurs will not be detected by scanning earlier (14–16 weeks). Subsequent scans (> 23 weeks) could be beyond legal limits for pregnancy termination in many countries, resulting in the loss of pregnancy management options [3].

The detection rate of the anomaly scan in a well-resourced environment is 44-80% of all fetal anomalies, and 90-95% of all major cardiac and central nervous system defects. This variety is due to operator experience, maternal body habitus, fetal position and the quality of equipment, and needs to be noted when a suboptimal scan leads to decreased confidence [4].

Medico-Legal Framework: What Must Be Documented

In most jurisdictions the anomaly scan is imposed an implied duty to carry out a scan to see if there are major structural abnormalities that can be seen by a competent operator at 18-22 weeks. A failure to identify the anomaly in a scan, if it could have been detected, is a potential basis for clinical negligence if the operator did not follow a systematic protocol, failed to document the sub-optimal scan or failed to arrange specialist review if standard views were not obtained [5].

Medico-Legal Warning — Non-Visualisation Must Be Documented

- Every standard view attempted must be recorded, whether obtained or not. A view that cannot be obtained must be documented with the reason (e.g., 'fetal position', 'maternal body habitus') and a recommendation for repeat scan.
- Silence about a failed view is not equivalent to a normal finding — it constitutes an incomplete examination, which may be indistinguishable from negligence in litigation.
- Where standard views are persistently unobtainable, formal referral to a fetal medicine unit is the required standard of care.

SYSTEMATIC ANOMALY SCAN PROTOCOL — THE ORGAN-BY-ORGAN SEQUENCE

In all examinations, an organ-by-organ protocol is to be adhered to. The order of organs may be different as per the preference of the operator, but the protocol should be complete means all organs mentioned below should be assessed and documented. The ISUOG Basic Examination is the minimum standard, the ISUOG Detailed Examination standard is an additional set of views for high-risk patients or suspected anomalies [6].

HEAD & BRAIN BPD, HC, Cavum SP, Cerebellum, CM, Nuchal fold	1
FACE Profile, lips, orbits, nasal bone	2
SPINE Sagittal, coronal, axial — entire length	3
HEART (4-CH + OUTFLOWS) 4-chamber, LVOT, RVOT, 3VT view	4
THORAX & DIAPHRAGM Lung echogenicity, diaphragm integrity	5
ABDOMEN Stomach, bowel, kidneys, bladder, abdominal wall, cord insertion	6
LIMBS All four limbs, three long bones each, hands & feet	7
PLACENTA & LIQUOR Site, cord, AF/DVP, uterine arteries	8

Figure 3.1: The systematic anomaly scan protocol — eight organ systems surveyed in sequence. Each block is assigned a step number; the sequence is followed without deviation regardless of findings. Early discovery of one anomaly must not distract from completing the full survey, as multiple anomalies are common [1,5].

Table 3.1: Minimum anatomical survey for the ISUOG basic anomaly scan at 18-22 weeks. Each system must be individually documented. Inability to obtain a view must trigger a recommendation for repeat or specialist scan [1,2]

System	Minimum Views Required	What to Confirm
Head & Brain	Transventricular, transthalamic, transcerebellar	Atrial width <10 mm, BPD/HC, CSP, TCD, nuchal fold <6 mm
Face	Mid-sagittal profile, coronal (lips), axial (orbits)	Nasal bone, upper lip intact, palate if possible
Spine	Sagittal, coronal, axial at each level	Posterior elements closed, skin intact, lemon/banana signs absent
Heart	4-chamber, LVOT, RVOT, 3-vessel-trachea	Equal chambers, apex-forming LV, great vessel crossing, normal CTR
Thorax	Coronal + axial chest	Lung echogenicity, diaphragm continuity, no mediastinal shift
Abdomen	Axial stomach, cord insertion, transverse kidneys, bladder	Stomach bubble, intact abdominal wall, bilateral kidneys, bladder filling
Limbs	All four limbs; humerus, radius/ulna, femur, tibia/fibula	Three long bones per limb, hands and feet visible, no bowing
Placenta & Liquor	Placental site, cord insertion, AFI/DVP	No low-lying placenta over os, 3-vessel cord, normal liquor

Head and Brain — Standard Planes and Pathology

The Three Standard Brain Planes

Three sequential axial planes of the brain are obtained by tilting the transducer cephalad from the base of the skull. These are not the same, they aim at different levels of the anatomy and at various groups of anomalies [7].

BPD and HC: Measurement Rules

The BPD is measured at the level of the thalami and cavum septum pellucidum (CSP) with outer-to-inner (leading edge) callipers (outer table of the near skull to the inner table of the far skull) [8]. The HC is calculated as the outer circumference of the skull at the same level, and is traced around the outer calvarium using the ellipse function [9]. The use of a reference chart materially impacts gestational age dating at up to 4 days and the same chart should be used throughout pregnancy [10].

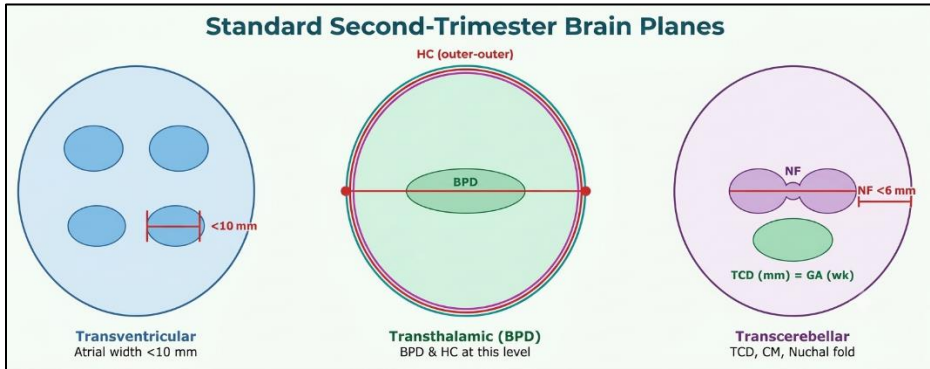


Figure 3.2: Standard second-trimester brain planes. Panel A: Transventricular plane — atrial width measured inner-to-inner at the level of the glomus of the choroid plexus (normal <10 mm at all gestations). Panel B: Transthalamic plane — BPD measured outer-to-inner (leading edge), HC measured as outer ellipse; cavum septum pellucidum (CSP) must be present in midline. Panel C: Transcerebellar plane — cerebellar diameter in mm approximates gestational age in weeks; cisterna magna depth 2-10 mm; nuchal fold <6 mm at 15-22 weeks

Ventriculomegaly: Definition and Grading

The size of the lateral ventricular atrium is measured inner-to-inner at the level of glomus of the choroid plexus, perpendicular to the axis of the ventricles [11]. Perhaps surprisingly, the atrial width is <10 mm at all gestational ages from 15-40 weeks, which is a key and important finding in the absence of proportional growth of the atrium to the brain [12]. The four levels of ventriculomegaly are:

Table 3.2: Grading of fetal ventriculomegaly at the anomaly scan. Bilateral isolated mild ventriculomegaly carries approximately 11% neurodevelopmental impairment; the risk rises substantially when associated anomalies are present

Grade	Atrial Width	Clinical Significance
Normal	<10 mm	No intervention required
Borderline	10.0-11.9 mm	Aneuploidy risk elevated; fetal MRI + karyotype discussion
Mild	12.0-15.0 mm	Detailed fetal anatomy + fetal MRI; TORCH serology
Severe	>15 mm	High risk of neurodevelopmental impairment; tertiary referral

Absent Cavum Septum Pellucidum: A Critical Marker

The CSP is a midline rectangular hypoechoic space in front of the thalami which can be seen as a hypoechoic box between the leaflets of the septum pellucidum. It is usually seen

from the age of 18 weeks. However, failure to detect the CSP at the transthalamic plane is abnormal and requires careful neurosonography to exclude a diagnosis of septo-optic dysplasia, agenesis of the corpus callosum, hydrocephalus or even holoprosencephaly [13]. A missing CSP should never be considered a positioning artefact.

Clinical Pearl — The CSP Rule

- If the CSP is absent, do NOT proceed to the next organ system. Stop and perform a dedicated neurosonographic assessment.
- Refer for tertiary fetal neurosonography and fetal MRI at ≥ 22 weeks. Document the absent CSP prominently in the report with appropriate clinical urgency [11].

Posterior Fossa Assessment: Cerebellum, Cisterna Magna, and Nuchal Fold

The three measurements on the transcerebellar plane are the transverse cerebellar diameter (TCD), the depth of the cisterna magna, and thickness of the nuchal fold [14]. This study showed that the approximate weeks of gestation from TCD (in mm) between 14 and 25 weeks is a useful cross check for the LMP and CRL dating [15]. The width of the cisterna magna is 2-10 mm, < 2 mm indicates obliteration (as seen in spina bifida — the 'banana sign') and > 10 mm is associated with a Dandy-Walker spectrum anomaly [16]. The nuchal fold at 15-22 weeks is measured from the outer calvarium to the outer skin at the transcerebellar level and is ≥ 6 mm for a major soft marker for trisomy 21 [17].

FACE, SPINE, THORAX — SYSTEMATIC ASSESSMENT

Fetal Face

Three planes should be acquired for the face: (1) mid-sagittal plane (assessing the nasal bone, convexity of the forehead, jaw profile and nuchal fold); (2) coronal plane of the lips (to assess an intact upper lip and, if possible, the primary palate); and (3) axial plane of the orbits (to measure inter-orbital distances and to confirm the presence of both lenses) [18]. An important soft marker for trisomy 21 is the absence or hypoplastic nasal bone at 18-22 weeks which raises the likelihood ratio for trisomy 21 to around 6.6 [19].

Checklist — Fetal Face Minimum Standard Views

- Mid-sagittal profile: nasal bone present and echogenic (same echogenicity as adjacent bone), forehead contour, jaw profile.
- Coronal lips: upper lip intact (no cleft), nostrils symmetric.
- Axial orbits: both orbits present, no hypertelorism/hypotelorism, lens echo present.
- Soft palate visualisation is desirable but not mandatory at basic scan level [12].

Fetal Spine

The spine should be examined in at least two planes (sagittal and coronal), and a sweep should be of the entire length of the spine, with an axial sweep highly recommended at each level [20]. Sagittal plane of the normal spine shows two parallel echogenic lines (posterior elements) converging at the sacrum. The normal lumbar spine has three ossification centres that form a closed triangle, an open defect (spina bifida) breaks this triangle and is related to posterior element splaying, meningocele or myelomeningocele and the Arnold-Chiari II malformation of the posterior fossa [21].

When a spine survey is suboptimal two cranial signs of spina bifida (the 'lemon sign' — bifrontal scalloping on axial head view, and the 'banana sign' — obliterated cisterna magna with downward-curved cerebellum) should be looked for and actively pursued [22]. The sensitivity of these cranial signs is about 95% at 16-24 weeks for the open spina bifida.

Thorax and Diaphragm

The thorax is assessed in axial and coronal planes. The cardiothoracic ratio (heart area to thoracic area) should be approximately 1:3 (CTR <0.33); an enlarged cardiac silhouette or a compressed small chest raises concern for cardiomegaly or skeletal dysplasia respectively [23]. The lung fields should be homogeneously echogenic and equal in size bilaterally; a unilateral echogenic lung mass (CCAM/CPAM, BPS) or herniated bowel loops (congenital diaphragmatic hernia — CDH) disrupts this symmetry [24]. Diaphragmatic integrity should be confirmed in the coronal plane by tracing the continuous muscular echogenic rim separating thoracic from abdominal contents.

Fetal Heart — The Four Views Every Sonologist Must Master

The lung fields are homogeneously echogenic and equal in size bilaterally and a unilateral echogenic lung mass (CCAM/CPAM) or herniated bowel loops (congenital diaphragmatic hernia — CDH) disturbs this symmetry [25]. In the coronal plane, the continuity of the diaphragm should be checked for by following the uninterrupted muscular, echogenic border between the thoracic and abdominal contents.

Congenital heart disease (CHD) is the most frequent major structural anomaly with an incidence of about 8/1000 live births [4,26]. The four-view cardiac screening protocol (four-chamber view, LVOT, RVOT and 3VT) is able to identify about 80% of major cardiac defects if it is performed and interpreted correctly [26].

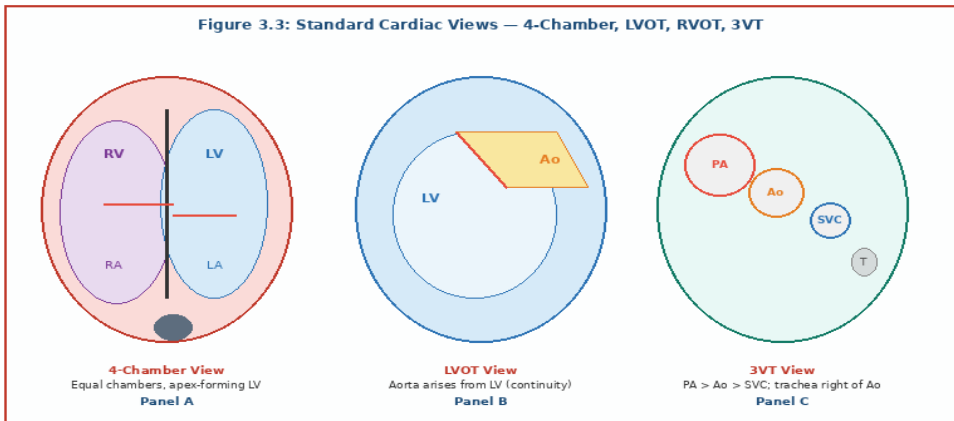


Figure 3.3: Standard cardiac screening views. Panel A: Four-chamber view — equal right and left chambers, intact interventricular septum, apex-forming left ventricle, atrioventricular valves at different levels (mitral higher, tricuspid lower). Panel B: LVOT view — demonstrating aortic root continuity with the anterior interventricular septum; aorta arises exclusively from the left ventricle. Panel C: Three-vessel-trachea (3VT) view — pulmonary artery (largest) anterior and leftmost, aorta (medium) posterior and rightward, superior vena cava (smallest) rightmost; all vessels in a V-shape relative to the trachea.

The Four-Chamber View: Ten Features to Check

The fetal spine is at or near the 3 or 9 o'clock position and the heart is oriented so that the apex faces to the left anterior thorax to get a four-chamber view. There are 10 features that need to be systematically evaluated [27]:

Checklist — 4- Chamber View: Ten Mandatory Assessments

- Position: heart in left chest, apex pointing left (levocardia).
- Cardiothoracic ratio: heart occupies approximately one-third of thoracic cross-section.
- Four chambers all present and symmetric: RA, LA, RV, LV.
- Interventricular septum (IVS): intact throughout; no VSD visible.
- Interatrial septum: intact with normal foramen ovale flap fluttering into LA.
- Apex-forming ventricle: left ventricle forms the cardiac apex.
- Mitral valve: inserts into posterior IVS — higher than tricuspid.
- Tricuspid valve: inserts into anterior IVS — lower than mitral (offset).
- Pulmonary veins: at least two seen entering the LA.
- Pericardial effusion: absent or trivial [13,16].

LVOT AND RVOT VIEWS: DETECTING OUTFLOW TRACT ANOMALIES

The left ventricular outflow tract (LVOT) view can be obtained by moving the transducer about 45 degrees from the four-chamber view towards the fetal right shoulder. The most important one is continuity of aortic-septum, that is, the anterior wall of the aortic root does not form a gap which would become an aortic-septal defect. Tetralogy of Fallot has loss of this continuity (aorta overriding IVS) while truncus arteriosus is characterized by the truncus. The main pulmonary artery is seen emerging from the right ventricle, and passing posteriorly to the right side, before bifurcating (transverse great arteries, the great arteries cross each other, if they are parallel, TGA is the diagnosis) [28].

In addition to the AC plane, which aids in biometry and stomach/UV assessment, the following axial planes are completed to assess the abdominal survey: renal plane—bilateral kidneys and renal pelvis; and cord insertion plane—abdominal wall integrity. The following planes are completed in the axial plane to complete the abdominal survey: renal plane—bilateral kidneys and renal pelvis; and cord insertion plane—abdominal wall integrity [29].

Three-Vessel-Trachea (3VT) View: The V-Sign

The 3VT view is obtained at the level of the fetal upper mediastinum. Three vessels appear, from left to right and front to back: the pulmonary artery (largest, leftmost, anterior), the aorta (medium, middle), and the superior vena cava (SVC, smallest, rightmost, posterior). They form a V-shape with the trachea at the right apex. Abnormalities to recognise: absent pulmonary artery (pulmonary atresia), enlarged aorta with small PA (tetralogy with severe stenosis), a persistent left superior vena cava (visible as a fourth vessel), and abnormal vessel-to-trachea relationship (vascular ring) [30].

Clinical Pearl — The 3VT View Makes Many Diagnoses

- Absent or small PA at 3VT with enlarged Ao: consider pulmonary atresia or critical PS.
- Parallel vessels (no crossing): consider TGA — refer immediately to fetal cardiologist.
- A fourth vessel to the left of the PA: persistent left superior vena cava (PLSVC) — associated with CHD in 30-40% of cases [4,13].
- Vessels entering chest from right of trachea rather than left: right aortic arch — associated with conotruncal anomalies [4].

ABDOMEN, LIMBS, PLACENTA — COMPLETING THE SURVEY

Abdominal Assessment: Three Axial Planes

Three axial abdominal planes complete the abdominal survey: (1) the AC plane for biometry and stomach/UV assessment, (2) the renal plane for bilateral kidneys and renal pelvis, and (3) the cord insertion plane for abdominal wall integrity [31].

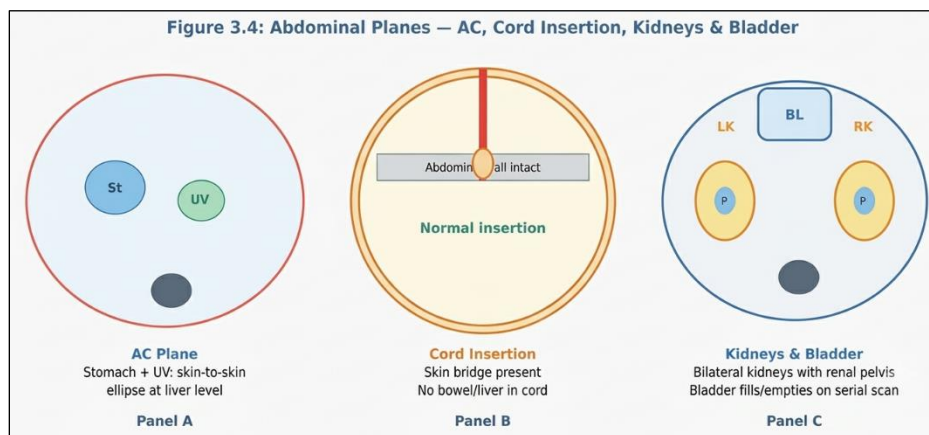


Figure 3.4: Standard abdominal planes at the anomaly scan. Panel A: AC (abdominal circumference) plane — ellipse at the level of the intrahepatic umbilical vein (UV) and stomach bubble; skin-to-skin outer measurement. Panel B: Cord insertion — normal skin bridge present at the umbilical cord-abdominal wall junction; absence indicates omphalocele or gastroschisis. Panel C: Transverse renal plane — both kidneys identified with renal pelvis (normal AP pelvis <5 mm at 18-22 weeks); bladder filling confirms renal function

Abdominal Circumference (AC): Technique

The 4 fetal biometry measurements included in the standard second trimester fetal biometry package are the biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL) [32]. These four parameters are then used to estimate the gestational age and from mid-trimester onwards for estimated fetal weight (EFW) using validated formulae, most commonly the Hadlock formula.

Critical Pitfall — AC Plane Errors

- Including the fetal heart in the AC plane: the transducer is too cephalad — obtain a separate cardiac view and re-establish the correct AC level.
- No stomach visible: either the stomach is empty (rescan in 20-30 minutes), the fetus has oesophageal atresia (consider if consistently absent), or the plane is too caudal.
- Long curved UV rather than short straight segment: plane is too cephalad or oblique — re-angle until the UV appears as a short T-shaped or linear structure [1,7].

Fetal Kidneys: Normal and Abnormal

Both kidneys must be identified in the transverse plane of the lumbar spine. They appear as elliptical structures with a peripheral hypoechoic cortex and a central echogenic sinus complex. The renal pelvis AP diameter should be <5 mm at 18-22 weeks (some units use <4 mm); mild pyelectasis (4-7 mm) is a soft marker for trisomy 21 [33]. Non-visualisation of one or both kidneys is a serious finding: unilateral renal agenesis is associated with contralateral anomalies in 30-40% of cases, while bilateral renal agenesis (Potter sequence) is lethal [34]. Bladder filling (cyclically over 30-40 minutes) confirms bilateral functional renal units.

Limb Survey: Long Bone Measurements

All four limbs must be confirmed present, with each limb evaluated for three segments (proximal, intermediate, distal — or rhizomelia, mesomelia, acromelia). The femur length (FL) is the primary long bone measurement for biometry [35]; additionally, the humerus, radius/ulna, and tibia/fibula should be confirmed as present and not bowed. Femoral length more than 2 standard deviations below the mean for gestational age in association with a short humerus and other features raises concern for a skeletal dysplasia [36]. Hands and feet should be demonstrated; fixed talipes (clubfoot) and polydactyly must be reported.

Placenta, Cord, and Liquor

The placental site, relationship to the internal cervical os, cord insertion (central, marginal, or velamentous), and number of cord vessels must all be documented [37]. A marginal cord insertion is associated with growth restriction; a velamentous cord insertion with vasa praevia — a life-threatening condition if undiagnosed before labour [38]. Amniotic fluid is assessed by either the amniotic fluid index (AFI: four-quadrant sum, normal 8-24 cm) or the deepest vertical pool (DVP: normal 2-8 cm).

Checklist — Placenta and Cord Minimum Documentation

- Placental site: anterior, posterior, fundal, lateral, low-lying (if within 2 cm of os — document exact distance).
- Umbilical cord: three-vessel cord (two arteries + one vein) confirmed on colour Doppler transverse section.
- Cord insertion: central / marginal (<2 cm from placental edge) / velamentous (into membranes).
- Liquor: DVP or AFI documented with normal range stated.
- If low-lying placenta at 18-22 weeks: request repeat transvaginal scan at 32-34 weeks for definitive placental site [1,17].

SECOND-TRIMESTER BIOMETRY — RULES, CHARTS, AND NORMAL RANGES

The 4 fetal biometry measurements included in the standard second trimester fetal biometry package are the biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL) [39]. These four parameters are then used to estimate the gestational age and from mid-trimester onwards for estimated fetal weight (EFW) using validated formulae, most commonly the Hadlock formula.

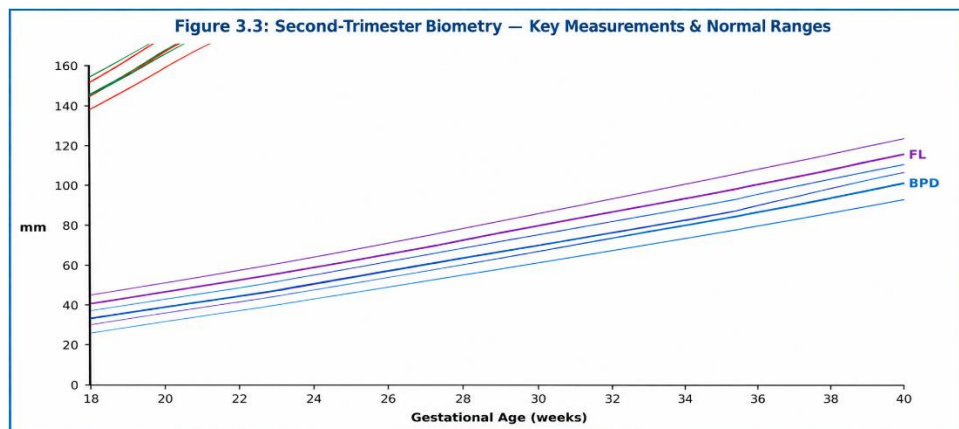


Figure 3.5: Second-trimester biometry curves for BPD, HC/pi, AC/pi, and FL plotted against gestational age. Shaded bands represent approximately ± 2 SD. Each measurement should be plotted on the same reference chart used throughout the pregnancy; deviations of >2 SD from the mean require explanation and serial growth assessment [1,30]

Table 3.3: Standard second-trimester biometric measurements, calliper placement rules, and approximate normal ranges at 20 and 28 weeks. Estimated fetal weight (EFW) error $\pm 15\%$ is inherent in the Hadlock formula and must be communicated to the clinician

Measurement	Calliper Placement	Normal at 20 wk	Normal at 28 wk	Reference
BPD	Outer leading edge to inner far edge at thalamic level [1]	48 ± 3 mm	72 ± 4 mm	[1,10]
HC	Outer ellipse at same plane as BPD [1]	175 ± 10 mm	262 ± 14 mm	[1,10]
AC	Outer ellipse at UV + stomach plane [7]	152 ± 11 mm	240 ± 16 mm	[7,8]
FL	Outer-to-outer femoral diaphysis (exclude distal epiphysis) [6]	34 ± 3 mm	55 ± 4 mm	[6,10]
EFW (Hadlock)	Calculated from BPD, HC, AC, FL [7]	$330 \text{ g} \pm 15\%$	$1000 \text{ g} \pm 15\%$	[7,30]

The HC/AC Ratio and FL/AC Ratio

Across the course of pregnancy the HC/AC ratio drops from >1.0 early on to ~ 1.0 at term [8]. A high HC/AC ratio in the third trimester (>1.0 after 36 weeks) indicates asymmetric fetal growth restriction (brain sparing), that is, the AC decreases more than the HC, and the fetus favors its brain over its liver glycogen stores [40]. Normally the FL/AC ratio is $22 \pm 2\%$ and a low ratio (short femur to a normal AC) is linked to Down syndrome.

Reference Chart Selection

The choice of biometric reference chart significantly affects whether a measurement is classified as normal or abnormal: A study by Salomon and colleagues showed discordances of up to 4 days in gestational age assignment and 10 percentile points in growth assessment depending on which chart was used [41]. Departments must adopt a single set of reference charts, apply them consistently, and state which chart was used in the report [42].

Soft Markers — The Genetic Sonogram Framework

Soft markers are sonographic findings that are minor variants in isolation — they do not define a structural anomaly — but whose presence alters the prior risk for chromosomal abnormality, particularly trisomy 21 [43]. The landmark work of Benacerraf and colleagues established the concept of the 'genetic sonogram' in which the combined presence of soft markers significantly increases the sensitivity for trisomy 21 detection in the second trimester [44].

Table 3.4: Soft markers for chromosomal abnormality at the second-trimester anomaly scan. Likelihood ratios (LR) for trisomy 21 are given for isolated markers in a background risk population. Management is modified by prior risk from first-trimester combined screening or cfDNA [18,19,20]

Soft Marker	Definition / Threshold	Likelihood Ratio T21	Management if Isolated
Nuchal fold ≥ 6 mm	NF at transcerebellar plane	LR 11.0 (major marker) [19,23]	Offer karyotype /cfDNA; tertiary ref.
Absent/hypoplastic nasal bone	No echogenic nasal bone at profile [18]	LR 6.6 [18]	Offer cfDNA or QF-PCR
EIF (echogenic intracardiac focus)	Dot in LV = papillary muscle calcification [29]	LR 1.5 (weak) [29]	Isolated in low-risk: no action needed
Choroid plexus cyst (CPC)	Round cyst ≥ 3 mm in choroid plexus [25]	LR 1.0-1.5 alone; T18 marker [25]	Check T18 features; if isolated: reassure
Renal pyelectasis	AP renal pelvis ≥ 4 mm at 18-22 wk [18]	LR 1.5-2.0 [18]	Repeat scan at 28-32 wk; isolated: low risk

Table 3.4: Continued...

Short femur / humerus	Biometric < 2.5th centile [20]	LR 1.6-2.7 [20]	Combined with other markers for risk
Echogenic bowel	Echogenicity $\geq$ bone [18,20]	LR 6.7; also CF, CMV, IUGR [18]	Offer karyotype + CF carrier testing

Clinical Pearl — The Isolated Soft Marker Rule

- A single isolated soft marker in a patient with a low background risk (first-trimester combined screen <1:1000 or negative cfDNA) does not require invasive testing.
- Two or more soft markers in combination substantially increase the likelihood ratio and invasive testing or cfDNA should be offered regardless of background risk [18,19,20].
- Echogenic bowel and thick nuchal fold (≥ 6 mm) are never truly 'isolated' soft markers — they always warrant further investigation regardless of background risk.

REPORTING TEMPLATES: THE ANOMALY SCAN

A structured anomaly scan report must document every organ system assessed, every measurement performed, every soft marker present or absent, and the overall conclusion with any recommended action. The following template reflects ISUOG and UK FASP standards and is designed to be medico-legally complete [45].

Template A: Normal Anomaly Scan (18-22 Weeks)

Section	Content
Clinical indication	Routine anomaly scan. GA by dates: [X wk + Y d]. Previous dating scan: [CRL X mm = X wk + Y d on DD/MM/YY].
Fetal number	Single live fetus. Cardiac activity confirmed.
Fetal lie & presentation	[Longitudinal / transverse / oblique]. Presenting part: [cephalic / breech / variable].
Biometry	BPD [X] mm HC [X] mm AC [X] mm FL [X] mm. EFW (Hadlock): [X] g ([X]th centile, [chart name]). GA by biometry: [X wk + Y d].
Head & Brain	Skull shape and integrity: normal. Midline echo: present. CSP: present. Thalami: normal. Lateral ventricles: normal (atrial width [X] mm). Cerebellum: [X] mm. Cisterna magna: [X] mm. Nuchal fold: [X] mm (normal <6 mm).
Face	Profile: normal. Nasal bone: present and echogenic. Upper lip: intact. Orbits: bilateral, symmetric.
Spine	Entire spine surveyed in sagittal and coronal planes. Posterior elements: intact. No mass lesion. Skin: intact.

Template A: Continued...	
Heart	Situs: normal (levocardia, stomach left). 4-chamber: equal chambers, intact IVS, atrioventricular offset normal. LVOT: aorta arising from LV, aortic-septal continuity present. RVOT: PA arising from RV, crossing aorta. 3VT: normal V-configuration. CTR: normal.
Thorax	Lungs: equal echogenicity bilaterally. No intrathoracic mass. Diaphragm: intact bilaterally.
Abdomen	Abdominal wall: intact cord insertion. Stomach: present, left side. Liver: normal. Bowel: normal echogenicity. Kidneys: bilateral, normal position and echogenicity. Renal pelvis: <5 mm bilaterally. Bladder: present and filling.
Limbs	All four limbs identified. Three segments confirmed each limb. Long bones: normal length and curvature. Hands and feet: visible, no fixed abnormality.
Placenta	Position: [anterior/posterior/fundal], upper segment, [X] cm from internal os. Cord insertion: [central/marginal]. Cord vessels: three (two arteries, one vein confirmed on colour Doppler).
Amniotic fluid	DVP [X] cm (normal 2-8 cm) / AFI [X] cm (normal 8-24 cm).
Soft markers	No soft markers for chromosomal abnormality identified.
Conclusion	Normal fetal anatomy survey at [X wk + Y d]. EFW [X] g ([Xth] centile). No structural anomaly identified. Routine obstetric follow-up.

Template B: Anomaly Scan with Identified Abnormality

Section	Content
Finding	Describe the anomaly precisely: location, size, characteristics, associated features.
Differential diagnosis	List the most likely diagnoses in order of probability based on the imaging findings.
Associated anomalies	Systematically document any additional anomalies; state if none found despite extended search.
Chromosomal risk	State whether the finding is associated with aneuploidy and current background risk if known.
Recommended action	Specific next step: fetal medicine referral / fetal echocardiogram / fetal MRI / karyotype / cfDNA / repeat scan at [gestation]. Urgency: [routine / within 1 week / urgent today].
Communication	State that findings have been discussed with [clinician name] / that patient counselling has been arranged. Do NOT communicate uncertain findings to the patient without specialist support present.

Template C: Suboptimal / Incomplete Anomaly Scan

Section	Content
Reason for suboptimal scan	[Maternal body habitus / fetal position / oligohydramnios / other]. Specify which views could not be obtained.
Views unobtained	List each standard view not achieved and reason.
Views obtained	Document all views that were successfully obtained and their findings.
Recommendation	Repeat anomaly scan in [X] weeks / Referral to fetal medicine unit for detailed scan. Do NOT report the scan as 'normal' if mandatory views are missing [1,22].

Key Takeaways

1. The anomaly scan is a medicolegal examination: every standard view must be attempted, documented as obtained or not, and a reason given for any failure. Absence of documentation = absence of examination [1,5,22].
2. The three brain planes (transventricular, transthalamic, transcerebellar) are not interchangeable — each detects different anomalies. All three must be obtained and documented individually [11].
3. Absent cavum septum pellucidum at the transthalamic plane is never a normal variant after 18 weeks — stop the survey and perform dedicated neurosonography, then refer for fetal MRI [11].
4. The four cardiac views (4-chamber, LVOT, RVOT, 3VT) together detect approximately 80% of major CHD — the screening standard is all four views, not the 4-chamber alone [13,15,16].
5. AC must be measured at the level of a short straight intrahepatic UV plus the stomach bubble — any other plane gives a biologically meaningless number. Presence of the fetal heart in the plane means the transducer is too cephalad [1,7].
6. A low-lying placenta at 18-22 weeks (within 2 cm of the internal os) requires a repeat transvaginal scan at 32-34 weeks — over 90% of low-lying placentas resolve by term [17].
7. Isolated soft markers require risk integration with first-trimester screening results. Thick nuchal fold (≥ 6 mm) and echogenic bowel are never truly 'isolated' — always prompt further investigation [18,19,20].
8. EFW carries an inherent error of $\pm 15\%$ with the Hadlock formula. Always communicate this uncertainty when reporting EFW to avoid clinical decisions based on spurious precision [7,30].
9. A single soft marker in a low-risk patient does not mandate invasive testing; two or more soft markers in combination substantially increase the T21 likelihood ratio regardless of background risk [18,19].
10. The choice of biometric reference chart affects gestational age assignment by up to 4 days — departments must standardise their chart and state it in every report [30].

FETAL GROWTH ASSESSMENT & DOPPLER SURVEILLANCE

Normal fetal growth is the physiological expression of an unimpaired placental supply line operating within an unstressed maternal milieu. When that supply line fails — whether from abnormal placentation, maternal vascular disease, or chromosomal or structural fetal pathology — the fetal circulatory system mounts an adaptive redistribution of blood flow that is detectable by ultrasound Doppler weeks before clinical or cardiotocographic deterioration [1]. This chapter provides the clinical definitions of fetal growth restriction (FGR), the Doppler surveillance parameters that guide timing of delivery, the biophysical profile, and the uterine artery Doppler framework for preeclampsia prediction [2].

DEFINING FETAL GROWTH RESTRICTION — THE 2016 DELPHI CONSENSUS

SGA Versus FGR: A Critical Distinction

Small-for-gestational-age (SGA) is a statistical descriptor: any fetus with an estimated fetal weight (EFW) or abdominal circumference (AC) below the 10th centile for gestational age. SGA is not synonymous with pathology - approximately 70% of SGA fetuses are constitutionally small and have normal Doppler and neonatal outcomes. Fetal growth restriction (FGR), by contrast, is a pathological condition in which the fetus fails to reach its genetically determined growth potential due to placental dysfunction, with associated Doppler and/or biometric evidence of compromise [3].

The 2016 Delphi Consensus definition — now adopted by ISUOG — provides the first internationally agreed criteria for FGR diagnosis, separating early-onset (<32 weeks) and late-onset (>=32 weeks) disease because these two entities have different Doppler profiles, different natural histories, and different surveillance algorithms [4].

Table 4.1: Comparison of early-onset and late-onset fetal growth restriction. These are distinct clinical entities requiring different surveillance protocols; conflating them leads to both under- and over-intervention

Feature	Early-Onset FGR (<32 wk)	Late-Onset FGR (>=32 wk)
Prevalence	~0.5% of all pregnancies [1]	~5-8% of all pregnancies [1]
Aetiology	Severe placental insufficiency; often associated with PE [3]	Mild/moderate placental dysfunction; often no PE [3]
UmA Doppler	Usually severely abnormal (AEDF/REDF) [7]	Often normal or mildly elevated PI [21]

Table 4.1: Continued....

MCA Doppler	Late finding; CPR <1.0 is poor prognostic sign [12]	CPR <1.0 is an early and important finding [19]
Perinatal mortality	High (20-30x background risk) [11]	Lower but elevated stillbirth risk [10]
Timing of delivery	Guided by DV Doppler and CTG [11]	Guided by CPR and labour induction at 37-38 wk [2]

Diagnostic Criteria (Delphi 2016)

The Delphi criteria define FGR by the combination of a small fetus (EFW or AC <3rd centile, or <10th centile with abnormal Doppler) and evidence of placental dysfunction [5]. The criteria are stratified by gestational age at diagnosis and the severity of the Doppler abnormality:

Table 4.2: Delphi Consensus 2016 diagnostic criteria for fetal growth restriction. An EFW or AC <3rd centile alone meets criteria at any gestation; the <10th centile threshold requires corroborating Doppler evidence [1]

Gestational Age	Biometric Criterion	Required Doppler Criterion
< 32 weeks	EFW or AC < 3 rd centile	Any — diagnosis made on biometry alone
< 32 weeks	EFW or AC < 10 th centile	UmA PI >95th centile, OR AEDF/REDF, OR DV PI >95th centile, OR PIV (pulsatile IV)
≥ 32 weeks	EFW or AC < 3 rd centile	Any — diagnosis made on biometry alone
≥ 32 weeks	EFW or AC < 10 th centile	CPR <5th centile OR UmA PI >95th centile

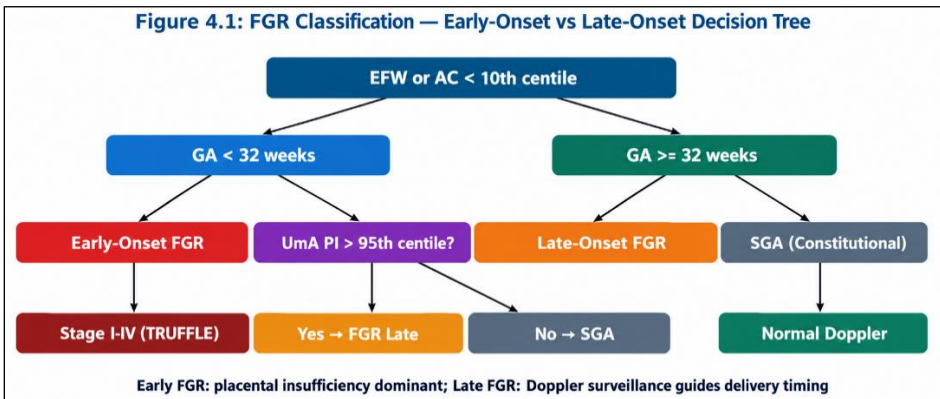
Figure 4.1: FGR Classification — Early-Onset vs Late-Onset Decision Tree

Figure 4.1: FGR classification algorithm. The first branch separates early- (<32 weeks) from late-onset (≥32 weeks) disease. For early FGR, umbilical artery Doppler is the dominant surveillance parameter. For late FGR, cerebroplacental ratio (CPR) is the key additional marker, as umbilical artery PI may remain in the normal range despite significant fetal compromise [1,2,3].

UMBILICAL ARTERY DOPPLER — THE PRIMARY SURVEILLANCE TOOL

Physiology: Why UaA Doppler Reflects Placental Resistance

The umbilical artery Doppler waveform reflects the downstream vascular resistance of the placental circulation. In a normal placenta, the villous capillary tree is a low-resistance, high-compliance system with abundant diastolic flow [6]. As placental infarction, villous obliteration, and vascular remodelling failure progress in FGR, downstream resistance rises, reducing and ultimately eliminating end-diastolic forward flow. The critical threshold is the loss of approximately 60-70% of the placental vascular cross-sectional area, at which point absent end-diastolic flow (AEDF) appears [7]. Reversed end-diastolic flow (REDF) reflects even more extreme resistance, associated with placental dysfunction affecting >80% of the villous tree [8].

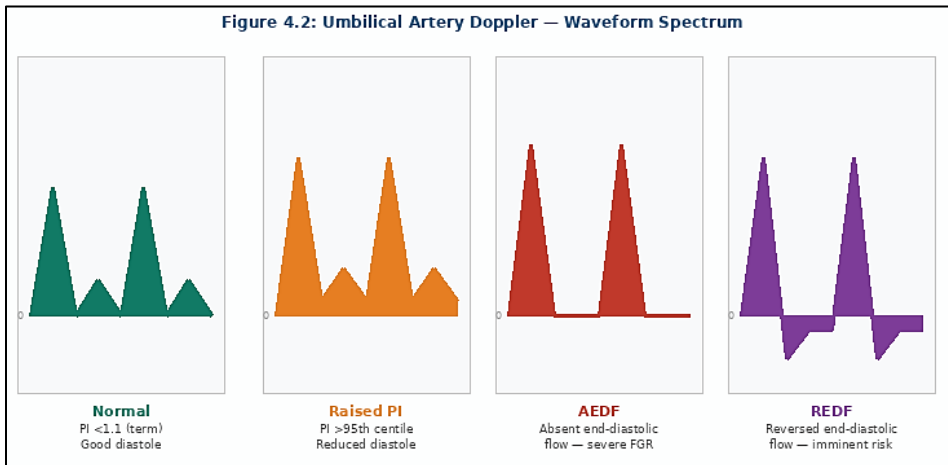


Figure 4.2: Umbilical artery Doppler waveform spectrum. From left: (1) Normal — healthy diastolic component, PI <1.1 at term; (2) Raised PI — diastolic notching or reduced diastolic component with PI >95th centile; (3) Absent end-diastolic flow (AEDF) — zero-flow at end-diastole, equivalent to approximately 60-70% placental vascular loss; (4) Reversed end-diastolic flow (REDF) — blood flows retrograde in diastole, indicating extreme placental resistance. AEDF and REDF mandate immediate escalation of surveillance or delivery [6,7].

Technique: Measurement Rules for UaA Doppler

Checklist — Umbilical Artery Doppler: Technical Standards

- Sample volume: free loop of cord (not placental or fetal end — each gives different resistance values).
- Angle of insonation: <30 degrees to cord axis. Angle correction: NOT required for PI (a ratio); required for absolute velocities.

Technique: Measurement Rules for UmA Doppler: Continued...

- Waveform: acquire 3-5 consecutive uniform waveforms in the absence of fetal breathing movements (which alter waveform morphology).
- Measurement: PI (pulsatility index) = (S-D)/mean is the preferred index; RI (resistance index) = (S-D)/S also acceptable [5].
- Interpretation: compare to gestational age-specific reference ranges. PI >95th centile = abnormal. Always correlate with EFW centile and clinical context [2,5].

Clinical Significance of Waveform Abnormalities

The progression from normal to raised PI to AEDF to REDF is a stepwise deterioration that has been validated in large prospective studies [8]. The TRUFFLE study established that ductus venosus (DV) Doppler - not umbilical artery alone - best predicts the timing of neonatal neurological compromise in early FGR, and that delivering on DV criteria (rather than on UmA criteria alone) improved neurological outcomes at 2 years [9]. However, UmA Doppler remains the surveillance foundation and must be recorded at every monitoring visit.

Table 4.3: Clinical management based on umbilical artery Doppler findings. The decision to deliver is never based on a single parameter — UmA findings must be integrated with DV Doppler, biophysical profile, CTG, and gestational age

UmA Finding	Clinical Stage	Recommended Action	Evidence
Normal PI	SGA — surveillance	Growth scan + UmA every 2 weeks [2]	[2,10]
PI >95th centile	Early FGR Stage I	Twice-weekly UmA + DV; consider steroids if <34 wk [2]	[2,11]
AEDF	FGR Stage II/III	In-patient monitoring; DV twice-weekly; delivery by 34 wk or earlier on DV criteria [11]	[7,11]
REDF	FGR Stage III/IV	Delivery when DV reversed a-wave or CTG abnormal; steroids urgently if <34 wk [2,11]	[11,23]

Medico-Legal Warning — AEDF and REDF Require Documented Action

- Absent or reversed end-diastolic flow on UmA Doppler is not a surveillance finding — it is a clinical emergency requiring same-day senior obstetric review.
- Failure to escalate care within 24 hours of documented AEDF or REDF, or failure to administer antenatal corticosteroids when delivery is anticipated before 34 weeks, constitutes a departure from the standard of care [2,11].

MIDDLE CEREBRAL ARTERY DOPPLER — BRAIN-SPARING AND FETAL ANAEMIA

The Brain-Sparing Response: MCA-PI

In the setting of reduced placental oxygen delivery, the fetal brain maintains its oxygen supply by vasodilating the cerebral arterioles - a response detectable as a fall in the MCA pulsatility index below the 5th centile for gestational age [10]. This 'brain-sparing' response is a compensatory adaptation, not a benign finding; it indicates that the fetus is under metabolic stress sufficient to activate cerebrovascular autoregulation [11].

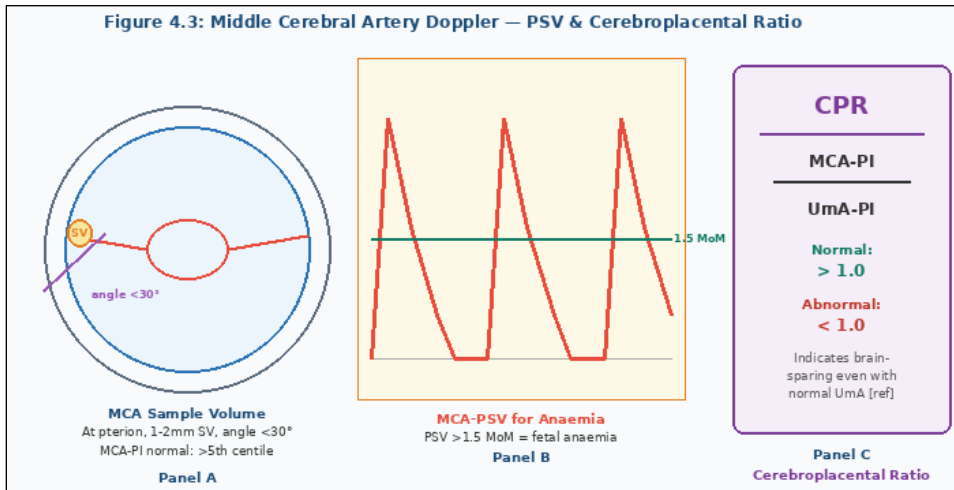


Figure 4.3: Middle cerebral artery Doppler. Panel A: Correct technique — sample volume placed 1-2 mm from the MCA origin at the pterion, with insonation angle <30 degrees to the vessel axis. Panel B: MCA peak systolic velocity (PSV) waveform for fetal anaemia surveillance; a PSV >1.5 multiples of the median (MoM) for gestational age has a sensitivity of >85% for moderate-to-severe fetal anaemia, replacing invasive amniocentesis for Rh-sensitised pregnancies [8]. Panel C: Cerebroplacental ratio (CPR) = MCA-PI / UmA-PI; CPR <1.0 indicates relative cerebral vasodilation relative to placental resistance, even when individual indices remain within normal limits.

Technique: MCA Doppler Measurement

Checklist — MCA Doppler: Technical Standards

- Plane: axial section of the fetal brain at the level of the sphenoid wing (pterion), with the Circle of Willis visible.
- Sample volume: 1-2 mm gate, placed within 1 cm of the MCA origin from the internal carotid artery.

Technique: MCA Doppler Measurement: Continued...

- Angle: <30 degrees (zero-angle preferred for absolute PSV measurement in anaemia surveillance).
- Fetal state: quiescent — fetal breathing and eye movements transiently reduce MCA-PI and raise PSV, creating false-positive results.
- Measure: PI for brain-sparing assessment. PSV (with angle correction) for anaemia surveillance [5,8].

The Cerebroplacental Ratio (CPR): The Most Sensitive Late-Onset FGR Marker

The cerebroplacental ratio ($CPR = MCA-PI / UaA-PI$) is the single most sensitive Doppler parameter for identifying late-onset FGR, where umbilical artery PI may remain within the normal range despite fetal compromise [12]. A $CPR < 1.0$, or <5th centile on gestation-specific nomograms, reflects relative cerebral vasodilation and peripheral vasoconstriction — the hallmark of the redistributed fetal circulation — even when individual MCA-PI and UaA-PI values are each within their respective normal ranges [13].

The PORTO study demonstrated that $CPR < 1.0$ in late-onset small-for-gestational-age fetuses independently predicted adverse perinatal outcome, including emergency caesarean for fetal compromise and neonatal acidosis, even when UaA-PI was normal [10]. This finding has fundamentally changed the management of late SGA/FGR, with most guidelines now recommending induction of labour at 37-38 weeks when $CPR < 1.0$ [14].

Clinical Pearl — CPR in Late FGR: The Hidden Compromise

- A fetus with EFW at the 9th centile and a normal UaA-PI but $CPR < 1.0$ at 36 weeks is a compromised fetus, not a constitutional small fetus.
- Calculate CPR at every Doppler assessment from 28 weeks onwards in all SGA fetuses — it provides information that UaA-PI alone cannot [2,10,19].
- $CPR < 1.0$ in a term SGA fetus: recommend induction of labour at 37-38 weeks rather than expectant management [2].

MCA-PSV for Fetal Anaemia: The Mari Criteria

In red-cell alloimmunisation (Rh disease, anti-Kell, anti-c), fetal haemolytic anaemia reduces blood viscosity, increasing cardiac output and raising MCA blood flow velocity — detectable as elevated peak systolic velocity (PSV) [15]. Mari and colleagues established that $MCA-PSV > 1.5$ multiples of the median (MoM) has a sensitivity of 88% and specificity of 82% for moderate-to-severe fetal anaemia ($Hb < 0.84$ MoM), effectively replacing serial amniocentesis for bilirubin assessment [16]. MCA-PSV should be measured fortnightly from 18 weeks in sensitised pregnancies, and the threshold for cordocentesis is confirmed $MCA-PSV > 1.5$ MoM on two consecutive measurements [17].

DUCTUS VENOSUS DOPPLER & ADVANCED VENOUS SURVEILLANCE

DV Waveform Physiology

The ductus venosus (DV) is a narrow vessel shunting oxygenated umbilical blood preferentially towards the fetal heart through the foramen ovale to the left atrium. Its Doppler waveform reflects right heart filling pressures: the S-wave (ventricular systole), D-wave (diastole), and a-wave (atrial contraction) are all normally forward (positive) [18]. As fetal cardiac function deteriorates under sustained placental insufficiency, right ventricular end-diastolic pressure rises and the a-wave diminishes, becomes absent, and finally reverses — progression that carries a sensitivity of approximately 80% for neonatal acidosis within 48-72 hours [19].

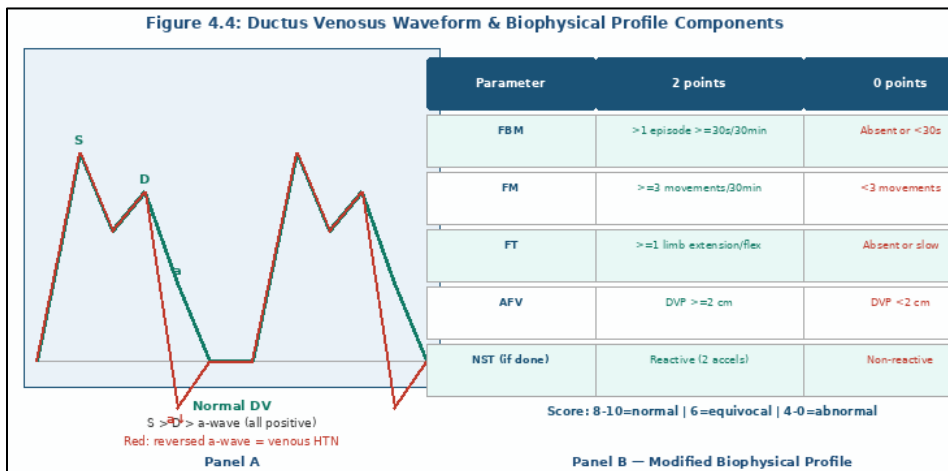


Figure 4.4: Ductus venosus waveform and biophysical profile. Panel A: Normal DV waveform (green) — S, D, and a-wave all positive; reversed a-wave (red overlay) indicating elevated venous pressure and impending fetal cardiac decompensation; these findings mandate delivery regardless of gestational age in most management algorithms [11,13]. Panel B: Modified biophysical profile (Manning 1987 criteria) — five components each scored 0 or 2; a score of 6 is equivocal (rescan within 24 hours), 4 or below is abnormal and warrants delivery consideration

Sequence of Doppler Deterioration in FGR

A landmark study by Baschat and colleagues mapped the temporal sequence of Doppler changes in severe FGR [20]. The sequence — from earliest to latest — is: (1) UmA-PI rises above 95th centile; (2) MCA-PI falls below 5th centile (brain-sparing); (3) AEDF on UmA; (4) REDF on UmA; (5) DV-PI rises above 95th centile; (6) Reversed DV a-wave; (7) Pulsatile umbilical vein (PIV). This sequence spans weeks in early FGR but may

compress to days or hours in acute deterioration. Simultaneous REDF and reversed DV a-wave is a pre-terminal finding [21].

Table 4.4: FGR staging and delivery timing based on integrated Doppler and biophysical assessment (adapted from Figueras & Gratacos 2014 and TRUFFLE). Stage IV constitutes an obstetric emergency

Stage	Doppler Criterion	Biophysical Finding	Timing to Delivery
I	UmA PI >95th centile	BPP 8/10; normal CTG	Expectant; deliver by 37 wk [2]
II	AEDF on UmA	BPP 6-8/10; reactive CTG	Deliver at 34 wk; earlier if DV worsens [11]
III	REDF on UmA; DV PI >95th centile	BPP 4-6/10; decelerations possible	Deliver at 30-32 wk; steroids urgently [2,11]
IV	Reversed DV a-wave or PIV	BPP ≤4/10; pathological CTG	Deliver NOW regardless of GA [11]

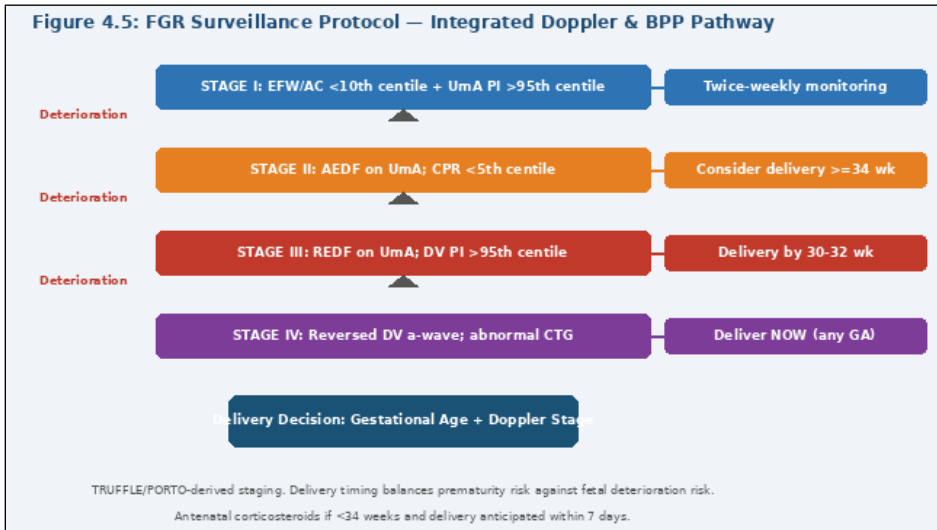


Figure 4.5: FGR surveillance protocol — integrated Doppler and biophysical pathway. Stages I-IV are defined by Doppler deterioration; delivery timing balances the risk of iatrogenic prematurity against fetal decompensation. Antenatal corticosteroids must be administered when delivery is anticipated before 34 weeks and there is sufficient time for effect (24-48 hours). Magnesium sulphate for neuroprotection is indicated before 32 weeks [2,11].

BIOPHYSICAL PROFILE (BPP) — INTEGRATING ACUTE AND CHRONIC FETAL STATUS

The Five Components and Their Scoring

The biophysical profile (BPP) integrates five parameters — four assessed on real-time ultrasound and one (the non-stress test, NST) on CTG — to produce a composite score reflecting both chronic (biometric, liquor) and acute (behavioural) fetal wellbeing [22]. Each parameter is scored 2 (normal) or 0 (abnormal); there are no intermediate scores.

Table 4.5: Biophysical profile components and scoring criteria (Manning 1987). FBM and NST are the most sensitive acute markers; fetal tone is the last to be lost. A score of 8-10 is normal; 6 is equivocal (repeat within 24 hours); 4 or below is abnormal and warrants delivery consideration [14,15].

Parameter	Normal (2 points)	Abnormal (0 points)	Physiological Basis
Fetal breathing movements (FBM)	≥1 episode of ≥30 s within 30 min [14]	Absent or <30 s total [14]	CNS respiratory centre integrity; hypoxia depresses FBM first [14]
Fetal movements (FM)	≥3 discrete body/limb movements in 30 min [14]	<3 movements in 30 min [14]	Motor cortex and spinal pathway integrity [14]
Fetal tone (FT)	≥1 episode of active extension/flexion of limb or trunk [14]	Absent or slow return to flexion [14]	Deepest CNS function; last to be lost in hypoxia [15]
Amniotic fluid volume (AFV)	Deepest vertical pool ≥2 cm [14]	DVP <2 cm [14]	Reflects renal perfusion; chronic hypoxia causes oligohydramnios [15]
Non-stress test (NST)	≥2 accelerations ≥15 bpm x 15 s in 20 min [30]	<2 accelerations in 40 min [30]	Autonomic nervous system integrity; acute hypoxia [30]

Modified BPP and Practical Application

The modified BPP — combining the NST (acute marker) with the amniotic fluid index or DVP (chronic marker) — has largely replaced the full BPP for routine surveillance because it is faster and has equivalent predictive accuracy [23]. A non-reactive NST in isolation should prompt full BPP assessment rather than immediate delivery, since fetal sleep cycles (lasting up to 40 minutes) can cause a temporarily non-reactive NST in a healthy fetus [24].

Clinical Pearl — Interpreting a Score of 6

- BPP of 6 is equivocal, not normal. It requires repeat assessment within 24 hours.
- If the repeat BPP remains 6, delivery should be considered — particularly if the AFV is reduced or the gestational age is term.
- BPP of 4 or below in a fetus >32 weeks: discuss delivery with the senior obstetrician within the same clinical session.

UTERINE ARTERY DOPPLER — PREECLAMPSIA AND FGR PREDICTION**Physiology of Uterine Artery Doppler**

Normal trophoblastic invasion of the spiral arteries by 22-24 weeks converts them from high-resistance muscular vessels into low-resistance conduits, obliterating their smooth muscle media [24,25,26]. This transformation is reflected sonographically in the uterine artery Doppler waveform: a normal second-trimester waveform shows a low-resistance pattern with absent or minimal early-diastolic notching and a PI well below the 95th centile [25].

Failure of trophoblastic invasion — the pathological basis of preeclampsia and placental FGR — results in persistently high-resistance uterine artery waveforms, characterised by a bilateral early-diastolic notch and elevated PI. The bilateral notch at 20-24 weeks has a positive likelihood ratio of approximately 7 for severe preeclampsia requiring delivery before 34 weeks [26].

First-Trimester Screening: 11-13 Weeks

Uterine artery Doppler at 11-13 weeks, combined with maternal factors (age, BMI, MAP, uterine artery PI) and placental growth factor (PIGF), forms the basis of the Fetal Medicine Foundation (FMF) first-trimester preeclampsia screening algorithm [27,28]. This algorithm achieves a detection rate of approximately 77% for preterm preeclampsia (<37 weeks) at a 10% false-positive rate — substantially superior to any single-factor screening approach. The screen-positive patient receives low-dose aspirin from 11-14 weeks, which reduces the risk of preterm preeclampsia by approximately 62% [28].

Second-Trimester Uterine Artery Doppler (20-24 Weeks)

Transvaginal (or transabdominal with appropriate technique) uterine artery Doppler at 20-24 weeks has a sensitivity of 40-50% for all preeclampsia and 60-70% for early-onset (< 34 weeks) preeclampsia. It is most useful as a risk-stratification tool: a bilateral notch or PI >95th centile at this gestation identifies a high-risk group warranting intensified surveillance (serial growth scans from 24 weeks, uterine artery re-assessment at 28-32 weeks) [29].

Table 4.6: Uterine artery Doppler at 20-24 weeks and clinical management. A bilateral notch is the strongest predictor for early-onset preeclampsia; its presence without aspirin already on board warrants an urgent discussion with the obstetric team about secondary prevention [25,26].

UtA Finding at 20-24 wk	Interpretation	Clinical Action
Bilateral PI <95th centile; no notch	Low risk of early-onset PE/FGR [25]	Routine care; no additional scans indicated [25]
Unilateral notch OR PI 95th-99th centile	Moderate risk [25]	Serial growth scans from 28 weeks; BP monitoring [25]
Bilateral notch AND PI >95th centile	High risk for early-onset PE (LR ~7) [26]	Growth scan every 4 weeks from 24 wk; aspirin if not already given; refer fetal medicine [25,26]

REPORTING TEMPLATES: FETAL GROWTH AND DOPPLER SURVEILLANCE

Growth and Doppler reports must communicate not only the measurements but their clinical interpretation and the recommended management step. A measurement without interpretation is a data point, not a clinical report [30].

Template A: Third-Trimester Growth Scan with Doppler

Field	Content
Clinical indication	Fetal growth assessment. GA: [X wk + Y d]. Previous growth scan: [date, EFW centile]. Indication: [SGA / FGR / maternal hypertension / previous IUGR / other].
Biometry	BPD [X] mm HC [X] mm AC [X] mm FL [X] mm. EFW (Hadlock): [X] g ([Xth] centile, [chart]). Interval growth from [date]: [+/- X g, equivalent to X g/week].
Umbilical artery Doppler	PI: [X] ([Xth] centile). S/D ratio: [X]. End-diastolic flow: [present / absent / reversed]. Waveform quality: [good / suboptimal — [reason]].
MCA Doppler	PI: [X] ([Xth] centile). PSV: [X] cm/s ([X] MoM [if anaemia surveillance]). Cerebroplacental ratio: [X] ([normal >1.0 / abnormal <1.0]).
DV Doppler (if Stage II+)	PI: [X] ([Xth] centile). a-wave: [positive / absent / reversed]. Waveform quality: [good].
Uterine artery Doppler (if requested)	Right UtA PI: [X] Left UtA PI: [X]. Notch: [present bilaterally / unilateral / absent]. Mean PI: [X] ([Xth] centile).
Amniotic fluid	DVP [X] cm / AFI [X] cm. [Normal / Oligohydramnios (DVP <2 cm) / Polyhydramnios (DVP >8 cm)].

Template A: Continued...	
FGR Stage	[No FGR — SGA only / Stage I / Stage II / Stage III / Stage IV] based on Delphi 2016 and ISUOG criteria [1,2].
Conclusion & Plan	EFW [X] g ([Xth] centile). UmA: [normal/abnormal]. CPR: [X] ([normal/abnormal]). FGR Stage [X]. Recommended: [repeat scan in X weeks / same-day obstetric review / in-patient admission / delivery discussion].

Template B: Fetal Anaemia Surveillance Report (MCA-PSV)

Field	Content
Indication	Maternal alloimmunisation: antibody [type], titre [X]. GA: [X wk + Y d]. Previous MCA-PSV: [date, value, MoM].
MCA-PSV	Right MCA: [X] cm/s at angle [X] degrees. Left MCA: [X] cm/s at angle [X] degrees. Higher value used: [X] cm/s. MoM for [X] wk: [X] MoM (median [X] cm/s from [reference chart]).
Interpretation	[<1.5 MoM: anaemia unlikely — continue fortnightly MCA-PSV / >1.5 MoM: moderate-to-severe anaemia cannot be excluded — discuss cordocentesis with fetal medicine].
Hydrops assessment	Scalp oedema: [absent/present]. Pleural effusion: [absent/present]. Ascites: [absent/present]. Pericardial effusion: [absent/present]. [No hydrops / Hydrops present — URGENT].

Key Takeaways
<ol style="list-style-type: none"> 1. SGA (EFW <10th centile) and FGR (SGA + Doppler or biometric evidence of placental dysfunction) are distinct entities requiring different management. Do not use 'SGA' and 'FGR' interchangeably in reports [1,2]. 2. The Delphi 2016 criteria define early (<32 wk) and late (≥32 wk) FGR separately — each has a different dominant Doppler parameter and a different surveillance algorithm [1]. 3. UmA Doppler is the primary surveillance parameter for early FGR; AEDF and REDF are clinical emergencies requiring same-day senior obstetric review and consideration of urgent delivery [2,11]. 4. CPR (<1.0) is the dominant parameter in late-onset FGR — it detects fetal compromise when UmA-PI is still within normal limits and is the primary trigger for induction of labour at 37-38 weeks [2,10,19]. 5. MCA-PSV >1.5 MoM is the non-invasive threshold for referral to cordocentesis in suspected fetal anaemia; always measure at zero angle of insonation and use a validated gestation-specific median chart [8].

Key Takeaways: Continued...

6. DV reversed a-wave indicates fetal cardiac decompensation; combined with REDF on UmA, it is a pre-terminal finding. Delivery is indicated regardless of gestational age [11,23].
7. The BPP score of 6 is equivocal — not normal. It requires repeat assessment within 24 hours; a persistent score of 6 in a term fetus warrants delivery discussion [14,15].
8. Bilateral uterine artery notching at 20-24 weeks with PI >95th centile carries a likelihood ratio of approximately 7 for severe early-onset preeclampsia — this is an actionable screening result requiring referral and intensified monitoring [25,26].
9. Always report the FGR stage explicitly in the conclusion of a growth/Doppler report. A measurement list without a clinical stage and recommended next step is an incomplete report [1,2].
EFW error is $\pm 15\%$ (Hadlock). A fetus at the 11th centile may be at the 5th centile or the 18th centile — serial measurements and growth velocity matter more than a single centile [7,30].

PLACENTA, CORD & AMNIOTIC FLUID

The placenta, umbilical cord, and amniotic fluid are not supporting actors in the obstetric ultrasound examination — they are the story. Placental position determines mode of delivery. Placental invasion depth determines whether a caesarean becomes a hysterectomy. Cord insertion variant determines whether labour is safe. Amniotic fluid volume reflects renal function, swallowing integrity, and the adequacy of uteroplacental transfer. No anomaly scan, growth scan, or third-trimester assessment is complete without a systematic evaluation of all three [1]. This chapter provides the classification systems, diagnostic criteria, ultrasound features, and structured reporting templates for placenta praevia, placenta accreta spectrum, cord abnormalities, vasa praevia, and amniotic fluid disorders [2].

PLACENTAL POSITION — NORMAL, LOW-LYING, AND PRAEVIA

Why Placental Position Matters

Placenta praevia — partial or complete covering of the internal cervical os by placental tissue — complicates 0.4-0.5% of pregnancies and is the leading cause of antepartum haemorrhage requiring emergency delivery [3]. The perinatal mortality associated with major praevia (covers the os) is approximately 0.8% in well-resourced settings, rising sharply when antenatal diagnosis is missed or delivery planning is inadequate [4]. Transvaginal ultrasound (TVS) is the gold standard for placental location assessment and is superior to transabdominal ultrasound in every trimester [5].

Classification System

Placenta praevia is classified by the relationship of the leading placental edge to the internal cervical os, measured on TVS [6]:

Table 5.1: Placenta praevia classification and mode of delivery guidance. The distance from the placental edge to the internal os is measured on transvaginal ultrasound. A distance of <20 mm at term is associated with an increased caesarean section rate [6,29]

Classification	TVS Distance to IOS	Mode of Delivery
Normal placentation	>20 mm from IOS [6]	Normal vaginal delivery [6]
Low-lying placenta	1-19.9 mm from IOS [1]	Vaginal delivery possible; individual assessment [6]
Marginal praevia	0 mm: edge at IOS [2]	Usually, caesarean section [2]
Major (complete) praevia	Placenta covers IOS [1,2]	Elective caesarean at 36-37 wk [2,13]

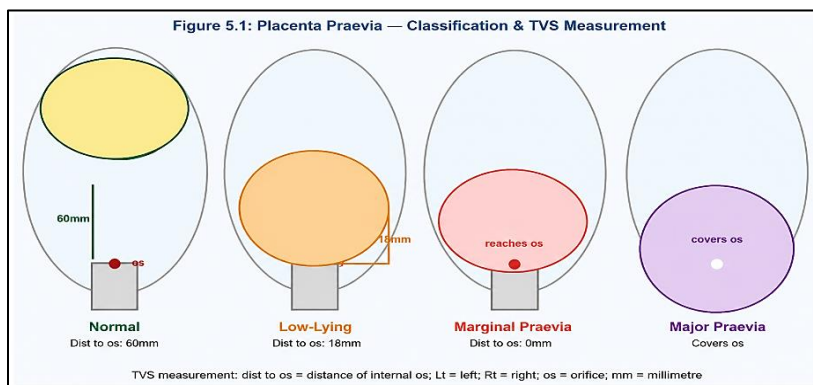


Figure 5.1: Placenta praevia classification on transvaginal ultrasound. The measurement is taken from the leading edge of the placenta to the centre of the internal os. Normal: >20 mm; Low-lying: 0.1-19.9 mm; Marginal praevia: placental edge reaches but does not cover the os (0 mm); Major praevia: placenta covers the os. The precise distance in millimetres must be stated in the report — qualitative descriptors alone are insufficient for surgical planning [2,6].

Timing of Placental Assessment

Approximately 90% of placentas that appear low-lying or praevia at the 18–22 week anomaly scan will migrate away from the os by 36 weeks due to differential growth of the lower uterine segment. Consequently, a low-lying or praevia placenta at the anomaly scan mandates a repeat TVS assessment — not at the next routine scan, but specifically targeted to placental position — at 32-34 weeks. Only if the repeat scan confirms persistent praevia should delivery planning, including anaesthetic review and crossmatch, be initiated [7].

Clinical Pearl — The Placental Migration Rule

- Anterior placentas migrate more reliably than posterior placentas because the anterior lower uterine segment expands preferentially in the third trimester.
- A posterior major praevia at 20 weeks has only a 40-50% chance of resolving by term, versus >90% for an anterior low-lying placenta [29].
- Always request TVS (not transabdominal) for third-trimester placental localisation — the full bladder, posterior position, and maternal habitus make TAS unreliable for the critical millimetre-range measurements [1,6].

Reporting Placental Position: Mandatory Elements

Checklist — Placenta Location Report: Six Required Elements

- Placental location: anterior / posterior / fundal / lateral — and which side if lateral.
- Relationship to internal os: exact distance in mm (or 'covers os by X mm') measured on TVS in sagittal plane.

Checklist: Continued...

- Lower uterine segment: any retroplacental hypoechoic zone or lacunae suggesting abnormal invasion.
- Cord insertion site: central / marginal / velamentous — document with colour Doppler if marginal.
- Timing of next scan: if low-lying or praevia, explicitly state 'repeat TVS placental localisation at 32-34 weeks'.
- Haemorrhage risk communication: if major praevia, document that findings have been communicated to the obstetric team [1,2,13].

PLACENTA ACCRETA SPECTRUM (PAS) — DIAGNOSIS AND ULTRASOUND FEATURES

Definition and Epidemiology

Placenta accreta spectrum (PAS) — encompassing accreta (villi contact the myometrium), increta (villi invade the myometrium), and percreta (villi penetrate the serosa or adjacent organs, most commonly the bladder) — complicates approximately 1 in 500 pregnancies overall but 1 in 10 pregnancies in women with a prior caesarean section and anterior placenta praevia [8]. Its incidence has risen in parallel with caesarean section rates worldwide, making it one of the fastest-growing causes of catastrophic obstetric haemorrhage [9]. Antepartum diagnosis by ultrasound is the single most important factor in reducing maternal mortality from PAS [10].

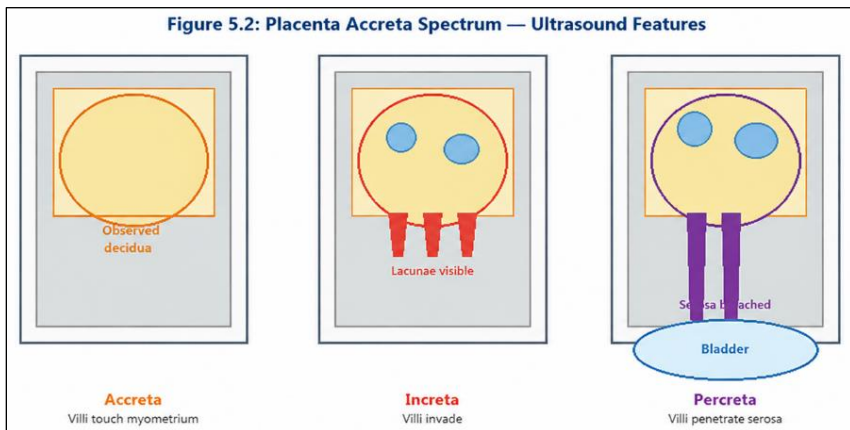


Figure 5.2: Placenta accreta spectrum — schematic cross-section of the uterine wall. Accreta: villi contact myometrium without invasion; the decidua basalis is absent but invasion stops at the outer myometrial boundary. Increta: villi invade through the myometrium; ultrasound lacunae (irregular sonolucent spaces within the placenta) are a key diagnostic feature. Percreta: villi breach the uterine serosa and may invade the bladder; loss of the posterior bladder wall echogenicity is a critical ultrasound sign.

Ultrasound Features of PAS

The European Working Group and ISUOG have standardised the ultrasound signs of PAS into primary signs (highly specific) and secondary signs (supportive) [11]. A diagnosis of PAS requires at least one primary sign, with secondary signs increasing confidence [12].

Table 5.2: Ultrasound signs of placenta accreta spectrum. Primary signs are the foundation of the diagnosis; secondary signs provide supporting evidence. No single sign is pathognomonic — diagnosis requires clinical context (prior uterine surgery + anterior praevia) plus imaging.

Sign	Description	Specificity / Notes
Placental lacunae (PRIMARY)	Multiple irregular sonolucent spaces within placenta, resembling 'Swiss cheese'; grade 1: 1-3 lacunae; grade 3: >6 irregular lacunae [4]	Grade 3 lacunae: sensitivity 79%, specificity 93% [4]
Loss of clear zone (PRIMARY)	Absent or irregular hypoechoic retroplacental zone between placenta and myometrium [4,5]	Sensitivity 57-93%; specific when combined with lacunae [4]
Bladder wall interruption (PRIMARY)	Loss of echogenic line of posterior bladder wall where placenta abuts; best seen on sagittal TVS [4,14]	Highly specific for percreta; mandates MRI [14,15]
Myometrial thinning	Myometrium <1 mm overlying placenta in lower segment [4]	Secondary sign; common in praevia even without PAS
Turbulent lacunar flow	High-velocity chaotic flow within lacunae on colour Doppler [5]	Secondary sign; increases diagnostic confidence [5]
Bridging vessels	Colour Doppler vessels crossing placenta-myometrium interface [5]	Secondary sign; correlates with increta/percreta [5]

Risk Stratification and the Role of MRI

The pre-test probability of PAS is dominated by two factors: prior uterine surgery (especially caesarean section) and anterior placenta praevia [13]. The risk of PAS in a woman with one prior caesarean and anterior praevia is approximately 11-25%; with three or more prior caesareans and anterior praevia, the risk approaches 50-67% [14]. When PAS is suspected on ultrasound in a patient with these risk factors, MRI is recommended as a complementary investigation for surgical planning - particularly to assess bladder invasion and parametrial extension - but it should not delay referral to a specialist PAS centre [15].

Medico-Legal Warning — Missed PAS Diagnosis

- A missed diagnosis of placenta accreta spectrum in a patient with anterior praevia and prior uterine surgery is the most preventable cause of massive obstetric haemorrhage.
- Any patient with placenta praevia over a uterine scar must have a targeted PAS assessment using the criteria above. Failure to document this assessment is a departure from the standard of care [2,5,13].

Medico-Legal Warning: Continued...

- If PAS is suspected, document the finding explicitly, communicate it immediately to the obstetric team, and arrange referral to a centre with a multidisciplinary PAS team (obstetrics, interventional radiology, haematology, urology) [5].

UMBILICAL CORD — NORMAL ANATOMY, INSERTION VARIANTS, AND PATHOLOGY

Normal Umbilical Cord Anatomy

The normal umbilical cord contains two umbilical arteries and one umbilical vein, embedded in Wharton's jelly and surrounded by a single layer of amnion [16]. The two arteries carry deoxygenated blood from the fetus to the placenta; the vein carries oxygenated blood from placenta to fetus. On colour Doppler transverse section, the two arteries are identified by their pulsatile arterial waveform; the single vein by its continuous venous flow. The normal umbilical cord measures 50-70 cm in length at term and has a helical coil pattern — the coiling index (number of coils per centimetre) normally averages 0.17-0.21 coils/cm [17]. Hypercoiling (>0.3 coils/cm) and hypocoiling (<0.1 coils/cm) are both associated with adverse perinatal outcomes [18].

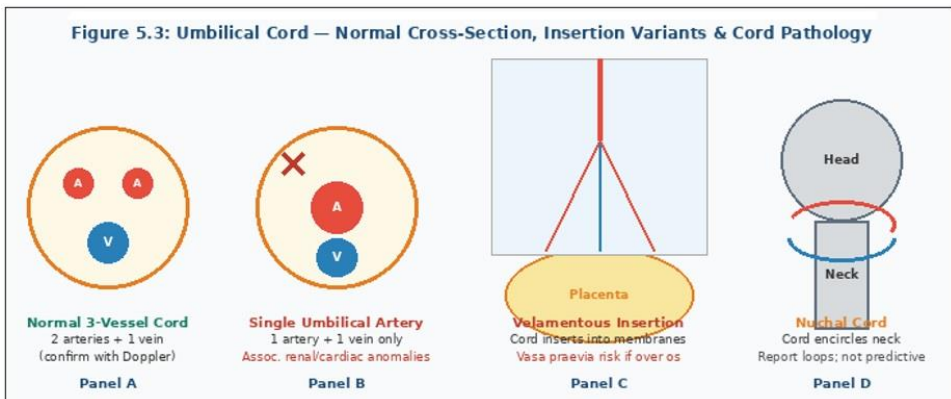


Figure 5.3: Umbilical cord anatomy and variants. Panel A: Normal three-vessel cord — two arteries (A, red) and one vein (V, blue) in Wharton's jelly; confirmed by colour Doppler transverse section. Panel B: Single umbilical artery (SUA) — one artery absent; associated with renal, cardiac, and chromosomal anomalies in 20-30% of cases. Panel C: Velamentous cord insertion — cord vessels fan out through the membranes before reaching the placental disc; the critical risk is vasa praevia if the unprotected vessels traverse the internal os. Panel D: Nuchal cord — cord encircles the fetal neck; document the number of loops but note that nuchal cord alone is not predictive of adverse outcome.

Single Umbilical Artery (SUA)

Single umbilical artery (SUA) affects approximately 0.5-1% of singleton pregnancies and 2.5-5% of twin pregnancies [16,25]. In isolation, SUA carries a low but non-negligible risk of associated anomalies: structural anomalies (particularly renal and cardiac) are found in approximately 20% of cases, and chromosomal abnormality in 5-10% [19]. The standard of care for an isolated SUA identified at the anomaly scan is a detailed anatomical survey with specific attention to the renal system and fetal heart, and consideration of fetal echocardiography [20].

Checklist — Isolated SUA: Minimum Required Assessment

- Confirm SUA with colour Doppler transverse section: only one pulsatile vessel (A) adjacent to the umbilical vein.
- Detailed renal survey: both kidneys, renal pelves, bladder — exclude renal agenesis, MCDK, VUR.
- Fetal heart: four-chamber + LVOT + RVOT + 3VT view — exclude structural CHD.
- Growth and liquor: normal liquor volume and normal EFW are reassuring.
- Consider fetal echocardiography at a specialist centre if any cardiac concern on screening views [25].
- Document: if no structural anomalies found, state 'isolated SUA — no additional anomalies identified; serial growth assessment recommended' [16].

Cord Insertion Variants

Normal cord insertion is central or paracentral, within the placental disc. Marginal insertion (the cord inserts within 2 cm of the placental edge) occurs in approximately 7% of placentas and is associated with growth restriction and preterm birth [21]. Velamentous insertion (the cord inserts into the fetal membranes, with unprotected vessels traversing the membranes before reaching the placental disc) occurs in 1-2% of singleton pregnancies and 5-10% of twin pregnancies [22]. The critical complication of velamentous insertion is vasa praevia when the unprotected membrane vessels traverse the internal cervical os [23].

VASA PRAEVIA — DIAGNOSIS, SIGNIFICANCE, AND MANAGEMENT

Why Vasa Praevia is a Sonographic Emergency

Vasa praevia occurs when fetal blood vessels - unprotected by Wharton's jelly or placental tissue - lie across the internal cervical os ahead of the fetal presenting part [24]. When membranes rupture (spontaneously or artificially), these vessels rupture simultaneously, causing rapid fetal exsanguination. The perinatal mortality of undiagnosed vasa praevia is 33-100%, depending on the speed of recognition; with prenatal diagnosis and planned caesarean delivery before membrane rupture, perinatal mortality falls to <3% [25]. This represents one of the most dramatic impacts of prenatal ultrasound diagnosis on perinatal outcome in all of obstetrics.

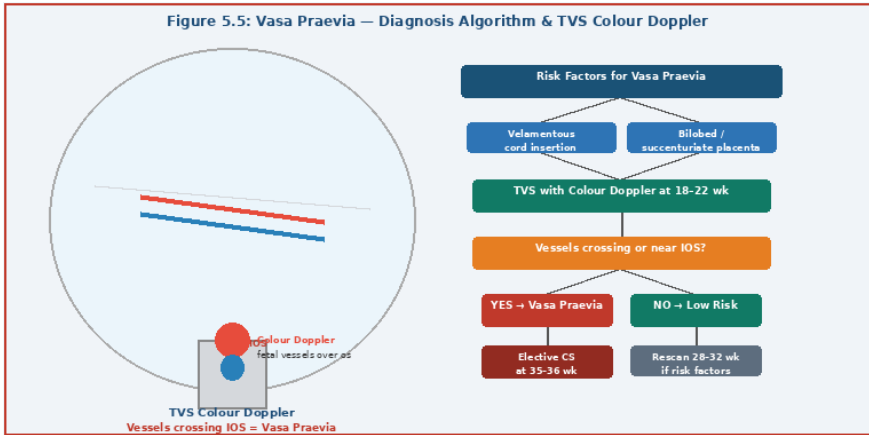


Figure 5.5: Vasa praevia — diagnosis algorithm and TVS colour Doppler. Left panel: transvaginal ultrasound showing colour Doppler signals of fetal blood vessels crossing the internal os ahead of the fetal presenting part — the pathognomonic sign of vasa praevia. Right panel: risk-stratified management algorithm. All high-risk patients (velamentous insertion, succenturiate/bilobed placenta, low-lying placenta at 18-22 weeks) require targeted TVS with colour Doppler at the internal os. Confirmed vasa praevia mandates elective caesarean section at 35-36 weeks with in-patient admission from 30-32 weeks [8,9,27].

Risk Factors and Screening Protocol

Vasa praevia is not a random event — it occurs almost exclusively in the presence of identifiable risk factors: velamentous cord insertion, bilobed or succenturiate-lobed placenta, low-lying placenta at the anomaly scan, and in-vitro fertilisation pregnancies (where the rate of velamentous insertion is 3-4 times background) [26]. A targeted colour Doppler TVS examination of the internal os at 18-22 weeks in all patients with these risk factors would identify the majority of cases — a policy shown to be cost-effective by formal economic modelling [27].

Clinical Pearl — Vasa Praevia Screening Protocol

- At the anomaly scan: always document cord insertion site (central/marginal/velamentous) with colour Doppler.
- If velamentous insertion is identified OR placenta is low-lying: perform targeted TVS colour Doppler of the internal os at the same visit.
- If colour Doppler shows pulsatile vessels crossing the IOS with a fetal heart rate pattern: this is vasa praevia until proven otherwise. Do not dismiss as maternal vessels — use spectral Doppler to confirm fetal heart rate.
- In IVF pregnancies: specifically, document cord insertion site at the 18-22-week scan; the rate of velamentous insertion is 3-fold higher than background [8,10,26].

Distinguishing Vasa Praevia from Maternal Vessels

The critical technical step is confirming that the colour Doppler signal over the internal os represents fetal (not maternal) vessels. This is achieved by placing pulsed-wave spectral Doppler over the vessel and confirming that the waveform rate matches the fetal heart rate (120-160 bpm), not the maternal pulse (60-100 bpm) [8,9]. The waveform morphology will be arterial (pulsatile) or venous (continuous) depending on which vessel is sampled. A pulsatile waveform at fetal heart rate is the definitive diagnosis of fetal artery — vasa praevia confirmed [9].

AMNIOTIC FLUID — VOLUME ASSESSMENT AND CLINICAL SIGNIFICANCE

Physiology of Amniotic Fluid

Amniotic fluid is produced primarily by fetal urine from approximately 16 weeks onwards, with additional contributions from pulmonary fluid secretion and transudation across the fetal skin (until keratinisation at approximately 22-24 weeks) [27]. It is resorbed principally by fetal swallowing (500-1000 mL/day at term) and intramembranous absorption. Normal volume at 34-36 weeks is approximately 800-1000 mL. Two clinical abnormalities — oligohydramnios (too little) and polyhydramnios (too much) — reflect disruption of this production-resorption balance and carry distinct differential diagnoses and clinical consequences [28].

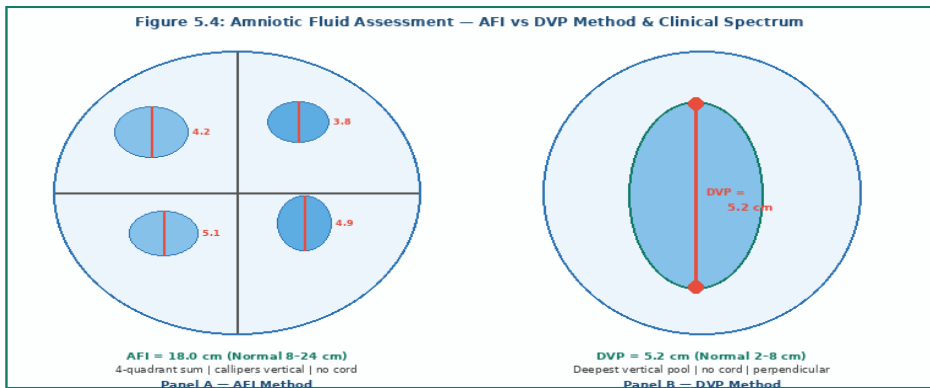


Figure 5.4: Amniotic fluid assessment methods. Panel A: Amniotic fluid index (AFI) — the uterus is divided into four quadrants by the umbilicus (horizontal) and linea nigra (vertical); the deepest vertical pool in each quadrant is measured with the transducer perpendicular to the floor, without cord or fetal parts in the column; the four values are summed. Normal AFI: 8-24 cm. Panel B: Deepest vertical pocket (DVP) — the single largest pocket is measured vertically; the pocket must be ≥ 1 cm in horizontal width. Normal DVP: 2-8 cm. Current evidence favours DVP as the method less likely to lead to unnecessary intervention [19].

AFI versus DVP: Which Method to Use

The Cochrane systematic review by Nabhan and Abdelmoula (2008) examined randomised trials comparing AFI and DVP as the standard for amniotic fluid assessment. The review found that AFI diagnosed oligohydramnios more frequently than DVP (LR 2.4), leading to a significantly higher rate of labour induction and operative delivery without improvement in perinatal outcomes [19]. Current ISUOG and ACOG guidance therefore recommends DVP as the preferred method for routine amniotic fluid assessment, reserving AFI for centres where longitudinal serial measurements with consistent technique are established [29].

Table 5.3: Amniotic fluid volume thresholds and clinical implications. DVP is the preferred method; AFI over-diagnoses oligohydramnios by approximately 2.4-fold compared with DVP, leading to unnecessary intervention [19]. Measurements should be taken perpendicular to the floor with no cord or fetal parts in the column [18,20].

Parameter	AFI Threshold	DVP Threshold	Clinical Implication
Normal	8-24 cm [17]	2-8 cm [18]	Routine surveillance [17,18]
Borderline low	5-7.9 cm [20]	2.1-2.9 cm [18]	Increased surveillance; review fetal wellbeing [18]
Oligohydramnios	<5 cm [20]	<2 cm [18]	Detailed fetal survey; UmA Doppler; consider delivery [18,23]
Polyhydramnios — mild	25-29.9 cm [21]	8-11.9 cm [21]	Detailed anatomy (GI/swallowing anomalies); GDM screen [21]
Polyhydramnios — severe	≥30 cm [21]	≥12 cm [21]	~50% associated with structural anomaly; karyotype discussion [21]

Oligohydramnios — Differential Diagnosis and Management

Oligohydramnios (DVP <2 cm or AFI <5 cm) has a differential diagnosis broadly categorised by mechanism: reduced fetal urine production, obstructed urinary outflow, chronic membrane rupture, or uteroplacental insufficiency. The most immediately life-threatening cause is bilateral renal agenesis (Potter sequence), in which anhydramnios develops from approximately 16 weeks and is uniformly lethal [30]. The most common cause in the third trimester is pre-labour rupture of membranes (PROM) — diagnosed clinically, not by ultrasound alone.

Table 5.4: Differential diagnosis of oligohydramnios by mechanism. Systematic interrogation of the fetal urinary tract — both kidneys (size, echogenicity, cysts), renal pelvises, bladder filling, and urethra — is mandatory in any case of oligohydramnios without an obvious explanation [16,18].

Mechanism	Differential Diagnosis	Sonographic Clues
Reduced urine output	Bilateral renal agenesis, bilateral MCDK, posterior urethral valves (PUV), bilateral PUJO [16]	Non-visualisation of kidneys/bladder; dilated posterior urethra (PUV) [16]
Placental insufficiency	FGR, post-dates, severe IUGR [12]	EFW <10th centile; abnormal UmA Doppler [12]
Membrane rupture	PROM, iatrogenic (amniocentesis) [16]	No structural fetal abnormality; normal kidneys [16]
Uteroplacental	Pre-eclampsia, maternal medications (NSAIDs, ACEi) [16]	Maternal history critical; check uterine artery Doppler

Polyhydramnios — Causes and Investigation

Polyhydramnios (DVP >8 cm or AFI >24 cm) affects approximately 1-2% of pregnancies and is associated with a structural anomaly in approximately 20% of mild and 50% of severe cases. The most important anomaly to exclude is oesophageal atresia — presenting with absent or persistently small stomach bubble and mild-to-moderate polyhydramnios from 20-22 weeks [31]. Other important causes include duodenal atresia (the 'double bubble' sign), diaphragmatic hernia with mediastinal shift, and any anomaly impairing fetal swallowing (neuromuscular, skeletal dysplasia, cleft palate) [32]. Gestational diabetes mellitus (GDM) is the most common maternal cause and must be excluded by glucose tolerance testing in all cases of unexplained polyhydramnios.

Checklist — Polyhydramnios Investigation Protocol

- Measure DVP precisely and grade severity (mild 8-11.9 cm; moderate 12-15.9 cm; severe ≥ 16 cm).
- Detailed fetal anatomy with specific attention to: stomach (present? fills normally?), duodenum (double bubble?), oesophagus, diaphragm, fetal swallowing movements.
- Fetal neuromuscular assessment: tone, breathing movements, facial movements.
- Maternal investigations: fasting glucose / OGTT; maternal blood group and antibodies.
- If structural anomaly found: offer chromosomal analysis (15-30% aneuploidy rate with structural anomaly + polyhydramnios) [21].
- If no cause found: label 'idiopathic polyhydramnios' (40-60% of cases) and arrange serial growth and liquor assessment every 4 weeks [21].

REPORTING TEMPLATES: PLACENTA, CORD AND AMNIOTIC FLUID

Template A: Placenta Assessment — Third-Trimester Localisation Scan

Field	Content
Clinical indication	Placental localisation follow-up. GA: [X wk + Y d]. Previous low-lying placenta at [date] scan.
Technique	Transvaginal ultrasound (TVS) — empty bladder. Sagittal plane through cervix and lower uterine segment.
Placental location	[Anterior / posterior / fundal / lateral]. Lower segment: [yes / no].
Distance to IOS	[X] mm from leading placental edge to centre of internal os on TVS. [Normal (>20 mm) / Low-lying (1-19.9 mm) / Marginal (0 mm, reaches os) / Major praevia (covers os)].
PAS features	[No lacunae / Grade 1-3 lacunae]. Retroplacental clear zone: [present / absent]. Bladder wall: [intact / interruption noted — describe]. Bridging vessels on colour Doppler: [absent / present].
Cord insertion	[Central / marginal (X mm from edge) / velamentous]. Colour Doppler at IOS: [no vessels over IOS / fetal vessels noted over IOS — see vasa praevia assessment].
Cervical length	[X] mm on TVS. [Normal (>=25 mm) / Short (<25 mm) / Funneling: present/absent].
Conclusion	[Normal placental location — no further localisation scan required / Low-lying — repeat TVS at X weeks / Major praevia confirmed — obstetric team informed; delivery planning required / PAS features present — refer to specialist centre].

Template B: PAS Assessment Report

Field	Content
Risk factors	Prior caesarean sections: [X]. Placenta praevia: [yes/no]. Anterior placenta: [yes/no]. Prior uterine surgery: [specify].
Primary PAS signs	Lacunae: [absent / grade 1 (1-3) / grade 2 (4-6) / grade 3 (>6)]. Clear zone: [present / absent / interrupted]. Bladder wall: [intact / defect at X location].
Secondary PAS signs	Bridging vessels: [absent / present — location]. Turbulent lacunar flow: [absent / present]. Myometrial thickness: [X] mm.
Doppler	Colour Doppler of lower uterine segment: [no bridging vessels / bridging vessels present]. Spectral Doppler: [high-velocity, low-resistance flow within lacunae: yes/no].
Overall assessment	[PAS unlikely / PAS possible (low confidence) / PAS probable (moderate confidence — 1 primary sign) / PAS highly likely (high confidence — 2+ primary signs or primary + secondary signs)].
Recommendation	[Routine follow-up / MRI recommended / Urgent referral to specialist PAS multidisciplinary centre / Obstetric team informed today — details on file].

Template C: Amniotic Fluid Assessment

Field	Content
Method used	[DVP / AFI]. Technique: [transducer perpendicular to floor, no cord/fetal parts in column, largest pocket in mm].
DVP measurement	[X.X] cm. Classification: [normal 2-8 cm / oligohydramnios <2 cm / polyhydramnios >8 cm].
AFI measurement (if used)	RUQ [X] cm + LUQ [X] cm + RLQ [X] cm + LLQ [X] cm = [X] cm total. Classification: [normal 8-24 cm].
If oligohydramnios	Fetal kidneys: [bilateral/unilateral/absent]. Bladder: [present and filling / absent]. Urethra: [normal / dilated posterior urethra]. Membranes: [intact / clinical PROM?]. UMa Doppler: [see Doppler section].
If polyhydramnios	Fetal stomach: [present / absent / small at X mm]. Bowel: [double bubble present / absent]. Diaphragm: [intact]. Swallowing movements: [observed / not observed]. Maternal glucose history: [normal / GDM / not tested].
Conclusion	[Normal amniotic fluid volume / Oligohydramnios — cause: [suspected cause] — recommended action / Polyhydramnios — cause: [suspected cause] — recommended action].

Key Takeaways

1. Placental position must be measured in millimetres from the leading edge to the internal os on TVS — qualitative descriptions ('low-lying', 'praevia') without a measurement are incomplete and insufficient for clinical decision-making [1,2,6].
2. Ninety percent of low-lying placentas at 18-22 weeks resolve by term; a targeted repeat TVS at 32-34 weeks is mandatory before deciding on mode of delivery. Never plan caesarean section based on a mid-trimester placental location alone [29].
3. Placenta accreta spectrum requires a targeted assessment in any patient with anterior praevia and prior uterine surgery. The most specific primary signs are grade 3 lacunae and bladder wall interruption; together they carry specificity >90% [4,5].
4. A missed PAS diagnosis in a high-risk patient is a preventable catastrophe. Document the PAS assessment explicitly in every report for patients with praevia over a scar, and communicate immediately to the obstetric team if PAS features are present [2,5,13].
5. Single umbilical artery requires a detailed renal and cardiac survey; structural anomalies are found in approximately 20% of cases. Isolated SUA without anomalies warrants serial growth assessment [16,25].

Key Takeaways: Continued...

6. Velamentous cord insertion mandates targeted TVS colour Doppler assessment of the internal os at the 18-22 week scan to exclude vasa praevia — the single condition where prenatal diagnosis reduces perinatal mortality from >50% to <3% [8,27].
7. Always confirm suspected vasa praevia by spectral Doppler: the waveform must match the fetal heart rate, not the maternal pulse. This one step prevents both false-positive and false-negative diagnoses [9].
8. DVP is the preferred amniotic fluid method: the Cochrane review confirmed that AFI over-diagnoses oligohydramnios 2.4-fold compared with DVP, leading to unnecessary inductions without perinatal benefit [19].
9. Polyhydramnios $\geq 50\%$ of the time in severe cases is associated with a structural anomaly — always perform a detailed anatomy survey, specifically targeting the GI tract and swallowing mechanism [21].
10. Oligohydramnios without ruptured membranes mandates a systematic evaluation of both fetal kidneys and the entire urinary tract; bilateral renal agenesis and posterior urethral valves are the two diagnoses that must not be missed [16,18].

MULTIPLE PREGNANCY

Multiple pregnancy is the highest-risk category in obstetric ultrasound — not because twins are always complicated, but because the complications that do occur are unique, rapidly progressive, and entirely preventable only through vigilant sonographic surveillance. The clinician who does not determine chorionicity at 11-14 weeks, who confuses a T-sign with a lambda sign, or who fails to recognise early twin-to-twin transfusion syndrome (TTTS) on a growth scan, sets in motion a chain of events that can result in the death or neurological injury of one or both fetuses. This chapter covers the ultrasound-based classification of multiple pregnancy, the diagnosis and staging of TTTS, selective fetal growth restriction (sFGR), monoamniotic complications, and the reporting standards that make management decisions possible [1].

CHORIONICITY AND AMNIONICITY — DETERMINATION AND CLINICAL SIGNIFICANCE

Why Chorionicity is the Single Most Important Fact in Twin Pregnancy

Monochorionic (MC) twins share a single placenta and are always connected by vascular anastomoses. This shared circulation is the biological basis for TTTS, selective FGR, twin anaemia-polycythaemia sequence (TAPS), and the neurological injury that follows single-twin death [2,3]. The perinatal mortality of monochorionic diamniotic (MCDA) twins is 3-5 times that of dichorionic diamniotic (DCDA) twins, even when structural anomalies are excluded [3,9]. Yet monochorionic and dichorionic pregnancies are externally identical — they can only be distinguished by ultrasound, and the optimal window is 11-14 weeks [4].

After 14 weeks, membrane thickness and insertion morphology become progressively less reliable discriminators as the membrane thins and the lambda sign involutes. After 20 weeks, chorionicity determination may be impossible in same-sex twins without a clear lambda sign, and same-sex DCDA twins may be misclassified as MCDA — with potentially catastrophic consequences for surveillance planning [5].

Medico-Legal Warning — Chorionicity Must be Determined at 11-14 Weeks
<ul style="list-style-type: none">Failure to determine chorionicity at the first-trimester scan, or failure to document the method used, is a departure from the standard of care in twin pregnancy management [1,23].A twin pregnancy referred for the first time at 20 weeks without chorionicity documentation requires urgent specialist assessment. Do not assume DCDA in a same-sex twin pregnancy — the consequences of missing MCDA are life-threatening [1,3].

How to Determine Chorionicity: The T-Sign vs Lambda Sign

Chorionicity is determined at 11-14 weeks by examining the membrane insertion at the chorionic surface of the placenta [6]. Two morphological signs are used:

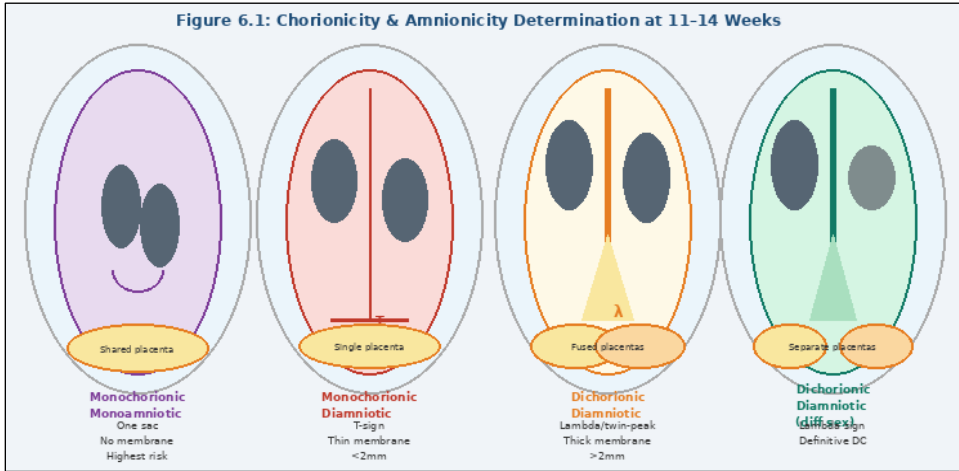


Figure 6.1: Chorionicity and amnionicity determination at 11-14 weeks. MCMA (monochorionic monoamniotic): single sac, no dividing membrane, single placenta — highest risk category. MCDA (monochorionic diamniotic): T-sign at membrane insertion (membrane meets the placental surface at a right angle without a placental wedge); thin membrane (<2 mm). DCDA same-sex: lambda (twin-peak) sign — a wedge of placental tissue projects into the base of the inter-twin membrane; thick membrane (>2 mm). DCDA different sex: definitive evidence of dichorionic pregnancy regardless of membrane morphology [1,14].

Table 6.1: Chorionicity and amnionicity features at 11-14 weeks. The lambda sign has a sensitivity of 97% and specificity of 99% for dichorionic pregnancy at 10-14 weeks; after 20 weeks sensitivity falls to <75% [1,14]

Feature	MCMA	MCDA	DCDA	References
Chorion count	1 chorion	1 chorion	2 chorions	[1,14]
Amnion count	1 amnion	2 amnions	2 amnions	[1]
Membrane at 11-14 wk.	No membrane visible	T-sign: thin, right-angle insertion	Lambda: thick, placental wedge at base	[1,14]
Membrane thickness	N/A	<2 mm (2 layers)	>2 mm (4 layers)	[1]
Placenta(s)	1 placenta	1 placenta	2 separate or fused placentas	[2]
Perinatal mortality	Highest (~9%)	~3-5x singleton [3]	~1.5-2x singleton [9]	[3,9]

SCAN SCHEDULE FOR MULTIPLE PREGNANCY

Surveillance intensity is dictated by chorionicity. ISUOG and NICE guidelines mandate different scan frequencies for MCDA and DCDA twins because the risk and speed of onset of MC complications requires fortnightly detection capability from 16 weeks onwards [7]:

Table 6.2: Recommended surveillance schedule for multiple pregnancy by chorionicity. MCDA twins require fortnightly scanning from 16 weeks to detect TTTS before Stage III develops; at Stage III, neurological injury is already occurring [1,4,23].

Gestational Age	DCDA Twins	MCDA Twins	MCMA Twins
11-14 wk	Chorionicity, NT, anomaly screen [1]	Chorionicity, NT, NT discordance [1,17]	Chorionicity, cord entanglement screen [1]
16 wk onwards	No routine scans until 20 wk [23]	Fortnightly DVP + bladder + UmA Doppler from 16 wk [1,23]	Fortnightly from 16 wk + cord Doppler [1,23]
18-22 wk	Anatomy survey; biometry [1]	Anatomy survey; biometry; TTTS screen [1]	Anatomy + cord entanglement assessment [1]
24-36 wk	Growth scans every 4 wk [23]	Fortnightly growth + Doppler throughout [1,23]	Weekly or more frequent inpatient from 28-30 wk [23]
Delivery	38 wk elective (DCDA) [23]	36-37 wk elective (MCDA) [23]	32-34 wk elective (MCMA) [23]

TWIN-TO-TWIN TRANSFUSION SYNDROME (TTTS) — DIAGNOSIS AND STAGING

Pathophysiology

TTTS occurs in approximately 10-15% of MCDA pregnancies and is caused by net unidirectional blood transfer through arteriovenous (AV) anastomoses from the donor to the recipient twin. The donor becomes hypovolaemic, oliguric, and growth-restricted; the recipient becomes hypervolaemic, polyuric, and at risk of cardiac failure and hydrops [8]. Without treatment, Stage II-IV TTTS has a perinatal mortality of approximately 80-100%; with fetoscopic laser ablation of placental anastomoses, survival of at least one twin approaches 85-90% [9].

The mechanism is not simply a transfusion — it is a hormonal and haemodynamic dysregulation cascade. Renin-angiotensin axis activation in the donor (due to hypovolaemia) and natriuretic peptide release in the recipient (due to volume overload) amplify the imbalance [10]. Understanding this explains why Stage I TTTS (DVP discordance without bladder absence) may resolve spontaneously in 20-25% of cases, while Stage III (Doppler abnormalities) has a much lower rate of spontaneous resolution [11].

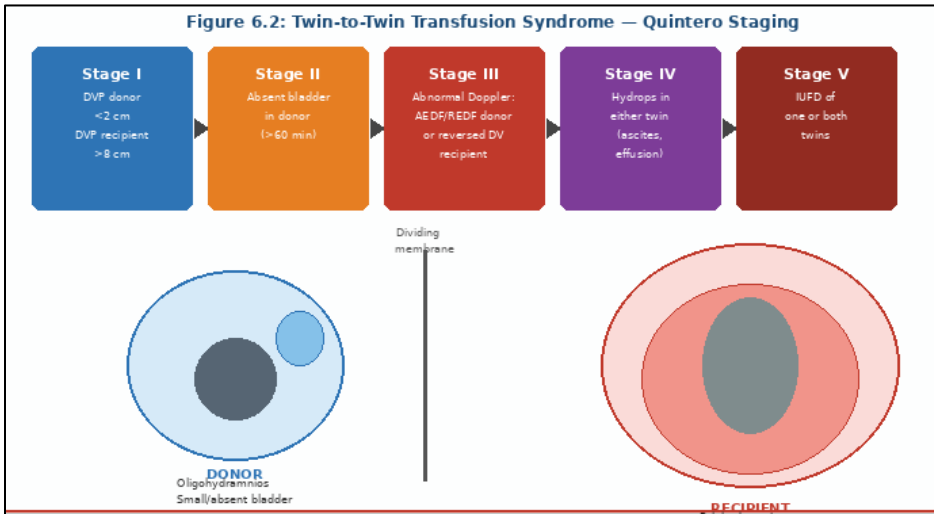


Figure 6.2: Twin-to-twin transfusion syndrome — Quintero staging diagram. The donor twin (left) develops oligohydramnios, absent bladder, and progressive Doppler abnormalities. The recipient twin (right) develops polyhydramnios and a distended bladder, progressing to hydrops. Staging is sequential (I through V) but progression can be rapid — Stage I to Stage IV within days is documented. A baseline scan and a repeat scan 1 week later is the minimum safe surveillance interval for known TTTS [4,11].

QUINTERO STAGING SYSTEM

The Quintero staging system classifies TTTS by the sequence of clinical deterioration and has been the standard since 1999, guiding both prognosis communication and treatment decisions [12]:

Table 6.3: Quintero staging system for TTTS. Staging directs treatment: Stage I may be managed expectantly with close surveillance; Stages II-IV are indications for fetoscopic laser photocoagulation at a specialist centre before 26 weeks, or for delivery if beyond 26 weeks [5,11,23].

Stage	Diagnostic Criterion	Clinical Features	Spontaneous Resolution	Refs
I	DVP donor <2 cm; DVP recipient >8 cm [4]	Bladder visible in donor; no Doppler abnormality	20-25% [8,11]	[4,8]
II	Stage I + absent bladder in donor on scan >60 min [4]	Donor severely oliguric; renal perfusion critically reduced	<5% [11]	[4,11]

Table 6.3 Continued...

III	Stage II + abnormal Doppler (AEDF/REDF UmA donor; reversed DV recipient) [4]	Cardiovascular compromise in one or both twins	Rare [11]	[4,5]
IV	Stage III + hydrops in either twin [4]	Ascites, pleural/pericardial effusion, skin oedema	None [4,5]	[4,5]
V	Intrauterine death of one or both twins [4]	Surviving co-twin at high risk of neurological injury [10,25]	N/A	[4,10]

DIAGNOSTIC CRITERIA: WHAT TO MEASURE AT EVERY MCDA SCAN**Checklist — MCDA Surveillance Scan: TTTS Assessment Protocol**

- DVP in each sac: measure largest vertical pocket perpendicular to floor, no cord, ≥ 1 cm horizontal width. Donor DVP < 2 cm = oligohydramnios; Recipient DVP > 8 cm = polyhydramnios.
- Bladder visibility in donor: if DVP < 2 cm, watch for ≥ 60 minutes for bladder filling. Document 'bladder visible' or 'bladder not visualised after 60 min of observation'.
- Umbilical artery Doppler of donor: PI, presence of end-diastolic flow (normal / AEDF / REDF).
- Ductus venosus Doppler of recipient: PI, a-wave (positive / absent / reversed).
- Bladder in recipient: distended bladder is Stage I+ in recipient; not a criterion but documents the sequence.
- Signs of cardiac dysfunction in recipient: TR on colour Doppler, myocardial hypertrophy, pericardial effusion [12].
- Hydrops screen in both twins: ascites, pleural effusion, pericardial effusion, skin oedema [4,11].

Clinical Pearl — The Stage I Dilemma: Watch or Treat?

- Stage I TTTS resolves spontaneously in approximately 20-25% of cases but progresses to Stage II-IV in approximately 25-30% [8,11].
- ISUOG and international consensus recommend expectant management with weekly surveillance for Stage I before 26 weeks, with immediate laser referral if staging progresses [1,11].
- Document clearly: the Quintero stage at each visit, the date, the DVP measurements, and the bladder observation time. A stage change without documentation may appear as 'missed TTTS' in retrospect [1,23].

SELECTIVE FETAL GROWTH RESTRICTION (SFGR) IN MONOCHORIONIC TWINS

Definition and Classification

Selective FGR (sFGR) in monochorionic twins is defined as EFW discordance of $\geq 25\%$ between the twins, with the smaller twin having EFW < 10 th centile for gestational age, in the absence of TTTS (i.e., no polyhydramnios in the larger twin's sac) [6,7]. It is classified by the umbilical artery Doppler of the smaller twin into three prognostically distinct types, as the vascular anastomoses in the monochorionic placenta create haemodynamic patterns not seen in singleton FGR [13]:

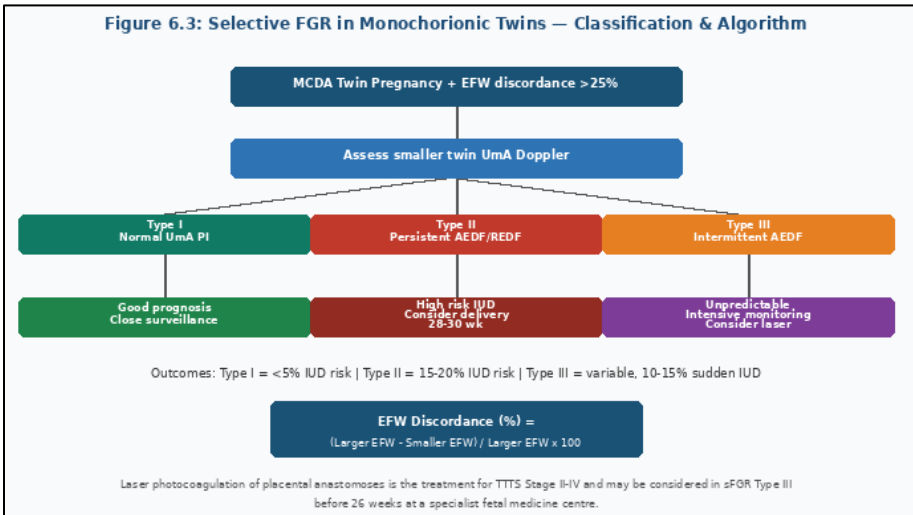


Figure 6.3: Selective FGR in monochorionic twins — classification by umbilical artery Doppler and management algorithm. EFW discordance is calculated as (larger EFW - smaller EFW) / larger EFW $\times 100$. Type I (normal UmA PI in smaller twin) carries a good prognosis; Type II (persistent AEDF/REDF) carries 15-20% IUD risk and usually requires delivery at 28-30 weeks; Type III (intermittent AEDF) is characterised by unpredictable sudden fetal deterioration due to large arterio-arterial anastomoses and requires intensive monitoring [6,7].

Table 6.4: Selective FGR classification in monochorionic twins (Gratacos 2007). Type III is uniquely dangerous because the intermittent AEDF reflects the haemodynamic influence of a large arterio-arterial anastomosis that can cause sudden haemodynamic collapse in the smaller twin, followed by acute TTTS in the survivor [6,27].

Type	UmA Doppler Pattern	Underlying Mechanism	IUD Risk
I	Normal PI in smaller twin [6]	Unequal placental sharing but adequate compensatory anastomoses [6,18]	<5%; good prognosis [6]
II	Persistent AEDF or REDF in smaller twin [6]	Severe unequal sharing, small anastomoses; mirrors singleton FGR [19]	15-20% [6]
III	Intermittent AEDF in smaller twin [6]	Large AA anastomosis bidirectional flow; haemodynamically unstable [6,27]	10-15% sudden IUD [6]

EFW Discordance Measurement

EFW discordance is calculated as: $(\text{larger EFW} - \text{smaller EFW}) / \text{larger EFW} \times 100\%$. A discordance of 25% is the clinically significant threshold in monochorionic twins; in dichorionic twins the threshold is also 25% but the management implications differ because there are no anastomoses to create the Type III pattern [14]. EFW discordance must be reported at every growth scan in multiple pregnancy — not just when it exceeds the threshold, so that the trend is visible [15].

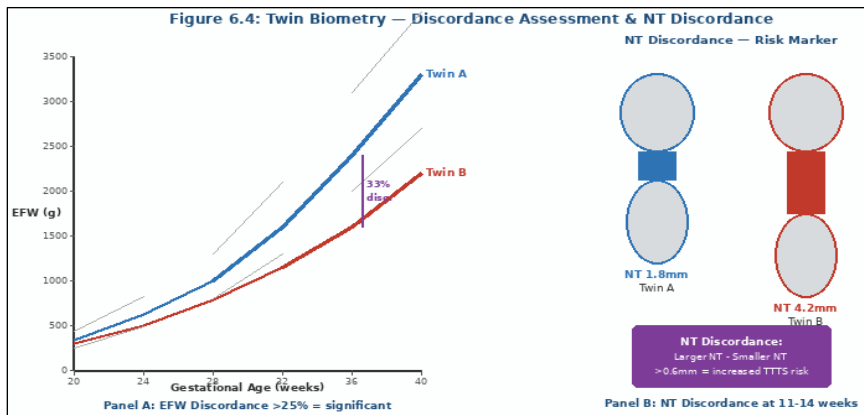


Figure 6.4: Panel A: EFW growth curves for discordant twins plotted against gestational age. Twin A (blue) tracks on the 50th centile while Twin B (red) falls below the 10th centile by 28 weeks; the discordance at 36 weeks exceeds 33%, well above the 25% threshold. Panel B: nuchal translucency (NT) discordance at 11-14 weeks — NT difference >0.6 mm between MCDA twins is associated with a significantly elevated risk of subsequent TTTS; this should prompt closer surveillance and early referral discussion [17].

MONOAMNIOTIC TWINS AND TRAP SEQUENCE

Monoamniotic Twins: The Highest-Risk Category

Monochorionic monoamniotic (MCMA) twins share both placenta and amniotic cavity, resulting in the inevitable entanglement of their umbilical cords from very early in pregnancy [16]. Cord entanglement is pathognomonic of MCMA twins and is present in virtually all cases; it does not in itself cause fetal demise, but when combined with cord compression or true cord knots, it is the mechanism of the 15-20% perinatal mortality specific to this diagnosis [17].

The diagnosis of MCMA is made at 11-14 weeks by the absence of an inter-twin membrane on TVS, with both twins moving freely within a single amniotic cavity and a single placental mass [18]. Colour Doppler demonstrating cord entanglement — 'colour chaos' at a point where the two cords cross — confirms the diagnosis [19].

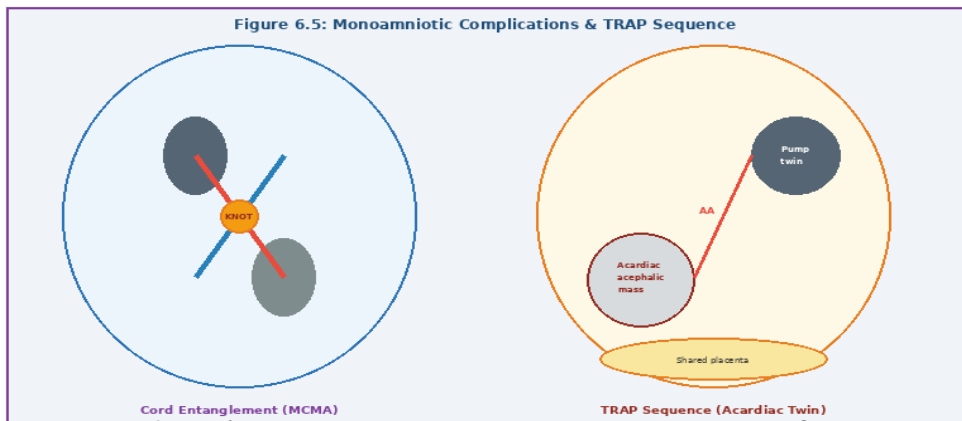


Figure 6.5: Monoamniotic twin complications. Panel A: Cord entanglement in MCMA twins — the two umbilical cords are intertwined, with a true knot visible as a focal hyperechoic tangle; colour Doppler shows bidirectional arterial and venous flow at the entanglement site ('colour chaos'). This is pathognomonic of MCMA twins. Panel B: Twin reversed arterial perfusion (TRAP) sequence — the acardiac, acephalic parasitic twin is perfused in a retrograde direction via an arterio-arterial anastomosis from the pump twin. The pump twin develops high-output cardiac failure; radiofrequency ablation of the acardiac twin's cord is the definitive treatment [13,20,29].

MANAGEMENT OF MCMA TWINS

MCMA twins require intensive surveillance, which most specialist centres deliver by weekly inpatient monitoring from 28-30 weeks with continuous CTG assessment [23]. Elective delivery by caesarean section at 32-34 weeks is the standard recommendation, balancing the risk of cord accident against the risk of prematurity [20]. Surveillance before

28 weeks relies on fortnightly ultrasound with cord Doppler assessment, looking for flow reversal within a knot and for biophysical profile deterioration.

Checklist — MCMA Twin Scan Protocol

- Confirm MCMA: absence of inter-twin dividing membrane on TVS with free fetal movement across expected membrane site.
- Cord Doppler: colour Doppler of both cords; document any visible entanglement, cord crossing, or focal colour chaos.
- Biometry of both twins: EFW discordance. In MCMA, discordance may be less reliable than in MCDA due to cord entanglement affecting DVP accuracy.
- Bladder and liquor: single sac DVP; both bladders visible.
- Signs of cord compromise: sustained bradycardia, decelerations on CTG, non-reactive NST.
- From 28 weeks inpatient: continuous CTG monitoring is standard care at most specialist centres [23].

TWIN REVERSED ARTERIAL PERFUSION (TRAP) SEQUENCE

TRAP sequence (also called acardiac twinning) is a rare but dramatic complication of MC pregnancy occurring in approximately 1% of MC pregnancies [13,20,29]. It is characterised by the presence of an amorphous, acardiac, and usually acephalic parasitic twin that has no cardiac function of its own but is perfused by retrograde arterial flow from the pump twin via an artery-to-artery anastomosis [21]. The pump twin sustains the circulation of the parasitic mass and is at risk of high-output cardiac failure, hydrops, and death — the risk of pump twin death is approximately 35-55% if untreated [22].

The sonographic diagnosis is made by demonstrating: (1) a mass with no recognisable cardiac activity or head structure; (2) retrograde (reversed) flow in the umbilical artery of the mass on Doppler; and (3) a normal pump twin connected to the mass via a shared placenta [23]. Treatment is radiofrequency ablation (RFA) of the acardiac twin's umbilical cord, which interrupts the parasitic circulation and allows the pump twin to recover cardiac function [24].

Clinical Pearl — Diagnosing TRAP on Doppler

- In TRAP, the acardiac twin's umbilical artery shows REVERSED flow (blood enters from placenta to fetus, not fetus to placenta) — the opposite of normal.
- This reversed arterial flow on spectral Doppler distinguishes TRAP from a dead co-twin (which shows no flow) and from a large placental chorioangioma (which shows arterial-venous shunting without reversal) [13,29].
- Always assess the pump twin's cardiac function: cardiomegaly (CTR >0.5), tricuspid regurgitation, and DVP >8 cm in the pump twin's sac indicate haemodynamic compromise and urgent referral for RFA [13,20].

TWIN ANAEMIA-POLYCYTHAEMIA SEQUENCE (TAPS) AND SINGLE INTRAUTERINE DEATH

TAPS — A Subtle Complication

TAPS is a chronic, slow transfusion through tiny residual AV anastomoses, occurring either spontaneously (3-5% of MCDA pregnancies) or after incomplete laser ablation for TTTS (2-13% post-laser) [20]. Unlike TTTS, TAPS presents without significant amniotic fluid discordance — normal DVPs in both sacs — making it invisible to the standard TTTS surveillance protocol if MCA-PSV is not also measured [25].

The diagnostic criteria are: MCA-PSV >1.5 MoM in the donor twin (anaemia) and MCA-PSV <1.0 MoM in the recipient twin (polycythaemia), with DVP discordance <8 cm (to exclude concurrent TTTS) [26]. TAPS surveillance therefore requires MCA-PSV measurement at every MCDA scan from 16 weeks onwards, not just in sensitised pregnancies [27].

Single Intrauterine Death in Multiple Pregnancy

In MCDA twins, death of one twin carries a 25-45% risk of neurological injury or death of the surviving co-twin — caused by acute haemodynamic transfusion through the anastomoses at the moment of death, resulting in acute hypovolaemia and hypotension in the survivor [28]. The critical concept is that once one twin dies, the damage to the survivor may already have occurred within hours; there is no intervention that reverses established white matter injury [29].

In DCDA twins, co-twin death carries a lower but still significant risk to the survivor (approximately 5-10%) due to thromboplastin release and potential disseminated intravascular coagulation, not haemodynamic transfusion [30]. The surviving co-twin requires urgent MRI of the fetal brain at 4-6 weeks after the event, and delivery timing must balance gestational age against the risk of neurological progression [31].

Clinical Warning — Single Twin Death in MCDA: Urgent Pathway

- Single twin death in MCDA is an obstetric emergency for the surviving twin. The damage from acute haemodynamic transfusion may occur within 30-60 minutes of death.
- Immediate delivery is NOT indicated for the co-twin unless gestational age and condition of the survivor warrant it — premature delivery adds iatrogenic risk to the already-injured survivor [10,25].
- Same-day fetal medicine referral, MRI of the fetal brain within 4-6 weeks, and a documented plan for neonatal neuroprotection are the standard of care [10,25].

REPORTING TEMPLATES: MULTIPLE PREGNANCY**Template A: First-Trimester Chorionicity Determination (11-14 Weeks)**

Field	Content
Fetal number	Twin pregnancy confirmed. Both twins viable — cardiac activity present in Twin A and Twin B.
Chorionicity determination	Method: [T-sign / lambda sign / fetal sex discordance / separate placentas]. Chorionicity: [Monochorionic / Dichorionic]. Amnionity: [Monoamniotic / Diamniotic]. Confidence: [high / limited — state reason].
Membrane	[Dividing membrane present / absent]. Insertion at placenta: [T-sign (MC) / Lambda/twin-peak sign (DC)]. Membrane thickness: [<2 mm consistent with MC / >2 mm consistent with DC].
Placenta(s)	[Single placental mass (MC) / Two separate placentas / Two placentas apparently fused — DC by lambda sign].
NT measurements	Twin A: CRL [X] mm, NT [X] mm. Twin B: CRL [X] mm, NT [X] mm. NT discordance: [X] mm [normal <0.6 mm for MCDA].
Risk assessment	[Combined first-trimester screen result if performed]. NT discordance: [significant risk for TTTS: yes/no].
Conclusion & plan	[MCDA: fortnightly scans from 16 weeks per ISUOG guidelines; refer to fetal medicine / DCDA: anomaly scan at 18-22 wk; growth scans every 4 wk from 24 wk / MCMA: refer immediately to fetal medicine specialist centre].

Template B: MCDA Fortnightly Surveillance Scan (16-36 Weeks)

Field	Content
Both twins viable	Twin A: cardiac activity present. Twin B: cardiac activity present.
Biometry	Twin A: BPD [X]mm, HC [X]mm, AC [X]mm, FL [X]mm, EFW [X]g ([Xth] centile). Twin B: BPD [X]mm, HC [X]mm, AC [X]mm, FL [X]mm, EFW [X]g ([Xth] centile). EFW discordance: [X]% [normal <25%].
Amniotic fluid	Twin A DVP: [X]cm [normal 2-8 cm]. Twin B DVP: [X]cm. [No TTTS criterion / DVP discordance: donor <2 cm + recipient >8 cm = TTTS Stage I+ criteria met].
Bladder (donor if DVP <2cm)	[Bladder visible in both twins / Bladder not visualised in smaller twin after [X] minutes of observation].
UmA Doppler	Twin A: PI [X], EDF [present/AEDF/REDF]. Twin B: PI [X], EDF [present/AEDF/REDF]. sFGR type if applicable: [I/II/III].

Template B: Continued...	
MCA-PSV (TAPS screen)	Twin A: PSV [X]cm/s = [X]MoM. Twin B: PSV [X]cm/s = [X]MoM. [No TAPS criteria / TAPS: one twin >1.5 MoM and other <1.0 MoM].
DV Doppler (if TTTS Stage I+)	Recipient DV: PI [X], a-wave [positive/absent/reversed].
TTTS staging	[No TTTS / TTTS Stage [X] — criteria met: (list criteria)].
Conclusion & plan	[No complications detected — next scan in 2 weeks / TTTS Stage [X] — immediate fetal medicine referral / sFGR Type [X] — management per protocol / TAPS suspected — refer fetal medicine].

Template C: Growth Scan for Dichorionic Twins

Field	Content
Biometry both twins	As per Template B biometry section. EFW discordance: [X]% [threshold for concern: >25%].
Doppler (if EFW <10 th centile or discordance >25%)	UmA PI and EDF status for the smaller twin. CPR if UmA normal.
Amniotic fluid	Twin A DVP: [X]cm. Twin B DVP: [X]cm.
Placenta	[Anterior/posterior/fundal]. [Separate placentas / fused placentas — dichorionic confirmed by earlier scan].
Conclusion	[Normal growth and concordance in DCDA twins / EFW discordance [X]% — [above/below] 25% threshold — [next scan in 4 weeks / urgent fetal medicine referral]].

Key Takeaways

1. Chorionicity must be determined at 11-14 weeks using the T-sign (MCDA) or lambda sign (DCDA). After 14 weeks, reliability falls sharply; after 20 weeks, it may be impossible in same-sex twins. A twin pregnancy without documented chorionicity is a medico-legal risk [1,14,23].
2. MCDA twins require fortnightly ultrasound from 16 weeks; the minimum at each visit is DVP in both sacs, bladder visualisation in the smaller twin (if DVP <2 cm), UmA Doppler, and MCA-PSV for TAPS detection [1,23].
3. Quintero staging requires all lower stages to be present before diagnosing a higher stage — do not jump from Stage I to Stage III. Document the stage and all supporting criteria explicitly at each visit [4,11].
4. Stage I TTTS may resolve in 20-25% but progresses in a similar proportion. Weekly surveillance is mandatory; any progression mandates same-day fetal medicine referral for laser consideration [8,11,23].

Key Takeaways: Continued...

5. sFGR Type III is uniquely dangerous because the large AA anastomosis can cause sudden unexpected IUD in the smaller twin, followed by acute TTTS in the survivor. Intensive monitoring and early delivery discussion are appropriate [6,27].
6. TAPS has normal DVPs in both sacs — it is invisible without MCA-PSV measurement. Include MCA-PSV at every MCDA scan from 16 weeks; do not wait for DVP discordance to screen for TAPS [1,20].
7. EFW discordance formula: $(\text{larger EFW} - \text{smaller EFW}) / \text{larger EFW} \times 100\%$. Report this at every growth scan; a trend from 15% to 28% discordance over 4 weeks is more alarming than a single 28% measurement [1,24].
8. MCMA twins require inpatient admission from 28-30 weeks for continuous CTG monitoring; the cord entanglement risk of sudden death is too high for outpatient fortnightly surveillance alone [23].
9. In TRAP sequence, the acardiac twin's umbilical artery shows REVERSED flow on Doppler — blood flows from the placenta into the parasitic twin, not from fetus to placenta. Retrograde arterial flow is the diagnostic hallmark [13,29].
10. Single twin death in MCDA requires same-day fetal medicine referral, MRI of surviving fetal brain at 4-6 weeks, and a documented care plan. Immediate delivery is not the default — gestational age and neurological status of the survivor guide timing [10,25].

CERVIX, PRETERM BIRTH & THIRD-TRIMESTER COMPLICATIONS

Preterm birth — delivery before 37 completed weeks — is the leading cause of neonatal mortality and the principal driver of long-term neurodevelopmental disability worldwide. Transvaginal cervical length measurement is the most accurate single predictor of spontaneous preterm birth available to the clinician, and the interventions it triggers — vaginal progesterone and cervical cerclage — have Level I evidence of efficacy [1]. This chapter covers the technique and interpretation of transvaginal cervical length measurement, the prediction and prevention of preterm birth, the sonographic assessment of third-trimester complications including placental abruption, uterine scar integrity, preeclampsia, and the structured reporting templates required for each scenario.

CERVICAL LENGTH MEASUREMENT — TECHNIQUE, PITFALLS, AND REFERENCE RANGES

Why Cervical Length Matters

The landmark NICHD study by Iams and colleagues in 1996 established the continuous inverse relationship between cervical length and spontaneous preterm birth risk in a population of unselected low-risk women [2]. At 24 weeks, a cervical length of ≤ 15 mm confers a relative risk of spontaneous preterm birth before 35 weeks of approximately 6.2 compared with a cervical length ≥ 40 mm; a length of ≤ 25 mm carries a relative risk of 3.8 [1]. These risks are continuous, not dichotomous — every millimetre of cervical length matters, and the decision threshold for intervention must be applied with an understanding of the population being screened [3].

Critically, the same cervical length carries different absolute risks in different populations. A cervical length of 25 mm at 22 weeks in a nulliparous woman with no prior preterm birth carries a much lower absolute risk than the same measurement in a woman with two prior mid-trimester losses. Risk stratification must combine cervical length with obstetric history, uterine anatomy, and cervical biomarkers [4].

TVS TECHNIQUE: THE SIX-STEP STANDARD

Transvaginal ultrasound (TVS) is the gold standard for cervical length measurement [5]. Transabdominal ultrasound is not acceptable for clinical cervical length measurement because bladder filling artificially elongates the cervix and the resolution is insufficient for the millimetre-range measurements required [6]. The following technique must be followed at every measurement:

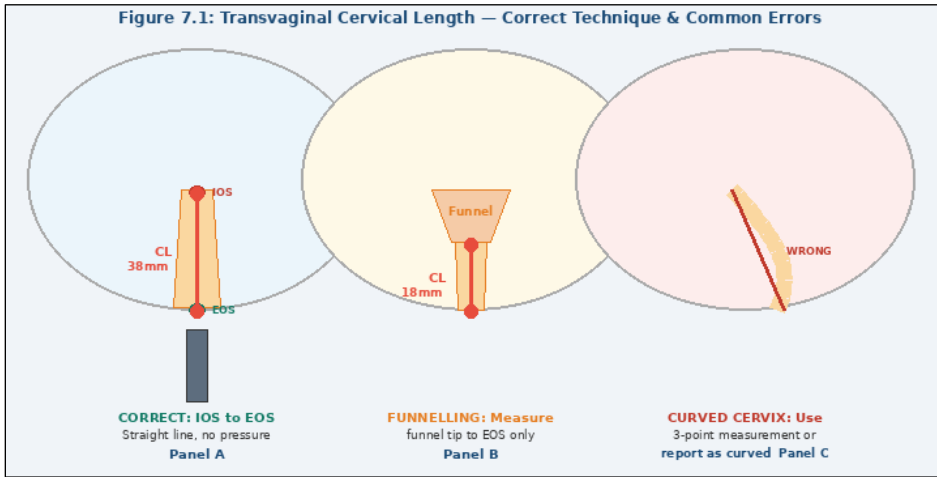


Figure 7.1: Transvaginal cervical length measurement technique. Panel A: Correct technique — probe in anterior fornix without excessive pressure, sagittal plane through the cervical canal, callipers from internal os (IOS) to external os (EOS) along the straight line of the canal; normal length 38 mm. Panel B: Funnelling — when funnelling is present, measure from the funnel tip (not the anatomical IOS) to the EOS — this is the functional cervical length; the example shows 18 mm functional length. Panel C: Curved cervix — a single straight calliper measurement underestimates the true canal length in a curved cervix; report as curved and use a 3-point or segmental measurement [6].

Checklist — TVS Cervical Length: Six-Step Protocol

- Empty the bladder: a full bladder artificially elongates the cervix by 2-8 mm. Always measure with the bladder emptied immediately before the examination.
- Insert the probe into the anterior fornix. Identify the cervical canal in mid-sagittal plane with the endocervical mucosa (echogenic line) visible throughout.
- Reduce pressure: withdraw the probe until the image blurs slightly, then gently re-advance to regain the image. Excessive fundal pressure elongates the cervix artificially.
- Measure from internal os to external os along the line of the closed cervical canal. If funnelling is present, measure from the funnel tip to the EOS only.
- Take three measurements over 3 minutes; record the shortest. This accounts for dynamic cervical shortening during the observation period.
- Perform a dynamic stress test: ask the patient to cough or perform a Valsalva manoeuvre and document whether the cervical length decreases by ≥ 5 mm (dynamic shortening) [1,6].

REFERENCE RANGES AND CLINICAL THRESHOLDS

The mean cervical length at 20-24 weeks in a low-risk population is approximately 38 mm, with a standard deviation of approximately 8 mm. The distribution is not symmetrical — short cervixes are clinically important and the lower end of the distribution is the focus of clinical attention. The following thresholds are used in clinical practice, with the caveat that management should be individualised [7]:

Table 7.1: Cervical length thresholds and interventions at 16-24 weeks. These thresholds apply to singleton pregnancies; twin pregnancy thresholds differ (CL <25 mm in twins warrants progesterone; cerclage is not recommended in twins without prior PTB) [2,5,30].

Cervical Length	Risk Category	Recommended Intervention	References
≥25 mm	Low risk [1,3]	Reassurance; no intervention in low-risk singleton [2]	[1,3]
20-24 mm	Intermediate risk [3]	Progesterone 200 mg vaginally nightly in prior PTB history [2,27]	[2,27]
16-24 mm	Elevated risk [2]	Vaginal progesterone 200 mg nightly (singleton, no prior PTB) [2,27]	[2,27,30]
≤15 mm	High risk [1,2]	Progesterone + cerclage discussion if prior PTB; fFN testing [4,26]	[1,4,26]
Funnelling present	Increased risk regardless of functional CL [3]	Measure functional CL; manage per functional CL threshold [6]	[3,6]

FUNNELLING: DEFINITION AND MEASUREMENT

Funnelling is the dilatation of the internal os with membrane prolapse into the cervical canal. It reflects the loss of the cervico-isthmic junction as the lower uterine segment begins to efface. Funnelling is described by its shape (T-shape = no funnel; V-funnel = early; U-funnel = advanced; sludge = echogenic material within the amniotic fluid near the IOS, representing cellular debris and associated with intrauterine infection) [8].

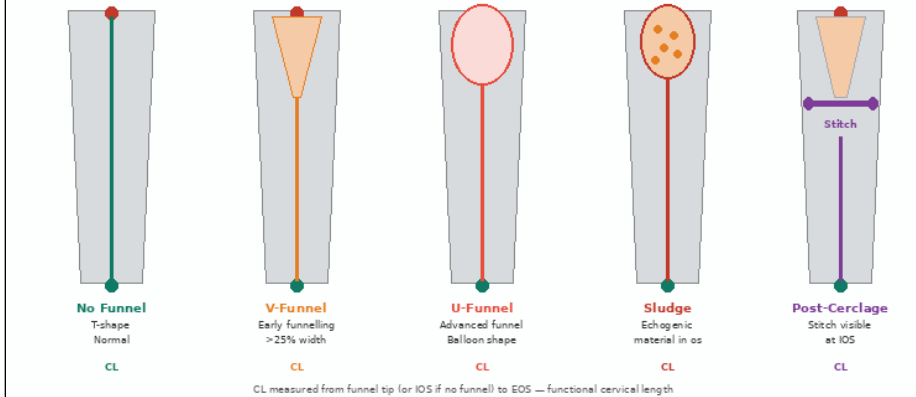
Figure 7.4: Cervical Incompetence — Funnelling Grades & Cerclage Position

Figure 7.4: Cervical funnelling grades and cerclage position. T-shape: closed IOS, no funnel — normal. V-funnel: early funnelling with a triangular prolapse of membranes into the cervical canal. U-funnel: advanced funnelling with a round or balloon-shaped membrane prolapse — functional cervical length often critically short. Sludge: echogenic particulate material within the amniotic fluid near the IOS — strongly associated with intrauterine infection and is an independent predictor of preterm birth [16,29]. Post-cerclage: echogenic stitch visible at the level of the IOS, with the cervical canal closed below [4,26].

Clinical Pearl — Sludge: The Silent Infection Marker

- Cervical sludge (echogenic amniotic fluid near the IOS) is not merely a cervical finding — it is strongly associated with subclinical intrauterine infection, histological chorioamnionitis, and spontaneous preterm birth within 7-14 days [16,29].
- When sludge is identified, consider amniocentesis for Gram stain, glucose, white cell count, and culture to exclude intrauterine infection before any intervention [16].
- Do not dismiss sludge as 'debris' or 'an artefact'. Document it explicitly in the report and communicate it urgently to the obstetric team [6,16].

PRETERM BIRTH — PREDICTION, PREVENTION, AND ULTRASOUND SURVEILLANCE

Epidemiology and Aetiology

Spontaneous preterm birth (sPTB) — including both preterm labour with intact membranes and preterm prelabour rupture of membranes (pPROM) — accounts for approximately 75% of preterm births; the remainder result from indicated (iatrogenic) delivery for maternal or fetal indications [9]. The leading risk factors are: prior spontaneous PTB (relative risk 2.5-5.0), uterine anomaly (especially bicornuate and septate uterus), cervical

surgery (LLETZ/conisation), multiple pregnancy, intrauterine infection, and extremes of inter-pregnancy interval [10].

Preterm birth is not a single disease — it is a syndrome with multiple aetiological pathways: pathological activation of maternal-fetal endocrine cascades, decidual senescence, intrauterine infection/inflammation, uteroplacental ischaemia/haemorrhage, and uterine overdistension [28]. The ultrasound practitioner is most directly involved in the detection of cervical shortening (the final common pathway of all these processes) and in the surveillance of at-risk pregnancies [11].

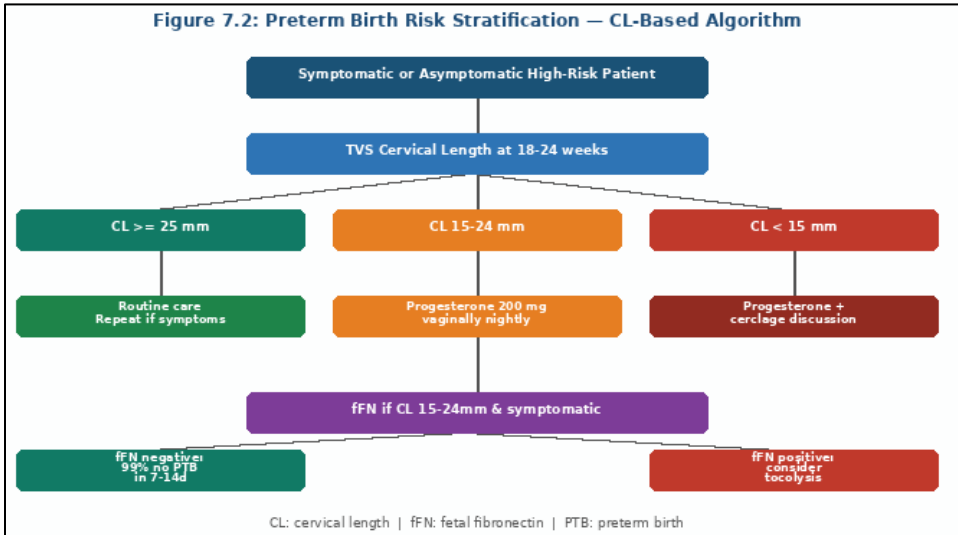


Figure 7.2: Preterm birth risk stratification and management algorithm. Cervical length at 18-24 weeks is the primary discriminator. Fetal fibronectin (fFN) is a complementary test in symptomatic women with CL 15-24 mm — a negative fFN result has a negative predictive value of >99% for spontaneous preterm birth within 7-14 days, allowing safe discharge and avoiding unnecessary tocolysis [8,7].

FETAL FIBRONECTIN: COMPLEMENTARY BIOMARKER

Fetal fibronectin (fFN) is a glycoprotein produced at the maternal-fetal interface. Its presence in cervico-vaginal secretions at ≥ 22 ng/mL (qualitative) or ≥ 200 ng/mL (quantitative threshold for higher risk) between 22 and 34 weeks indicates disruption of the chorioamniotic-decidual interface and predicts imminent preterm birth. The key clinical utility is its negative predictive value: a negative fFN test (qualitative < 10 ng/mL) in a symptomatic woman with a CL of 15-30 mm provides >99% reassurance that she will not deliver within the next 7-14 days, justifying safe discharge without tocolysis or transfer [12].

Clinical Pearl — The fFN Rule: It Rules OUT, Not In

- A positive fFN test has modest positive predictive value (~20-30%) for preterm birth within 14 days in symptomatic women. Treating all fFN-positive patients with tocolysis leads to unnecessary intervention.
- A negative fFN in a woman with CL ≥ 15 mm is one of the most reassuring findings in obstetric medicine — NPV $>99\%$ for delivery within 7-14 days [8].
- Do not perform fFN if: the patient has had intercourse in the last 24 hours, digital cervical examination in the last 24 hours, or if there is active vaginal bleeding — all cause false positives [8].

CERVICAL CERCLAGE: INDICATIONS AND ULTRASOUND-GUIDED APPROACH

Cervical cerclage is the surgical placement of a purse-string suture around the cervix to provide mechanical support. Three categories of indication exist: history-indicated (placed at 12-14 weeks based on prior mid-trimester loss), ultrasound-indicated (placed at 16-24 weeks when CL ≤ 25 mm in a woman with prior spontaneous PTB), and rescue cerclage (placed when dilated IOS with prolapsing membranes is identified) [13].

Meta-analysis by Berghella and colleagues demonstrated that ultrasound-indicated cerclage reduces the rate of preterm birth before 35 weeks by approximately 30% in singleton pregnancies with prior PTB and CL ≤ 25 mm [4]. Critically, cerclage is NOT indicated in: twin pregnancies without prior PTB (the CERAGEM trial showed harm in twins without cerclage indication), asymptomatic women without prior PTB regardless of CL, or when clinical chorioamnionitis is suspected [14].

Table 7.2: Cervical cerclage indications and evidence base. The distinction between history-indicated and ultrasound-indicated cerclage is clinically important — the evidence applies to specific populations and should not be extrapolated beyond them [4,26].

Cerclage Type	Indication	Evidence Summary
History-indicated	3+ prior mid-trimester losses or PTB; placed at 12-14 wk [4,26]	Cochrane review: reduces PTB <34 wk (RR 0.65) in this group [26]
Ultrasound-indicated	CL ≤ 25 mm at 16-24 wk AND prior spontaneous PTB [4]	Meta-analysis: reduces PTB <35 wk by ~30% (RR 0.70) [4]
Rescue cerclage	Dilated IOS with visible membranes; CL ≤ 10 mm [4,26]	Observational evidence only; high infection risk; specialist decision [26]
NOT indicated	Twins without prior PTB; asymptomatic without prior PTB regardless of CL [4,26]	No benefit shown; possible harm in twins [4,26]

VAGINAL PROGESTERONE: THE PRIMARY PREVENTION TOOL

Vaginal progesterone 200 mg nightly is the primary pharmacological intervention for preventing preterm birth in women with a short cervix identified on mid-trimester TVS [15].

THIRD-TRIMESTER HAEMORRHAGE — PLACENTAL ABRUPTION AND SCAR INTEGRITY

Placental Abruption

Placental abruption — premature separation of a normally sited placenta from the uterine wall before delivery of the fetus — complicates approximately 0.5-1% of pregnancies and carries a perinatal mortality 10-15 times that of non-abrupted controls [16]. The clinical presentation classically involves painful vaginal bleeding, uterine tenderness, and fetal distress, but approximately 20% of cases present with concealed haemorrhage (no external bleeding) and 10-20% show minimal symptoms until catastrophic haemodynamic collapse [17].

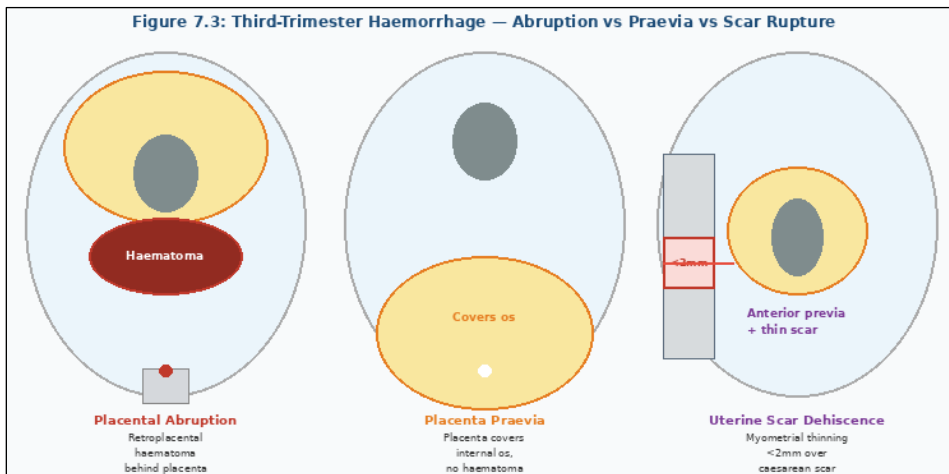


Figure 7.3: Third-trimester haemorrhage — differential diagnosis on ultrasound. Left: Placental abruption — a retroplacental haematoma appears as a hypoechoic (acute) or mixed-echogenicity collection between the placenta and myometrium; its sonographic sensitivity is only 25-50% — a normal scan does not exclude abruption. Centre: Placenta praevia — placenta covers the internal os, producing antepartum bleeding without pain; TVS is the definitive investigation. Right: Uterine scar dehiscence — myometrial thinning <2 mm over the anterior lower segment in a patient with prior caesarean and anterior praevia; this is a pre-rupture finding requiring immediate obstetric assessment [13,14,15].

Sonographic Features of Placental Abruption

Ultrasound is poorly sensitive for placental abruption — the overall sensitivity is approximately 25-50% — because acute haemorrhage is isoechoic to the placenta and may not be visible [18]. An apparently normal ultrasound scan does not exclude abruption; clinical assessment takes precedence. When visible, abruption may appear as:

Table 7.3: Sonographic appearances of placental abruption and their clinical correlations. A normal ultrasound never excludes abruption — sensitivity is 25-50% at best. The diagnosis remains primarily clinical; ultrasound is used to assess fetal wellbeing and liquor volume, and to exclude placenta praevia [13,14].

Sonographic Appearance	Stage / Timing	Clinical Correlation
Isoechoic to placenta	Acute (<24 h): haemorrhage same echogenicity as placenta [13]	May be invisible — clinical diagnosis takes precedence [13]
Hyperechoic retroplacental collection	1-2 days: clot becomes hyperechoic [14]	Most specific sign; seen in 25-50% [13,14]
Hypoechoic collection	Subacute (>1 week): liquefying haematoma [14]	May mimic normal retroplacental clear zone [14]
Preplacental haematoma	Between placenta and amniotic fluid [13]	Less common; associated with poor perinatal outcome [13]
Placental thickening (>4 cm)	Non-specific sign; seen with acute bleeding into placenta [14]	Supportive finding; measure at thickest perpendicular point [14]

Medico-Legal Warning — Abruption is a Clinical, Not Sonographic, Diagnosis

- A patient presenting with painful antepartum haemorrhage and uterine tenderness has placental abruption until proven otherwise, regardless of the ultrasound findings.
- Documenting 'no retroplacental collection seen on ultrasound' in the context of clinical abruption does NOT reassure and must not delay emergency obstetric intervention [13,14].
- The sonographer's role in suspected abruption is: (1) exclude placenta praevia, (2) assess fetal wellbeing (biophysical profile, Doppler), (3) assess amniotic fluid (oligohydramnios in abruption is an ominous sign), and (4) document any visible haematoma. Do not reassure on the basis of a normal scan [13].

UTERINE SCAR ASSESSMENT IN THE THIRD TRIMESTER

Lower uterine segment (LUS) thickness assessment in the third trimester is performed in women with prior uterine surgery to stratify the risk of uterine rupture during trial of labour after caesarean (TOLAC) [19]. The myometrial thickness is measured on TVS or transabdominal ultrasound in the sagittal plane at the level of the bladder reflection, measuring only the myometrium (not including the overlying bladder serosa or the fetal presenting part) [20].

A full LUS thickness (including serosa) of <3.5 mm, or a myometrial thickness alone of <2.3 mm at 36-38 weeks, is associated with a significantly elevated risk of uterine rupture or dehiscence during TOLAC — reported sensitivity 88-95%, specificity 65-73% for scar defect [21]. A thickness ≥ 3.5 mm is associated with a very low risk of rupture and supports planned TOLAC [22].

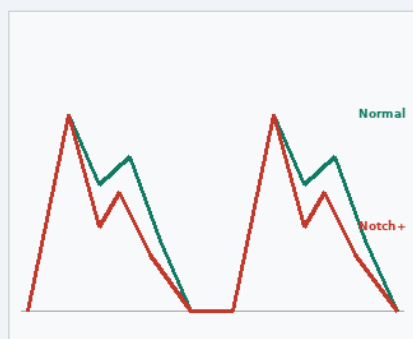
Checklist — LUS Thickness Assessment: Technique and Reporting

- Gestational age: perform at 36-38 weeks; earlier measurements are less predictive.
- Bladder: partially fill the bladder (100-150 mL) to provide an acoustic window over the LUS.
- Plane: mid-sagittal, with the probe angled to be perpendicular to the LUS at the thinnest point (not the thickest).
- Measure: full-thickness LUS (myometrium + serosa) and myometrium alone. Report both.
- Thresholds: full thickness <3.5 mm = increased rupture risk; myometrium alone <2.3 mm = increased risk [15].
- Document: presence of any scar niche, discontinuity, or focal thinning. Communicate urgently if <2.5 mm in a patient planning TOLAC [15].

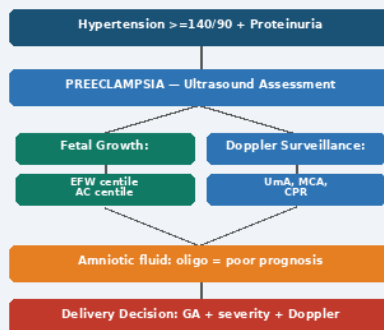
PREECLAMPSIA AND HYPERTENSIVE DISORDERS — THIRD-TRIMESTER ULTRASOUND ROLE

Ultrasound in the Diagnosis and Management of Preeclampsia

Preeclampsia (PE) — new-onset hypertension $\geq 140/90$ mmHg after 20 weeks with proteinuria or end-organ dysfunction — is a multisystem disease caused by abnormal placentation [23]. Ultrasound does not diagnose preeclampsia (this is a clinical-biochemical diagnosis) but plays three critical roles in its management: (1) assessment of fetal growth and wellbeing in the context of uteroplacental insufficiency; (2) assessment of amniotic fluid volume; and (3) Doppler surveillance to guide timing of delivery [24].

Figure 7.5: Third-Trimester Complications — Preeclampsia & Maternal Assessment

Uterine Artery Doppler
Bilateral notch = 7x PE risk
Panel A



Delivery at 34-37 wk depending on severity
<34 wk: steroids + Mg for neuroprotection
Panel B — PE Ultrasound Pathway

Figure 7.5: Third-trimester complications — preeclampsia and maternal assessment. Panel A: Uterine artery Doppler at 20-24 weeks — normal waveform (green) with forward diastolic flow and no early-diastolic notch; abnormal waveform (red) with bilateral early-diastolic notch and elevated PI. Bilateral notching at this gestation confers a likelihood ratio of approximately 7 for severe early-onset preeclampsia. Panel B: Ultrasound management pathway for confirmed preeclampsia — biometry, Doppler surveillance, and amniotic fluid assessment form the basis of delivery timing decisions in conjunction with maternal clinical parameters [21,22].

Fetal Assessment in Preeclampsia

Preeclampsia-associated FGR follows the same Doppler deterioration sequence as placenta-mediated FGR described in Chapter 4 — UaA PI elevation, MCA brain-sparing, and DV deterioration — and should be managed with the same Doppler-based staging system [24]. Several specific features of PE-associated FGR deserve emphasis:

Table 7.4: Ultrasound parameters in fetal assessment with preeclampsia. These thresholds apply to delivery timing decisions made in conjunction with the clinical severity of maternal preeclampsia — severe maternal disease (hypertensive crisis, HELLP, eclampsia) mandates delivery regardless of Doppler findings [21,22,24].

Assessment Parameter	Clinical Significance in PE	Action Threshold
EFW and AC centile	PE-associated FGR typically asymmetric (AC falls first) [21]	EFW <10th centile: intensify Doppler surveillance [21,22]
Amniotic fluid (DVP)	Oligohydramnios (DVP <2 cm) in PE indicates severe placental dysfunction [22]	DVP <2 cm: discuss delivery regardless of gestational age [22]

Table 7.4 Continued...

Umbilical artery PI	AEDF/REDF indicates severe uteroplacental insufficiency [22]	AEDF at ≥ 34 wk: deliver. AEDF at < 34 wk: steroids + deliver within 48-72 h [22]
CPR (< 1.0)	Brain-sparing common in PE-FGR even with normal UmA PI [22]	CPR < 1.0 at ≥ 37 wk: deliver. < 37 wk: individualise with MFM [22]
Ductus venosus	Reversed a-wave = imminent cardiac decompensation [22]	Reversed DV a-wave: deliver regardless of GA [22]

HELLP Syndrome — Sonographic Liver Assessment

HELLP syndrome (Haemolysis, Elevated Liver enzymes, Low Platelets) occurs in approximately 0.5-0.9% of all pregnancies and in 10-20% of severe preeclampsia cases [24]. Ultrasound assessment of the maternal liver may reveal subcapsular haematoma (a hypoechoic or mixed-echogenicity collection beneath the liver capsule), hepatic infarct, or free intraperitoneal fluid from hepatic rupture — the most catastrophic complication, with a maternal mortality approaching 60% if not immediately managed surgically [25]. Any maternal complaint of right upper quadrant or epigastric pain in the context of known PE should trigger a maternal hepatic ultrasound assessment.

Clinical Warning — Hepatic Subcapsular Haematoma in HELLP

- A hepatic subcapsular haematoma in the context of HELLP syndrome is a pre-rupture finding. It requires immediate senior obstetric and surgical review.
- Do NOT perform abdominal palpation, uterine fundal pressure, or any physical manoeuvre that may increase intra-abdominal pressure if a hepatic haematoma is identified on ultrasound [24].
- Free fluid in the hepatorenal space (Morrison's pouch) in a patient with HELLP and right upper quadrant pain may represent hepatic rupture — activate the major haemorrhage protocol immediately [24].

PRETERM PREMATURE RUPTURE OF MEMBRANES (PPROM) — ULTRASOUND ROLE

Ultrasound in pPROM: What It Can and Cannot Do

Preterm premature rupture of membranes (pPROM) before 37 weeks complicates approximately 3% of pregnancies and accounts for approximately one-third of all preterm births [26]. The diagnosis of pPROM is clinical — based on history, speculum examination, pooling, and biochemical markers (AmniSure, ActimPROM); ultrasound is not a diagnostic tool for membrane rupture and cannot reliably detect membrane defects [27].

However, ultrasound serves four important roles in pPROM management: (1) documenting oligohydramnios (AFI or DVP) as confirmation of ongoing leakage; (2) assessing fetal growth and Doppler in the context of cord compression risk with oligohydramnios; (3) monitoring amniotic fluid volume serially to assess whether membranes have sealed and fluid is reaccumulating; and (4) measuring the residual pocket to assess risk of umbilical cord prolapse and cord compression — a DVP <2 cm indicates severe oligohydramnios requiring close monitoring for fetal decelerations [28].

Checklist — Ultrasound in pPROM: Four Required Assessments

- Amniotic fluid: DVP in all four quadrants. Document DVP and AFI. Severe oligohydramnios: DVP <2 cm — intensify CTG monitoring for cord compression.
- Fetal presentation: confirm presenting part and relationship to cord (colour Doppler to exclude cord presentation/prolapse near the IOS).
- Biophysical profile: FBM, FM, FT, DVP. Absent FBM in the context of pPROM may indicate subclinical chorioamnionitis [16,29].
- Umbilical artery Doppler: serial assessment. Worsening UmA PI with oligohydramnios may reflect cord compression rather than placental insufficiency [17].

Antenatal Corticosteroids and Magnesium Sulphate — The Sonographer's Role

The sonographer and sonologist play a critical indirect role in the administration of two life-saving interventions for the preterm fetus: antenatal corticosteroids (ACS) and magnesium sulphate (MgSO₄). ACS (dexamethasone or betamethasone) reduce the risk of respiratory distress syndrome, intraventricular haemorrhage, and neonatal death when given within 7 days of anticipated preterm delivery between 24 and 34 weeks, with partial benefit at 34-36 weeks. MgSO₄ administered before 32 weeks reduces the risk of cerebral palsy in the preterm infant by approximately 30% [29].

The sonographic findings that should trigger the obstetric team to consider these interventions include: CL ≤15 mm with symptoms, AEDF or REDF on UmA Doppler, reversed DV a-wave, BPP ≤4/10, and any condition requiring delivery before 34 weeks. The sonologist must communicate these findings to the obstetric team with sufficient urgency that the 24-48hour window for ACS to take effect is not lost by delayed communication [30].

REPORTING TEMPLATES: CERVIX AND THIRD-TRIMESTER COMPLICATIONS

Template A: Cervical Length Assessment

Field	Content
Clinical indication	Cervical length assessment. GA: [X wk + Y d]. Indication: [prior PTB / short CL on previous scan / twin pregnancy / cervical surgery / symptoms of PTL / routine screening].
Technique	Transvaginal ultrasound. Bladder emptied immediately prior. Three measurements taken over 3 minutes. Shortest value recorded.
Cervical length	Shortest of three measurements: [X] mm. [Normal ≥ 25 mm / Short 16-24 mm / Very short ≤ 15 mm].
Internal os	[Closed / Funnelling present — type: [T/V/U/sludge]]. If funnelling: funnel depth [X] mm, funnel width [X] mm, functional CL (funnel tip to EOS): [X] mm.
Dynamic shortening	[No dynamic shortening on Valsalva / Cervical length shortened by [X] mm on Valsalva — dynamic cervical incompetence].
Amniotic membrane	[Not visible at IOS / Membrane visible at IOS — rescue cerclage discussion required].
Sludge	[Absent / Present — echogenic material adjacent to IOS. Intrauterine infection must be excluded — recommend clinical assessment and amniocentesis discussion].
Conclusion & plan	[Normal CL — routine follow-up / Short CL [X] mm — commence vaginal progesterone 200 mg nightly; repeat TVS in [4 / 2 / 1] week(s) / Very short CL ≤ 15 mm — cerclage discussion; fFN if symptomatic; immediate obstetric review].

Template B: Third-trimester complication — suspected abruption or haemorrhage

Field	Content
Clinical context	GA: [X wk + Y d]. Presentation: [painful/painless bleeding / suspected abruption / routine]. Haemodynamic status: [stable / unstable].
Fetal viability	Cardiac activity: [present / absent]. Fetal movement: [observed / not observed]. Fetal heart rate: [X] bpm.
Placental site	[Anterior / posterior / fundal]. Distance from IOS: [X] mm. [No praevia / Low-lying / Praevia — covers os].
Retroplacental space	[Normal retroplacental clear zone / Retroplacental collection: [X x Y x Z] mm, [echogenicity: hypo/iso/hyperechoic] — consistent with [haematoma / normal clear zone].

Template B: Continued...	
Amniotic fluid	DVP: [X] cm / AFI: [X] cm. [Normal / Oligohydramnios — DVP <2 cm].
Fetal wellbeing	BPP: [X]/10 (FBM [2/0], FM [2/0], FT [2/0], DVP [2/0]). UmA Doppler: PI [X], EDF [present/AEDF/REDF].
LUS assessment (if prior LSCS)	Full LUS thickness: [X] mm. Myometrium alone: [X] mm. [Normal >=3.5 mm / Thinned <3.5 mm — increased rupture risk during TOLAC].
URGENT conclusion	[No retroplacental collection — placenta praevia excluded. Fetal wellbeing: [normal/compromised]. Recommend: [continue monitoring / immediate obstetric review / delivery]].

Template C: Preeclampsia Surveillance Scan

Field	Content
Clinical context	GA: [X wk + Y d]. Maternal BP: [X/Y] mmHg. Proteinuria: [present / absent]. Indication: [PE surveillance / gestational hypertension / HELLP].
Biometry	EFW (Hadlock): [X] g ([Xth] centile). AC: [X] mm ([Xth] centile). HC/AC ratio: [X].
Umbilical artery	PI: [X] ([Xth] centile). EDF: [present / AEDF / REDF].
MCA / CPR	MCA-PI: [X]. UmA-PI: [X]. CPR: [X] ([normal >1.0 / abnormal <1.0]).
Ductus venosus	PI: [X]. a-wave: [positive / absent / reversed].
Amniotic fluid	DVP: [X] cm. AFI: [X] cm. [Normal / Oligohydramnios].
Maternal liver (if HELLP suspected)	[Not assessed / Assessed — liver parenchyma: [homogeneous / focal abnormality — describe]. Subcapsular fluid: [absent / present — volume]. Free fluid: [absent / present in Morrison's pouch — URGENT]].
Conclusion & delivery discussion	EFW [X]g ([Xth] centile). Doppler status: [normal / UmA PI elevated / AEDF / REDF]. DVP: [X] cm. Recommended: [continue surveillance; next scan [date] / Urgent obstetric review — delivery discussion required / IMMEDIATE obstetric review — [reversed DV / REDF / BPP <=4]].

Key Takeaways

1. TVS cervical length is the most accurate predictor of spontaneous preterm birth. Always measure with an emptied bladder, minimum pressure, and report the shortest of three measurements over 3 minutes [1,6].
2. When funnelling is present, measure from the funnel tip to the EOS — this is the functional cervical length. The anatomical IOS-to-EOS measurement overestimates the protective cervical tissue [6].
3. Cervical sludge is not an artefact — it is associated with subclinical intrauterine infection and is an independent predictor of preterm birth. Communicate urgently to the obstetric team and consider amniocentesis discussion [16,29].
4. Vaginal progesterone 200 mg nightly reduces preterm birth before 33 weeks by 45% in women with CL ≤ 25 mm. This is one of the highest-impact ultrasound-triggered interventions in all of obstetrics [2,27,30].
5. A negative fFN test in a symptomatic woman with CL ≥ 15 mm has a $>99\%$ NPV for delivery within 7-14 days — this result justifies safe discharge and avoidance of tocolysis [8].
6. Ultrasound has only 25-50% sensitivity for placental abruption. A normal scan does not exclude abruption — the diagnosis is clinical. The sonographer's role is to exclude praevia, assess fetal wellbeing, and document any visible haematoma [13,14].
7. LUS thickness <3.5 mm at 36-38 weeks in a woman planning TOLAC is associated with significantly elevated risk of uterine rupture — communicate this finding to the obstetric team promptly before labour is allowed to commence [15].
8. In preeclampsia, reversed DV a-wave or REDF mandates delivery regardless of gestational age. Oligohydramnios (DVP <2 cm) in PE is an ominous independent indicator of severe placental dysfunction [21,22].
9. Hepatic subcapsular haematoma in HELLP syndrome is a pre-rupture emergency — avoid all physical abdominal manoeuvres and activate the major haemorrhage protocol immediately [24].
10. The sonologist's timely communication of AEDF/REDF, reversed DV, or BPP $\leq 4/10$ directly determines whether the obstetric team has the 24-48 hours required for antenatal corticosteroids to exert their neuroprotective effect before delivery [18,19].

FETAL ANOMALIES: SYSTEM-BY-SYSTEM DIAGNOSIS

The detection of a fetal structural anomaly is one of the most consequential moments in prenatal medicine — for the parents who must make decisions under uncertainty and grief, for the clinician who must translate images into prognosis, and for the multidisciplinary team that must translate prognosis into a birth plan. This chapter provides a structured, system-by-system approach to the sonographic diagnosis of the most clinically significant fetal anomalies encountered in routine obstetric practice: central nervous system malformations, congenital heart disease, thoracic anomalies, abdominal wall defects, gastrointestinal anomalies, urinary tract anomalies, and skeletal dysplasias. For each system, the sonographic diagnostic criteria, associated anomalies, chromosomal risk, prognosis, and reporting requirements are addressed [1].

CENTRAL NERVOUS SYSTEM ANOMALIES

Neural Tube Defects Spina Bifida and Anencephaly

Neural tube defects (NTDs) — encompassing anencephaly, encephalocele, and spina bifida — occur in approximately 1-2 per 1000 pregnancies and represent the most common severe CNS malformation detectable by prenatal ultrasound [2]. Anencephaly is uniformly lethal and is characterised by absence of the calvarium above the orbits with replacement by angiomatous stroma; it is detectable from 11 weeks onwards and should be diagnosed at the first-trimester scan. Open spina bifida (myelomeningocele) results from failure of posterior neural tube closure and is associated with the Arnold-Chiari II malformation in virtually all cases — producing the pathognomonic cranial signs of lemon (bifrontal scalloping) and banana (downward herniation of the cerebellum) at the second-trimester scan [3].

The two cranial signs have a sensitivity of approximately 95% for open spina bifida between 16 and 24 weeks [4]. The lemon sign refers to a concave scalloping of the frontal bones on axial head section, producing a lemon-shaped calvarium in place of the normal ovoid shape. The banana sign refers to anterior displacement of the cerebellum (away from the tentorium) by downward hindbrain herniation, obliterating the cisterna magna and producing a curved banana-shaped cerebellar profile [5]. These cranial signs should trigger a dedicated spinal survey to identify the level of the defect.

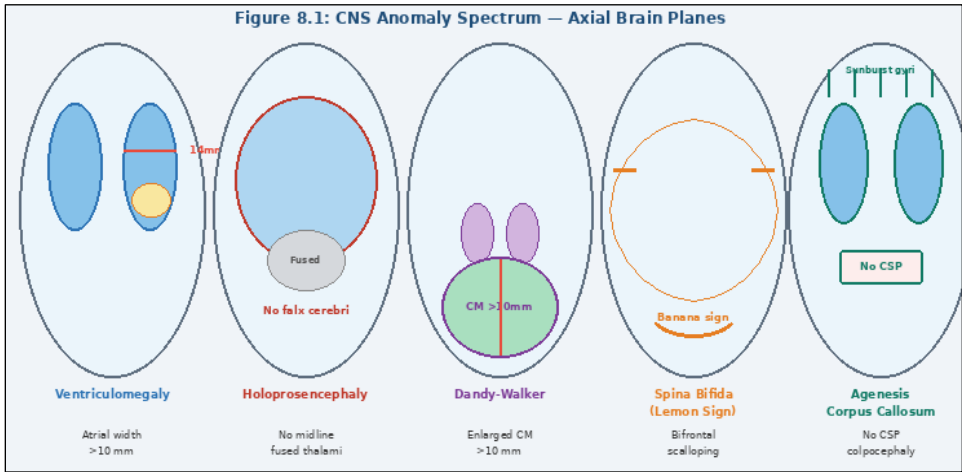


Figure 8.1: CNS anomaly spectrum on axial brain planes. Ventriculomegaly: enlarged lateral ventricles with atrial width >10 mm — the choroid plexus dangles in the dependant portion of the dilated ventricle (dangling choroid sign). Holoprosencephaly: fused monoventricle with absent midline, fused thalami, and no falx cerebri — the alobar type shown here is the most severe. Dandy-Walker malformation: enlarged cisterna magna (>10 mm) with variable hypoplasia of the cerebellar vermis. Lemon sign of spina bifida: bifrontal scalloping producing the characteristic lemon-shaped skull; banana sign (cerebellar herniation) visible at the transcerebellar plane. Agenesis of corpus callosum: absent CSP, colpocephaly (teardrop-shaped posterior horns), and widely spaced parallel gyri (sunburst or racing-car appearance) [3,4].

VENTRICULOMEGALY CLASSIFICATION AND ASSOCIATED ANOMALIES

Ventriculomegaly is defined as an atrial width ≥ 10 mm at the level of the glomus of the choroid plexus (as described in Chapter 3). When ventriculomegaly is identified, a systematic search for associated anomalies is mandatory because the prognosis is critically dependent on whether the ventriculomegaly is isolated or syndromic [6]. The following associations are of greatest clinical importance:

Table 8.1: Associated anomalies with ventriculomegaly and their clinical significance. Isolated mild ventriculomegaly (10-12 mm) in a chromosomally normal fetus carries approximately 90% chance of normal neurodevelopmental outcome; severe ventriculomegaly (>15 mm) has a substantially higher rate of adverse outcome even when apparently isolated [3,4].

Associated Finding	Likely Aetiology	Prognosis	Refs
Open spina bifida	Arnold-Chiari II (virtually 100% of open NTD) [1]	Neurodevelopmental outcome depends on lesion level [1]	[1,3]
Agenesis corpus callosum	Developmental malformation; chromosomal (T18, T13, 18p-) [4]	Variable; isolated ACC has ~70% normal outcome [4]	[4]
Cerebral haemorrhage	Maternal alloimmune thrombocytopenia, infection, vascular [3]	Guarded; depends on volume and timing [3]	[3]
Infection (CMV, Toxo)	Periventricular calcification, echogenic bowel, hepatomegaly [3]	Poor when periventricular calcifications present [3]	[3]
Chromosomal anomaly	T21, T18, T13; karyotype in all cases >15 mm [20,21]	Depends on karyotype [20]	[20,21]

HOLOPROSENCEPHALY SPECTRUM AND RECOGNITION

Holoprosencephaly (HPE) is caused by failure of cleavage of the embryonic prosencephalon into two cerebral hemispheres. It is classified as alobar (complete non-separation, monoventricle, fused thalami, no falx), semilobar (partial separation posteriorly), and lobar (nearly complete separation with only anterior fusion) [7]. Alobar HPE is the most severe and most recognisable sonographically — a large central fluid-filled monoventricle fills the skull with no midline echo, no CSP, and fused thalami forming a single midline mass. Facial anomalies (cyclopia, proboscis, midline cleft lip and palate) are present in 75% of alobar HPE cases and are pathognomonic of the severe end of the spectrum [8].

Chromosomal abnormalities (particularly trisomy 13) are found in approximately 50% of HPE cases, making karyotyping mandatory. The prognosis for alobar HPE is uniformly poor — the majority die in the neonatal period and survivors have profound disability [9].

Clinical Pearl HPE versus Hydranencephaly

- Holoprosencephaly: a monoventricle with fused thalami, cortical rim of brain tissue present, falx absent anteriorly.
- Hydranencephaly: virtually complete absence of cerebral hemispheres replaced by CSF, with an intact falx (present posteriorly). The cortical mantle is absent or a thin rim only. Caused by bilateral ICA occlusion [3,4].
- The distinction matters: HPE has chromosomal implications for future pregnancies; hydranencephaly is usually sporadic vascular [3].

POSTERIOR FOSSA ANOMALIES DANDY-WALKER AND ARACHNOID CYSTS

The Dandy-Walker malformation (DWM) spectrum includes classic DWM (enlarged posterior fossa cyst communicating with fourth ventricle, complete or partial vermian agenesis, upward displacement of tentorium), Dandy-Walker variant (partial vermian hypoplasia without cyst enlargement), and mega cisterna magna (enlarged cisterna magna >10 mm with intact vermis and normal fourth ventricle) [10]. Classic DWM is associated with chromosomal abnormalities (trisomy 18, 13, triploidy) in approximately 50% and with other structural anomalies in 50-70% of cases [11]. Isolated mega cisterna magna without vermian abnormality carries an excellent prognosis and does not require termination counselling.

AGENESIS OF CORPUS CALLOSUM

Agenesis of the corpus callosum (ACC) is characterised by three sonographic signs on axial scan: (1) absent CSP (the most reliable indicator — no CSP at the transthalamic plane mandates further investigation in all cases); (2) colpocephaly — the posterior horns of the lateral ventricles are relatively dilated and teardrop-shaped; and (3) widely spaced parallel lateral ventricles on coronal section, producing the 'Viking helmet' or 'racing car' appearance [12]. Associated anomalies are present in approximately 50% of cases; isolated ACC (confirmed on fetal MRI ≥ 22 weeks) carries approximately 70% chance of normal intelligence in the chromosomally normal fetus [13].

CONGENITAL HEART DISEASE SYSTEMATIC DIAGNOSIS**Epidemiology and Screening Performance**

Congenital heart disease (CHD) is the most common major structural anomaly, affecting approximately 6-8 per 1000 live births. The four-view cardiac screening protocol (four-chamber view, LVOT, RVOT, 3VT — as detailed in Chapter 3) detects approximately 75-85% of major cardiac defects amenable to prenatal detection in experienced hands [14]. The detection rate for specific defects varies enormously: transposition of the great arteries (TGA) — the most common cyanotic CHD — has a detection rate of 65-70% with four-

view screening; tetralogy of Fallot 65-75%; hypoplastic left heart syndrome (HLHS) 90-95% [15].

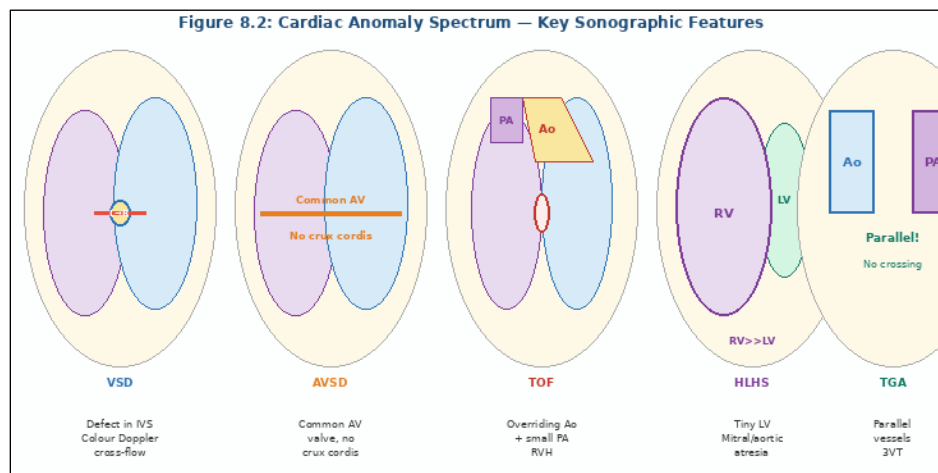


Figure 8.2. Cardiac anomaly spectrum. VSD: defect in the interventricular septum with colour Doppler demonstrating left-to-right shunting. AVSD: common atrioventricular valve with absence of the atrioventricular crux — the most common CHD in trisomy 21. TOF: overriding aorta straddling the IVS with a VSD below, small pulmonary artery, and right ventricular hypertrophy. HLHS: tiny left ventricle with mitral and/or aortic atresia the right ventricle is massively enlarged and dominates the four-chamber view. TGA: parallel great vessels at the 3VT level without the normal crossover the aorta and pulmonary artery fail to cross [6,7,8].

Key Cardiac Anomalies: Diagnosis and Prognosis

Table 8.2: Major congenital heart defects, sonographic features, chromosomal risk, and prognosis. TGA carries an excellent prognosis with surgical repair if detected prenatally (planned delivery at a cardiac centre); undetected TGA presenting in collapse carries 15-30% early mortality [7,8].

Anomaly	Key Sonographic Feature	Chromosomal Risk	Prognosis / Notes
VSD (isolated)	Defect in IVS; colour Doppler cross-flow [6]	Low if isolated [20]	Small: may close spontaneously. Large: surgical repair [7]
AVSD (complete)	Common AV valve; no crux cordis; primum ASD [6]	T21 in 40-50% [9,25]	Surgical repair ~6 months; excellent outcome if isolated [9]

Table 8.2 Continued...

TOF	Overriding aorta (>50%), VSD, small PA, RVH [6]	T21, 22q11 del [20,25]	Surgical repair in infancy; good long-term outcome [7]
HLHS	Tiny LV, mitral/aortic atresia; RV dominant [6,8]	Low (<5%) [7]	Norwood or transplant; 5-yr survival ~65-70% [7,8]
TGA	Parallel great vessels (no crossing) at 3VT [6]	Low (<5%) [7]	Arterial switch at birth; excellent outcome if detected [7,8]
Ebstein's anomaly	Apically displaced tricuspid valve; massively dilated RA [6]	Low; lithium association [7]	Wide spectrum; severe forms have poor prognosis [7]

Increased Nuchal Translucency and CHD

An increased nuchal translucency (NT) at 11-14 weeks in a chromosomally normal fetus is associated with a 3-5% risk of major structural CHD — predominantly the right heart lesions (pulmonary stenosis, TOF, AVSD) and left heart lesions (HLHS, coarctation) [16]. The risk increases as the NT increases: NT 3.5-4.4 mm carries approximately 15% CHD risk; NT $\geq$ 6.5 mm carries a 30-40% risk [26]. All fetuses with NT $\geq$ 3.5 mm and normal karyotype should be referred for fetal echocardiography at 18-22 weeks [17].

Medico-legal warning increased NT and fetal echocardiography

- A normal second-trimester four-view cardiac screen does not negate the need for specialist fetal echocardiography when NT was $\geq$ 3.5 mm at 11-14 weeks.
- The four-view screen has a 75-85% sensitivity for major CHD; fetal echocardiography by a trained cardiologist achieves >95% sensitivity. These are not equivalent [6,7,25].
- Failure to arrange fetal echocardiography after NT $\geq$ 3.5 mm with normal karyotype is a departure from the standard of care in most specialist guidelines [25,26].

THORACIC ANOMALIES CDH, CCAM, AND BPS

Congenital Diaphragmatic Hernia (CDH)

Congenital diaphragmatic hernia (CDH) complicates approximately 1 in 2500-4000 pregnancies and carries a mortality of 25-30% in unselected series. Left-sided CDH (75% of cases) is characterised by herniation of the stomach, small bowel, and sometimes the

liver into the left hemithorax, with leftward displacement of the mediastinum and heart [18]. The liver-to-thorax ratio (LiTR) and the lung-to-head ratio (LHR) — measured as the product of the longest two orthogonal diameters of the contralateral lung divided by the head circumference — are the primary prognostic indicators: observed LHR/expected LHR (o/e LHR) <25% predicts mortality >65% and is the threshold for consideration of fetal tracheal occlusion (FETO) at specialist centres [19].

The key sonographic features of CDH are: (1) cardiac displacement away from the side of the hernia; (2) absence of the normal stomach bubble in the left upper abdomen (instead, the stomach may be seen within the thorax at the level of the heart); (3) absence of the diaphragmatic line on the affected side; and (4) polyhydramnios in severe cases (due to oesophageal compression impairing swallowing) [20].

Checklist CDH Sonographic Assessment Protocol

- Confirm side: cardiac displacement direction indicates contralateral hernia. Right-sided CDH: liver herniates; liver-in-thorax carries worse prognosis [12].
- Lung measurements: measure contralateral lung on axial view at four-chamber level. Calculate observed/expected LHR (o/e LHR) using gestation-specific nomograms. o/e LHR <25% = poor prognosis; ≥45% = good prognosis [12].
- Stomach position: within thorax (left CDH) confirms gastric herniation. Right-sided CDH: stomach remains in abdomen but liver is in chest.
- Liver position: 'liver-in' (hepatic herniation into thorax) is the most powerful adverse prognostic indicator and should be specifically sought and reported [12].
- Associated anomalies: CDH is associated with CHD (10-15%), chromosomal anomaly (T18, T13) in 10-20% — perform a complete anatomy survey and offer karyotyping [11,12].
- Amniotic fluid: polyhydramnios in ~20% of CDH document DVP [11].

CONGENITAL PULMONARY AIRWAY MALFORMATION (CPAM) AND BRONCHOPULMONARY SEQUESTRATION (BPS)

CPAM (formerly CCAM) is a cystic lung lesion arising from abnormal branching of the bronchopulmonary tree, classified by cyst size (macrocytic ≥5 mm; microcystic <5 mm) [11,19]. The CPAM volume ratio (CVR = CPAM volume / head circumference) predicts the risk of hydrops and the need for fetal intervention: CVR >1.6 is associated with a 75% risk of hydrops; CVR <1.6 carries a <3% risk [11]. Most CPAMs regress in size during the third trimester; serial monitoring with CVR calculation is the cornerstone of surveillance [21].

Bronchopulmonary sequestration (BPS) is a non-functioning lung mass with a systemic arterial blood supply (from the aorta) that does not communicate with the bronchial tree. The pathognomonic feature is a feeding vessel from the thoracic or abdominal aorta detectable by colour Doppler the 'vascular pedicle' [22]. BPS is typically echogenic (microcystic), predominantly left-sided, and often regresses spontaneously. When BPS and CPAM features coexist (hybrid lesion), the distinction may require postnatal CT or MRI [23].

ABDOMINAL WALL DEFECTS GASTROSCHISIS AND OMPHALOCELE

Abdominal wall defects are detected at the 18-22 week anomaly scan by failure to confirm a normal skin-bridged cord insertion. The two most common defects — gastroschisis and omphalocele — are sonographically distinct and carry fundamentally different clinical implications [24].

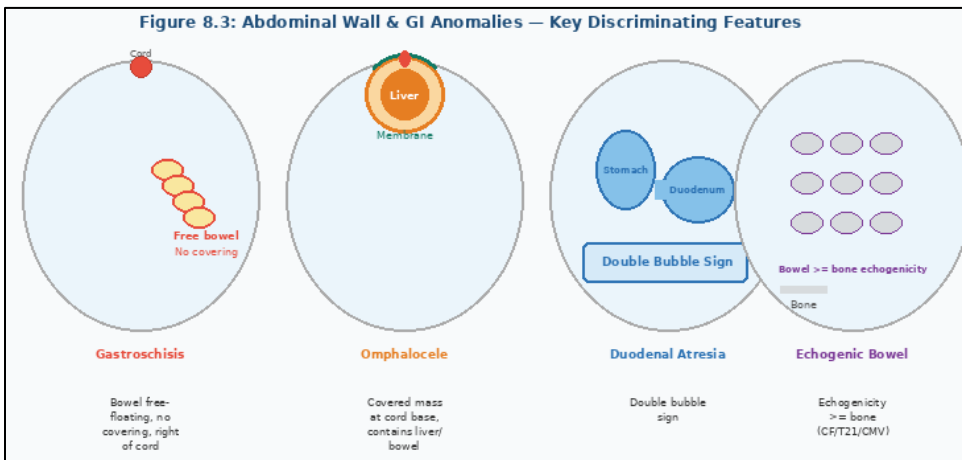


Figure 8.3: Abdominal wall and GI anomalies. Gastroschisis: free-floating bowel herniating through a right paraumbilical wall defect with no covering membrane — the cord inserts normally to the left of the defect. Omphalocele: a membrane-covered mass containing bowel and/or liver herniating through the umbilical ring at the cord base — the cord inserts at the apex of the sac. Duodenal atresia: the double bubble sign — two fluid-filled structures (stomach and dilated duodenal cap) in the fetal abdomen separated by the pylorus; associated with trisomy 21 in 30%. Echogenic bowel: bowel echogenicity equal to or greater than adjacent bone — associated with CF, CMV, fetal growth restriction, and chromosomal anomaly [14,15].

Table 8.3: Gastroschisis versus omphalocele the key discriminating features. The distinction is not merely academic: an omphalocele mandates a full chromosomal and structural assessment; a gastroschisis requires bowel surveillance for complications of prolonged exposure but rarely has chromosomal implications [14,15,28].

Feature	Gastroschisis	Omphalocele	References
Defect site	Right paraumbilical; usually 2-4 cm [14]	Central, through umbilical ring [14]	[14,15]
Covering membrane	Absent — bowel free-floating [14]	Present — peritoneal/amniotic membrane [14]	[14]
Cord insertion	Normal — to the left of defect [14]	At apex of sac [14]	[14,15]
Liver herniated?	Rarely [14]	In 50% — worsens prognosis [28]	[14,28]
Chromosomal risk	Very low (<1%) [15]	30-40% (T18, T13, T21) [28]	[15,28]
Associated anomalies	Bowel atresia (10-15%); growth restriction [15]	CHD (30-50%); chromosomal (30-40%) [20,28]	[15,28]
Delivery planning	Term vaginal delivery acceptable; NICU immediately [14,15]	Elective CS often preferred for liver-in [14]	[14]

GASTROINTESTINAL ANOMALIES OBSTRUCTION AND ECHOGENIC BOWEL

Upper GI Obstruction Oesophageal and Duodenal Atresia

Oesophageal atresia (OA) affects approximately 1 in 3500 pregnancies and is most reliably detected by the combination of persistently absent or small stomach bubble (on repeated scans at least 30 minutes apart) and polyhydramnios [25]. Approximately 85% of cases have a tracheo-oesophageal fistula (TOF) that allows some amniotic fluid to reach the stomach, making the stomach visible (though small) in the majority — which is why the 'absent stomach' criterion is not as reliable as might be expected [26]. The VACTERL association (Vertebral, Anal atresia, Cardiac, Tracheo-Esophageal, Renal, Limb defects) should be actively excluded when OA is suspected [27].

Duodenal atresia produces the classic double bubble sign two cystic structures in the upper abdomen connected by the pylorus representing the distended stomach and the obstructed duodenum [28]. Polyhydramnios is present in approximately 50% by the third trimester. Trisomy 21 is associated with duodenal atresia in approximately 30% of cases, making karyotyping mandatory [29].

Echogenic Bowel A Critically Important Soft Marker

Echogenic bowel is defined as bowel echogenicity equal to or greater than that of adjacent bone (the iliac crest or femur), assessed without colour Doppler and in the absence of calcifications [30]. It is found in approximately 0.5-1.5% of mid-trimester scans and is associated with a broad and clinically important differential diagnosis: cystic fibrosis (CF) carrier testing should be offered to both parents (CF is the cause in approximately 1.5-3% of echogenic bowel cases); fetal anaemia (swallowed blood from abruption or haemolysis); cytomegalovirus (CMV) infection; trisomy 21 and 18 (likelihood ratio approximately 6-7 for T21) [31]. When echogenic bowel is grade 2 or 3 (equal to or brighter than bone), the complete investigation protocol should be initiated [32].

Checklist Echogenic Bowel Investigation Protocol

- Confirm grade: must be equal to or greater than adjacent bone echogenicity without gain adjustment. Grade 1 (mildly bright) does not meet diagnostic threshold.
- Search for associated anomalies: ventriculomegaly, hepatic calcifications, growth restriction, polyhydramnios — each raises the probability of a significant aetiology.
- Offer CF carrier testing to both parents: if both are carriers (1 in 4 chance of affected fetus), discuss amniocentesis for CF gene mutation analysis.
- Maternal CMV and toxoplasmosis serology: if primary infection suspected (IgG seroconversion or high IgM).
- Karyotype / cfDNA: T21 and T18 are associated with echogenic bowel [20,22].
- Growth scan at 28-32 weeks: echogenic bowel from swallowed blood (abruption) is associated with FGR and placental insufficiency [22].

URINARY TRACT ANOMALIES CLASSIFICATION AND MANAGEMENT

Urinary tract anomalies (UTA) are the most common group of fetal anomalies detected by prenatal ultrasound, affecting approximately 0.5-1% of all pregnancies. Most are mild (renal pyelectasis, mild hydronephrosis) with excellent postnatal outcomes; a critical minority — bilateral renal agenesis, bilateral MCDK, posterior urethral valves — are life-threatening [33].

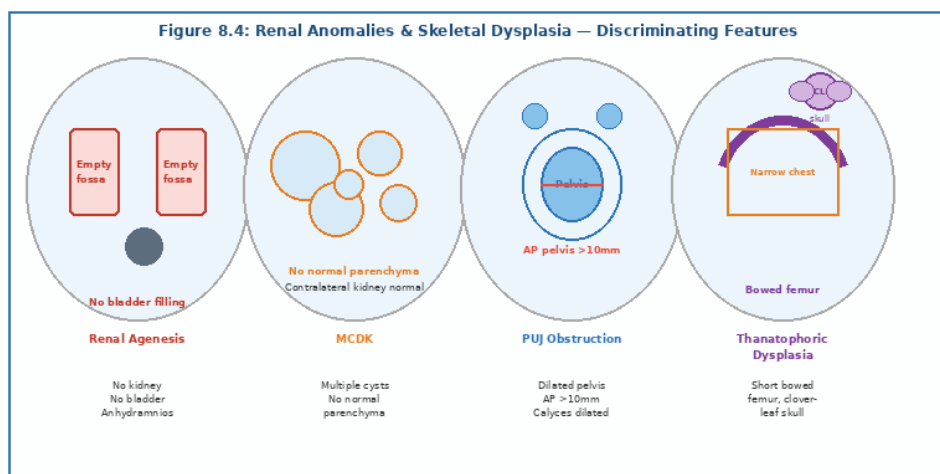


Figure 8.4: Renal anomalies and skeletal dysplasia. Renal agenesis: empty renal fossae bilaterally with absent bladder and anhydramnios — the adrenal gland fills the renal fossa ('lying down adrenal sign'). MCDK: a cluster of non-communicating cysts of varying sizes replacing the normal renal parenchyma — no excretory function; contralateral kidney normal (if unilateral). PUJ obstruction: dilated renal pelvis with AP diameter >10 mm and dilated calyces; the ureter is not dilated (distinguishing it from vesicoureteric junction obstruction). Thanatophoric dysplasia: severely shortened bowed femur with a cloverleaf skull deformity (kleeblattschaedel) and narrow chest — lethal skeletal dysplasia with the highest incidence in this group [5,17].

Table 8.4: Urinary tract anomalies: sonographic features, prognosis, and key management steps. The keyhole sign (dilated bladder + dilated posterior urethra resembling a keyhole on sagittal view) is pathognomonic of posterior urethral valves in a male fetus and mandates immediate specialist referral [17].

Anomaly	Sonographic Features	Prognosis / Key Action	References
Bilateral renal agenesis	Empty fossae, no bladder, anhydramnios; lying-down adrenal [5]	Lethal — Potter sequence; counselling [17]	[17,27]
Unilateral renal agenesis	One empty fossa; contralateral hypertrophy; liquor normal [18]	Good if isolated; renal function normal with one kidney [18,27]	[18,27]
MCDK (bilateral)	Multiple cysts replacing both kidneys; no bladder; anhydramnios [5]	Lethal — as bilateral renal agenesis [17]	[17]
MCDK (unilateral)	Cysts one side; contralateral kidney normal; liquor normal [5]	Good; most involute by 2 years; monitor contralateral [5,18]	[5,18]

Table 8.4 Continued...

PUJ obstruction	Renal pelvis AP >10 mm at 18-22 wk; dilated calyces; normal ureter [18]	Most mild cases resolve; surgery if AP >20 mm at term [18,27]	[18,27]
Posterior urethral valves	Male fetus; bilateral hydronephrosis; thick-walled bladder; dilated posterior urethra (keyhole sign); oligohydramnios [17]	Prognosis depends on renal function; fetal cystoscopy in selected cases [17]	[17]

Posterior Urethral Valves the Keyhole Sign

Posterior urethral valves (PUV) affect male fetuses exclusively and represent the most common cause of severe obstructive uropathy in the neonate [34]. The pathognomonic ultrasound finding is the keyhole sign — a dilated urinary bladder communicating with a dilated posterior urethra, creating a keyhole-shaped fluid structure in the pelvis on sagittal view [35]. Additional features include bilateral hydroureteronephrosis, echogenic renal cortex (indicating dysplasia from back-pressure), thick-walled hyperechoic bladder, and oligohydramnios or anhydramnios in severe cases [36]. Oligohydramnios with bilateral renal cortical changes is a poor prognostic indicator and associated with pulmonary hypoplasia.

Clinical Pearl Distinguishing PUV from Prune Belly Syndrome

1. PUV: male fetus; dilated posterior urethra (keyhole sign); thick bladder wall; bilateral hydroureter and hydronephrosis; oligohydramnios in severe cases.
2. Prune belly syndrome: male fetus; massively dilated bladder (megacystis) without posterior urethral dilatation — the urethra is patent; abdominal wall deficiency visible on sagittal scan; hydroureteronephrosis [17].
3. The distinction matters because PUV is treatable by postnatal valve ablation, whereas prune belly requires complex multi-staged surgery [17].

Skeletal Dysplasias Recognition and Lethal versus Non-Lethal Classification

Skeletal dysplasias affect approximately 1 in 4000 pregnancies and collectively carry a mortality of approximately 25%. The essential first question when a short femur is identified is: is this skeletal dysplasia lethal or not? The two most reliable indicators of lethality are: (1) the chest-to-abdomen ratio — a thoracic circumference below the 5th centile for gestation (narrow chest) indicates pulmonary hypoplasia and predicts lethality with approximately 85% sensitivity; and (2) bone mineralisation — severely reduced echogenicity of long bones and skull (acoustic shadowing absent) indicates osteogenesis imperfecta type II, which is uniformly lethal [37].

Table 8.5: Lethal versus non-lethal skeletal dysplasias. The chest-to-abdomen circumference ratio below the 5th centile, absent bone acoustic shadowing, and bowed long bones with multiple fractures are the most reliable indicators of lethality at the 18–22-week scan [5].

Dysplasia	Key Features	Lethal?	References
Thanatophoric dysplasia	Severely short bowed femurs; cloverleaf skull (type 2); flat vertebrae; narrow chest [5]	YES — lethal. Pulmonary hypoplasia universal [5]	[5]
Achondroplasia	Moderately short femur; large head; trident hands; spine narrowing [5]	NO — good prognosis for intelligence and lifespan [5]	[5]
OI type II	Severely undermineralised bones; multiple fractures in utero; flat chest [5]	YES — lethal. Ribs beaded; skull compressible on probe [5]	[5]
OI type III	Moderate bowing; fractures; some mineralisation present [5]	NO but severe disability [5]	[5]
Short-rib polydactyly	Extremely short ribs; polydactyly; narrow chest; CHD [5]	YES lethal in most forms [5]	[5]

THE MULTIDISCIPLINARY TEAM PATHWAY AND POST-DIAGNOSIS COUNSELLING

When a fetal anomaly is identified, the ultrasound report is the beginning of a clinical pathway, not the end of it. The sonologist's role extends beyond image interpretation to ensuring that the right clinical team is activated in the right sequence [38]. The reporting language must be precise, prognostically accurate, and free of assumptions about parental preferences — it is the clinician's role (and the medical team's role), not the sonologist's, to counsel parents about the implications of a diagnosis [39].

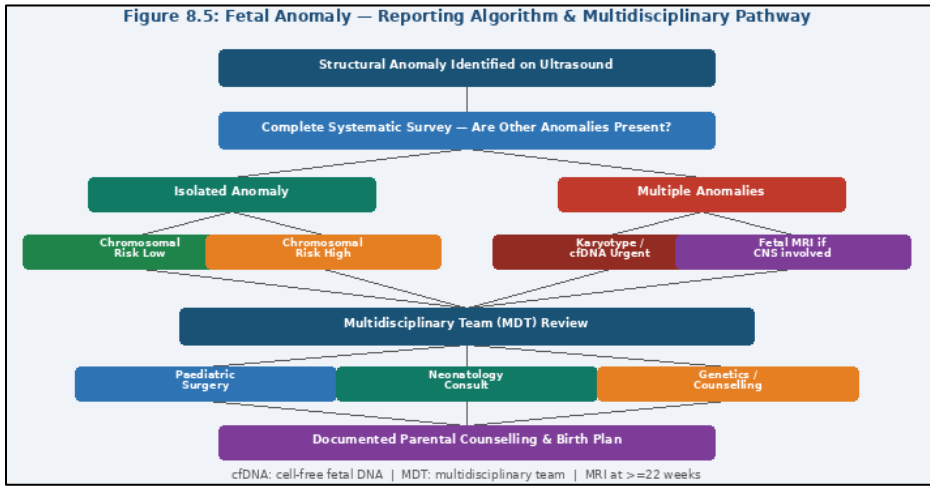


Figure 8.5: Fetal anomaly reporting algorithm and multidisciplinary team pathway. When a structural anomaly is identified, the first step is completing the systematic survey to identify additional anomalies — the presence of multiple anomalies substantially raises chromosomal risk and changes prognosis. The pathway then diverges based on chromosomal risk assessment and the organ systems involved, triggering specific specialist referrals. All cases should ultimately reach a documented multidisciplinary team (MDT) discussion before parental counselling, ensuring that the prognostic information provided to parents is comprehensive, consistent, and clinically accurate [2,5].

Reporting an Anomaly: Mandatory Elements

Checklist Anomaly Report: Mandatory Documentation

- Describe the anomaly precisely: location, dimensions (three planes), echogenicity, relationship to adjacent structures. Avoid imprecise language ('abnormal-looking brain').
- State the most likely diagnosis and differential: 'Appearances are most consistent with X; Y and Z cannot be excluded and specialist assessment is recommended.'
- Document the systematic survey: state explicitly which systems were assessed and their findings — do not document only the abnormal system.
- State chromosomal risk: 'This finding is associated with chromosomal abnormality in approximately X% of cases.' Offer amniocentesis / cfDNA discussion.
- State associated anomaly search: 'No additional anomalies identified on extended survey' OR 'The following additional anomalies were identified: [list]'.
- Recommend the specific next steps: fetal medicine referral / fetal echocardiography / fetal MRI / genetics counselling — with a timeframe (urgent / within 1 week / routine).

Checklist Anomaly Report: Mandatory Documentation

- Document communication: 'Findings discussed with [senior clinician]. Parental counselling arranged by [team].' Do not communicate uncertain diagnoses to parents without appropriate specialist support present [2,5].

ROLE OF FETAL MRI

Fetal MRI at ≥ 22 weeks provides superior soft-tissue resolution for CNS anomalies compared with ultrasound and is indicated when: (1) CNS anomaly is suspected but incompletely characterised on ultrasound (ACC, posterior fossa anomaly, ventriculomegaly with uncertain aetiology); (2) maternal obesity or oligohydramnios limits ultrasound resolution; (3) a lethal diagnosis has been made and the parents require additional certainty before a major management decision [4,12]. MRI does not replace ultrasound as the first-line modality — it is a complementary investigation that should be requested through the fetal medicine team [40].

Cell-Free Fetal DNA (cfDNA) and Invasive Testing

Cell-free fetal DNA (cfDNA, non-invasive prenatal testing — NIPT) screens for trisomies 21, 18, and 13 with sensitivity $>99\%$ and specificity $>99.9\%$ in high-risk populations [41]. However, cfDNA is a screening test, not a diagnostic test — a positive cfDNA result requires confirmation by invasive testing (chorionic villus sampling or amniocentesis) before a definitive diagnosis is communicated to parents or a pregnancy termination is arranged [42]. When a structural anomaly is identified on ultrasound, invasive testing is preferred over cfDNA because: (1) cfDNA does not detect submicroscopic chromosomal rearrangements (microdeletions/duplications) which are found in 4-6% of structurally abnormal fetuses with normal conventional karyotype; (2) a negative cfDNA result does not exclude clinically important chromosomal abnormalities in this context [43].

Medico-Legal Warning cfDNA Is Not Diagnostic

- Communicating a positive cfDNA result to a patient as a diagnosis of trisomy 21 (or any other condition), without explaining that confirmatory invasive testing is required, is a medico-legally dangerous practice.
- Equally, using a negative cfDNA result to falsely reassure a patient that their anomaly-scan finding has no chromosomal basis is inappropriate. In the context of a structural anomaly, invasive testing with microarray analysis should be offered directly [20,21].

Reporting Templates: Fetal Anomaly

Template A: Isolated Structural Anomaly Report Framework

Field	Content
Clinical context	GA: [X wk + Y d]. Indication: [routine anomaly scan / referral for suspected anomaly]. Scan quality: [good / limited by maternal habitus / fetal position].
Anomaly description	[System]: [Precise anatomical description of the anomaly — location, dimensions in three planes, echogenicity, relationship to normal structures]. Example: 'Left lateral ventricle: atrial width [X] mm at the level of the glomus of the choroid plexus. The choroid plexus hangs dependently in the dilated ventricle (dangling choroid sign). Right atrial width: [X] mm (normal).'
Differential diagnosis	'Appearances are most consistent with [diagnosis]. Differential diagnoses include [list]. Specialist assessment is required to confirm the diagnosis and exclude associated findings.'
Associated anomalies	'Extended systematic survey performed. [No additional structural anomaly identified / The following additional anomalies were identified: (list)].' — document each system assessed.
Chromosomal risk	'[Anomaly] is associated with chromosomal abnormality in approximately [X]% of cases. Karyotyping by amniocentesis or cfDNA screening with confirmatory invasive testing is recommended. This has been discussed with [name].'
Recommended actions	'1. Fetal medicine unit referral — [urgent / within 1 week]. 2. Fetal echocardiography — [if CHD risk]. 3. Fetal MRI — [if CNS anomaly incompletely characterised]. 4. Genetics counselling — [if chromosomal or syndromic differential].'
Communication	'Findings communicated to [senior clinician] at [time]. Parental counselling to be arranged by the fetal medicine team. Findings not disclosed to the patient pending specialist review: [Yes / No — specify what was communicated and by whom].'

Template B: Multiple Anomalies Chromosomally High-Risk Report

Field	Content
Anomaly 1	[System 1]: [Precise description].
Anomaly 2	[System 2]: [Precise description]. Note: the combination of [anomaly 1] and [anomaly 2] raises the probability of [specific chromosomal anomaly, e.g. trisomy 18].
Additional anomalies	[System 3, 4...]: [Description]. / 'No further anomalies identified despite extended survey.'
Overall impression	'The combination of findings is highly suggestive of [syndrome / chromosomal anomaly]. Invasive testing with chromosomal microarray analysis is recommended urgently.'
Fetal wellbeing	Cardiac activity: [present]. Growth: EFW [X]g ([Xth] centile). Liquor: DVP [X]cm. Doppler: [normal / abnormal].
URGENT plan	'Immediate senior obstetric and fetal medicine review arranged. Invasive testing offered and [accepted / declined — documented in notes]. MDT meeting to be convened [date].'

Key Takeaways

1. When a CNS anomaly is found, the absent CSP is never a normal variant after 18 weeks — it is the red flag that mandates dedicated neurosonography and fetal MRI at ≥ 22 weeks before any prognostic statement is made to parents [3,4].
2. The lemon and banana cranial signs have 95% sensitivity for open spina bifida between 16-24 weeks — an absent cisterna magna on the transcerebellar plane should trigger an immediate full spinal survey [1,3].
3. All fetuses with NT ≥ 3.5 mm and normal karyotype require fetal echocardiography at 18-22 weeks — the four-view screen is not equivalent to fetal echocardiography [25,26].
4. The TGA diagnosis is made at the 3VT level: parallel great vessels without the normal crossing pattern. Early prenatal diagnosis enables planned delivery at a cardiac centre, reducing early mortality from $>15\%$ to $<5\%$ [7,8].
5. Gastroschisis has a very low chromosomal risk ($<1\%$) but a high risk of bowel complications; omphalocele has a 30-40% chromosomal risk and requires karyotyping in all cases [14,15,28].
6. Duodenal atresia ('double bubble') carries a 30% trisomy 21 risk — always offer karyotyping and perform a dedicated cardiac assessment [20].

Key Takeaways: Continued...

7. Echogenic bowel equal to or greater than bone echogenicity mandates CF carrier testing, CMV serology, karyotype discussion, and a growth scan at 28-32 weeks [22].
8. The keyhole sign in a male fetus (dilated bladder + dilated posterior urethra) is pathognomonic of posterior urethral valves — refer to fetal medicine and paediatric urology immediately [17].
9. Lethal skeletal dysplasia is suggested by a thoracic circumference below the 5th centile (pulmonary hypoplasia), severely bowed or fractured long bones, and absent bone acoustic shadowing. Do not provide reassurance based on isolated short femur alone [5].

cfDNA is a screening test, not a diagnostic test. A structural anomaly on ultrasound requires invasive testing with chromosomal microarray, not just cfDNA — microarray detects clinically significant microdeletions missed by cfDNA in 4-6% of structurally abnormal fetuses [20,21].

OBSTETRIC ULTRASOUND IN SPECIAL SITUATIONS

Beyond the systematic protocols of the anomaly scan and the growth surveillance visit lies a series of clinical situations that demand a different — and often more technically demanding — application of ultrasound. These include the deployment of advanced imaging modalities (3D/4D ultrasound, tomographic imaging, STIC for the fetal heart), the ultrasound guidance of invasive prenatal procedures, the challenging assessment of the posterior fossa and complex CNS anatomy, the recognition and investigation of hydrops fetalis in all its aetiological diversity, the post-dates pregnancy requiring intensified biophysical surveillance, the intrapartum period where ultrasound is increasingly replacing clinical examination for fetal head position and station, and the broader framework of ultrasound safety in pregnancy. This chapter provides practical guidance for each of these special situations, with the technical detail and medico-legal awareness that clinical practice demands [1].

Advanced Ultrasound Modalities — 3D, 4D, and Tomographic Imaging

Principles of 3D/4D Ultrasound Acquisition

Three-dimensional (3D) ultrasound acquires a volumetric dataset by sweeping the transducer through a defined tissue volume, capturing a series of 2D frames that are subsequently reconstructed into a three-dimensional volume by the scanner software [2]. Four-dimensional (4D) ultrasound is simply real-time 3D acquisition — volume acquisition at sufficient frame rate (typically 5-15 volumes/second) to display fetal movement in real time [2]. The clinical value of these modalities in obstetrics lies not in their spectacle but in their ability to display anatomical planes that are geometrically impossible to acquire in 2D — particularly the coronal and sagittal views of the fetal face, the coronal view of the posterior fossa (for vermian assessment), and the simultaneous display of multiple orthogonal planes through any anatomical structure [3].

CLINICAL INDICATIONS FOR 3D/4D ULTRASOUND

Three-dimensional ultrasound is a complementary — not a replacement — modality for obstetric scanning. It has established clinical utility in specific situations where it provides information beyond 2D capability [4].

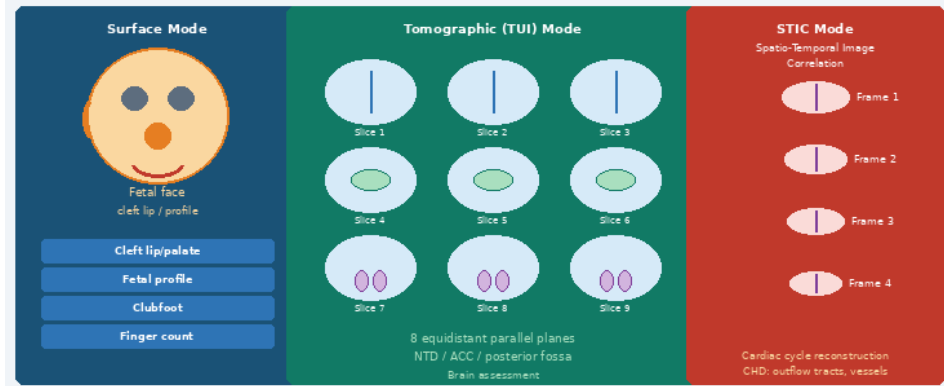
Figure 9.1: 3D/4D Ultrasound — Acquisition Modes & Clinical Applications

Figure 9.1: Advanced ultrasound acquisition modes and clinical applications. Surface rendering (left): the rendered fetal face allows assessment of facial clefts, dysmorphic features, and profile abnormalities that may be invisible on standard 2D axial views — particularly mid-face defects and bilateral cleft lip. Tomographic ultrasound imaging or TUI (centre): a grid of 8 equidistant parallel planes through the fetal brain, acquired from a single 3D volume, allowing simultaneous assessment at multiple levels — invaluable for NTD, posterior fossa, and corpus callosum assessment. STIC mode (right): spatio-temporal image correlation reconstructs the cardiac cycle from a 3D acquisition, enabling frame-by-frame analysis of all cardiac chambers and outflow tracts in a single volume — particularly useful when outflow tract views are unobtainable in 2D [1,2].

Table 9.1: Clinical indications for 3D/4D ultrasound in obstetrics. These modalities add specific anatomical information in targeted situations; routine use for all patients is not supported by evidence and adds acquisition time and cost without proven benefit in low-risk populations [1,2].

Indication	3D/4D Modality	Clinical Advantage over 2D
Fetal face assessment	Surface rendering; multiplanar display [1]	Coronal lip/palate plane unobtainable in 2D in many cases [2]
Posterior fossa / vermis	TUI (tomographic ultrasound imaging) in coronal plane [2]	Midsagittal vermian plane reproducible from 3D volume [2,17]
Corpus callosum	Multiplanar reconstruction; coronal view [2]	Coronal plane for callosal body not obtainable in 2D mid-pregnancy [2]
Fetal cardiac outflow tracts	STIC (spatio-temporal image correlation) [1]	All outflow tract views from one acquisition; reduces operator dependence [1]

Table 9.1 Continued....

Skeletal anomalies	Surface + maximum mode rendering [2]	Bone architecture, polydactyly, craniosynostosis [2]
Uterine morphology	Coronal reconstruction of uterine cavity [2]	Classification of Mullerian anomalies; septate vs bicornuate [2]

TOMOGRAPHIC ULTRASOUND IMAGING (TUI) FOR BRAIN ASSESSMENT

TUI, also called multiplanar tomographic imaging, generates a grid of parallel slices at user-defined intervals from a 3D brain volume. The standard neurological TUI protocol applies 8 equidistant planes from the transcerebellar to the transthalamic level, displayed simultaneously. This allows the entire supratentorial and infratentorial brain to be reviewed in a single image, facilitating detection of focal pathology (periventricular heterotopia, subependymal pseudocysts, cortical development anomalies) that may be missed on sequential 2D acquisitions [5]. TUI is particularly valuable when fetal position makes sequential 2D planes difficult — a single 3D acquisition can be angulated retroactively to generate any desired plane.

Safety of 3D/4D Ultrasound — Thermal and Mechanical Indices

All diagnostic ultrasound, including 3D/4D modalities, must adhere to the ALARA principle (As Low as Reasonably Achievable). Two indices displayed on the scanner monitor quantify the potential for biological effect: the Thermal Index (TI) quantifies the potential for tissue heating (TIS for soft tissue, TIB for bone, TIC for cranium), and the Mechanical Index (MI) quantifies the potential for mechanical effects including cavitation [6]. For obstetric scanning, the recommended limits are TI <0.7 throughout pregnancy and TI <1.0 for scans of brief duration in the second and third trimesters; MI <0.3 is preferred in the first trimester when organogenesis is ongoing [7].

4D real-time scanning has a higher temporal average intensity than 2D scanning at equivalent output settings because the beam dwells longer in a given volume. The sonologist should reduce output power when performing prolonged 3D/4D acquisitions, particularly in the first trimester and particularly when the beam is directed at the fetal brain or orbit [8]. Doppler modes (especially pulsed-wave spectral Doppler) have higher TI than B-mode and should be used with the minimum dwell time necessary to obtain the measurement [9].

Safety Warning Doppler and Thermal Index in the First Trimester

- Pulsed-wave spectral Doppler (used for cardiac Doppler, DV Doppler, or MCA Doppler) has a TI of 1.5-2.5 in first-trimester applications — significantly above the recommended limit of 0.7.

Safety Warning Doppler and Thermal Index in the First Trimester: Continued...

- In the first trimester, use M-mode (not spectral Doppler) to confirm cardiac activity and measure fetal heart rate. Spectral Doppler applied to the embryonic heart before 10 weeks should be avoided unless clinically essential [21,24].
- The thermal index displayed on the scanner is the primary safety guide — if TI exceeds 0.7 during a first-trimester scan, reduce output power or switch to a lower-output mode [21].

INVASIVE PRENATAL PROCEDURES — ULTRASOUND GUIDANCE**Amniocentesis — Technique and Safety**

Amniocentesis is performed from 15 weeks onwards and involves the ultrasound-guided transabdominal insertion of a 20–22-gauge needle into a pool of amniotic fluid for the aspiration of 10-20 mL of fluid for karyotype, chromosomal microarray, biochemical assay, or infection studies [12,13]. The procedure-related pregnancy loss rate from modern meta-analyses is 0.11-0.30% above the background miscarriage rate — approximately 1 in 400 to 1 in 900 procedures [10].

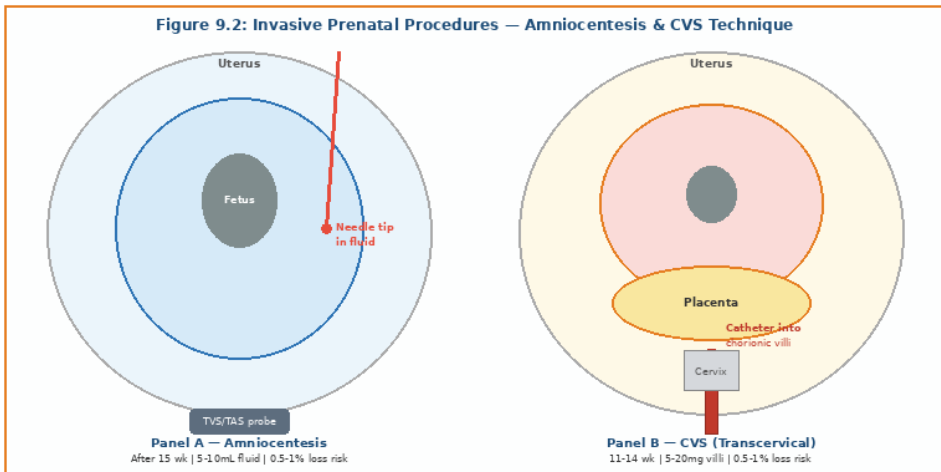


Figure 9.2: Invasive prenatal procedures. Panel A: Amniocentesis — a 20-22 gauge needle is inserted transabdominally under continuous ultrasound guidance, with the needle tip visible as an echogenic dot within a pool of amniotic fluid away from the fetus and placenta. The needle angle must keep the tip visible throughout the procedure. Panel B: Chorionic villus sampling (CVS) — transcervical approach shown; a flexible catheter is guided under transabdominal ultrasound surveillance into the placental substance (the echogenic chorionic villi); the transcervical approach is used at 11-14 weeks when the placenta is posterior or inaccessible transabdominally [12,13,15].

Checklist — Amniocentesis: Pre-procedure Ultrasound Assessment

- Gestational age confirmation: ≥ 15 weeks (risk higher at 14 weeks, increased talipes risk at < 15 weeks).
- Fetal viability: document cardiac activity before and after the procedure.
- Placental location: identify the placenta and plan the needle path to avoid it where possible. Transplacental amniocentesis is acceptable but increases feto-maternal haemorrhage risk.
- Fluid pocket selection: identify the largest accessible fluid pool away from the fetus, cord, and fetal face.
- Cord insertion: identify and avoid the placental cord insertion.
- Rhesus status: anti-D immunoglobulin required for Rh-negative unsensitised women — document [12,13,15].

Chorionic Villus Sampling (CVS) — Technique and Comparison with Amniocentesis

CVS is performed at 11-14 weeks and provides placental tissue (chorionic villi) for chromosomal or molecular analysis. It can be performed by either a transcervical approach (flexible catheter guided into the chorion frondosum under transabdominal ultrasound surveillance) or a transabdominal approach (needle biopsy of the placenta under direct ultrasound guidance), with the choice determined by placental location [11]. The procedure-related loss rate for CVS is comparable to amniocentesis at experienced centres: approximately 0.22% above background from the most recent meta-analysis [12].

Table 9.2: Amniocentesis versus CVS — key procedural differences. CVS allows earlier diagnosis (11-14 weeks) but carries the risk of confined placental mosaicism (CPM), where a chromosomal abnormality in the placenta does not reflect the fetal karyotype — requiring amniocentesis confirmation in approximately 1-2% of cases [12,14].

Feature	Amniocentesis	CVS	References
Optimal gestation	≥ 15 weeks [13]	11-14 weeks [12]	[12,13]
Sample obtained	Amniotic fluid (fetal cells, AFP) [13]	Chorionic villi (placental cells) [12]	[12,14]
Approach	Transabdominal only [13]	Transabdominal or transcervical [12]	[12,14]
Procedure loss rate	0.11-0.30% above background [15]	0.22% above background [15]	[13,15]
Result turnaround	2-3 weeks (culture); 48h (QF-PCR) [13]	7-10 days (culture); 48h (QF-PCR) [12]	[12,13]
Limitations	Cannot do before 15 wk; late diagnosis [13]	Confined placental mosaicism (1-2%) [12,14]	[12,14]

Ultrasound Guidance Principles for All Invasive Procedures

Checklist — Ultrasound Guidance: Universal Principles for All Invasive Procedures

- Pre-procedure: document fetal viability, position, placental site, liquor volume, and planned needle/catheter path. Obtain informed consent with procedure-specific risk figures [15].
- Needle/catheter visibility: the tip must be continuously visible throughout the procedure. An echogenic, hyperechoic tip is more visible than a smooth surface — use a needle guide or free-hand technique with the transducer parallel to the needle.
- Real-time monitoring: maintain continuous ultrasound display throughout the procedure. Stop immediately if the fetus moves into the needle path.
- Post-procedure: document fetal cardiac activity, absence of haemorrhage at the puncture site, and amniotic fluid level (amniocentesis). Re-confirm viability 30-60 minutes after the procedure.
- Documentation: report must include: needle/catheter size and approach, puncture site, any complications observed, sample volume and appearance, and fetal status post-procedure [12,13,15].

POSTERIOR FOSSA AND ADVANCED CNS ASSESSMENT

The FAST Protocol for Posterior Fossa Evaluation

The posterior fossa is one of the most challenging and most frequently misinterpreted regions in obstetric neurosonography. The most important single concept is that the appearance of the cisterna magna, the cerebellar vermis, and the fourth ventricle must be evaluated together — no single measurement is diagnostic in isolation [13]. The FAST (fetal anatomical structure tomography) approach to the posterior fossa acquires a 3D volume in the transcerebellar plane and reconstructs the midsagittal view of the vermis, which is not obtainable in the axial 2D plane and which provides the definitive assessment of vermian development [14].

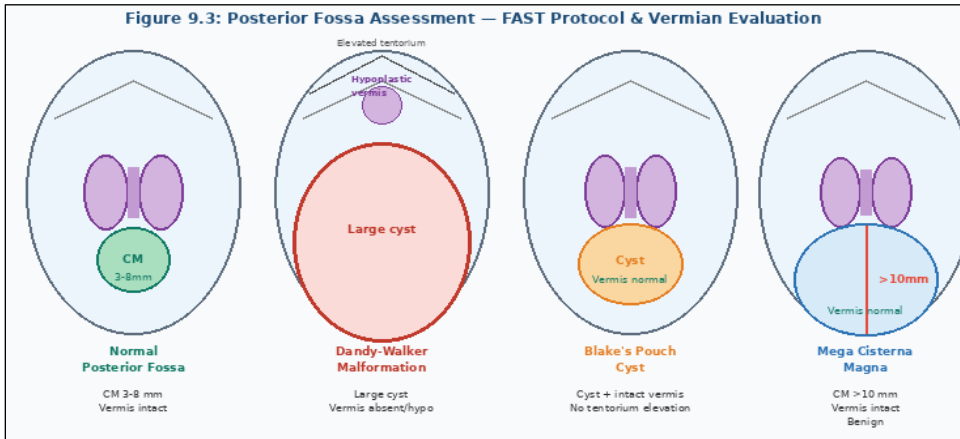


Figure 9.3: Posterior fossa assessment — differential diagnosis of four key entities. Normal: vermis intact, cisterna magna 3-8 mm, fourth ventricle normal size, tentorium in normal position. Dandy-Walker malformation (DWM): enlarged posterior fossa cyst communicating with the fourth ventricle, hypoplastic or absent vermis, elevated tentorium — the keystone diagnostic triad. Blake's pouch cyst: a cyst posterior to the cerebellum communicating with the fourth ventricle but with a morphologically intact vermis and no tentorium elevation — distinguishing this from DWM requires careful vermian assessment, ideally by 3D midsagittal reconstruction. Mega cisterna magna: cisterna magna >10 mm but intact vermis and normal fourth ventricle — a benign variant requiring no intervention [2,17].

Differentiating Posterior Fossa Anomalies

The four posterior fossa entities shown in Figure 9.3 carry radically different prognostic implications and must be distinguished with precision [15]:

Table 9.3: Posterior fossa differential diagnosis and prognosis. The distinction between DWM and Blake's pouch cyst is the vermian status — intact vermis virtually excludes DWM. Mega cisterna magna with intact vermis is benign and should not generate unwarranted parental anxiety. Referral for fetal MRI at ≥ 22 weeks is appropriate when the vermian status cannot be definitively confirmed on 2D ultrasound [2,17].

Entity	Vermis	CM Size	4th Ventricle	Prognosis
Normal	Intact [2]	3-8 mm [2]	Normal [2]	Normal [2]

Table 9.3 Continued...

Dandy-Walker malformation	Absent/hypoplastic [2]	>10 mm cyst [2]	Communicates with cyst [2]	Variable; 50% chromosomal [2,17]
Blake's pouch cyst	Intact [2]	Cyst present [2]	May communicate [2]	Good if isolated [2,17]
Mega cisterna magna	Intact [2]	>10 mm [2]	Normal size [2]	Excellent (benign) [2]
Cerebellar hypoplasia	Present but small [17]	Variable [17]	Normal [17]	Poor neurodevelopment [17]

Clinical Pearl — The Midsagittal Vermis: The One View That Changes Everything

- The definitive assessment of the cerebellar vermis requires a midsagittal plane — which cannot be obtained reliably in 2D axial scanning but is readily reconstructed from a 3D volume.
- On the 2D transcerebellar axial plane, a DWM and a Blake's pouch cyst may appear identical. The midsagittal view — showing whether the vermis is present and connected to the fourth ventricle — is the discriminating plane [2,17].
- If you cannot obtain this view: acquire a 3D posterior fossa volume and refer to fetal neurosonography or fetal medicine for analysis. A report that cannot distinguish DWM from Blake's pouch cyst has significant prognostic implications and must not default to 'posterior fossa cyst' without qualification [2].

HYDROPS FETALIS — RECOGNITION, CLASSIFICATION, AND INVESTIGATION

Definition and Classification

Hydrops fetalis is defined as the abnormal accumulation of fluid in two or more fetal compartments: skin (oedema ≥ 5 mm), pleural effusion, pericardial effusion (>2 mm), and ascites [15]. Placental thickness >4 cm and polyhydramnios are supportive findings. Hydrops is classified as immune (caused by maternal red-cell alloimmunisation — predominantly Rh D, anti-c, and anti-Kell disease) or non-immune (all other causes) [16]. Non-immune hydrops fetalis (NIHF) now accounts for approximately 90% of all hydrops cases as Rh prophylaxis programmes have dramatically reduced immune disease in developed countries [17].

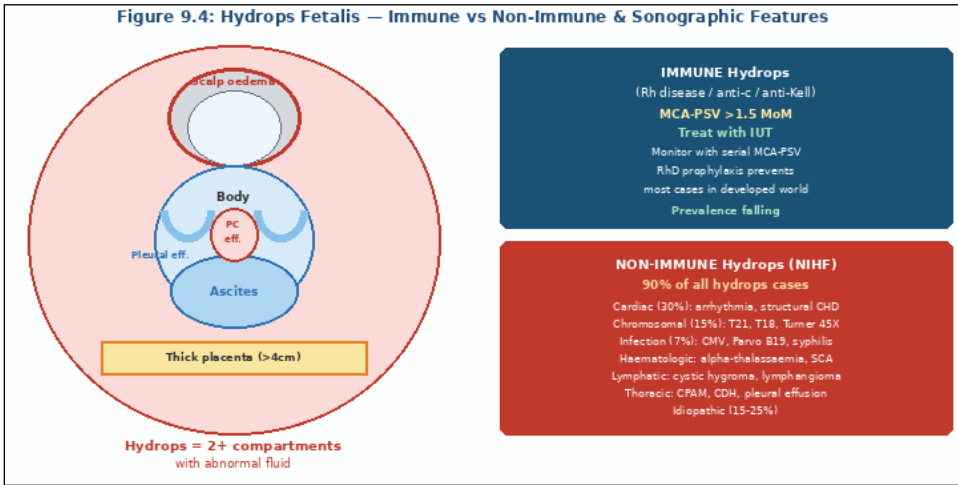
Figure 9.4: Hydrops Fetalis — Immune vs Non-Immune & Sonographic Features

Figure 9.4: Hydrops fetalis — classification and sonographic features. Left panel: the complete sonographic picture of hydrops — scalp oedema (skin thickening ≥ 5 mm over the calvarium), bilateral pleural effusions (anechoic crescents in both hemithoraces), pericardial effusion (fluid around the heart), fetal ascites (fluid in the abdominal cavity), and a thickened placenta (>4 cm). Two or more of these features must be present for the diagnosis. Right panel: the aetiological classification separating immune hydrops (Rh disease — now rare with prophylaxis) from non-immune hydrops (NIHF) — the dominant challenge in contemporary practice, with cardiac causes (30%) and chromosomal causes (15%) heading the differential [8,9].

Non-Immune Hydrops — Systematic Investigation

NIHF carries a perinatal mortality of approximately 30-50% across all causes, but within this overall figure the prognosis varies enormously by aetiology [8,9]. Identifying a treatable cause — particularly fetal anaemia (Parvo B19), fetal cardiac arrhythmia, or large CPAM — is the clinical priority, as intervention may be curative [18]. The systematic investigation protocol is as follows:

Checklist — NIHF Investigation Protocol (Ultrasound and Clinical)

- Complete fetal anatomical survey: cardiac anomaly (30% of NIHF) — four views + outflow tracts. Thoracic mass (CPAM, CDH, BPS). Abdominal mass or tumour. Skeletal dysplasia.
- Fetal echocardiography: arrhythmia (SVT, complete heart block) is a treatable cause — document fetal heart rate and rhythm on M-mode.
- MCA-PSV: fetal anaemia (Parvo B19, alpha-thalassaemia, alloimmunisation) — PSV >1.5 MoM indicates moderate-severe anaemia [10].

Checklist — NIHF Investigation Protocol (Ultrasound and Clinical)

- Maternal serology: full blood count; Kleihauer-Betke; red cell antibodies; Parvo B19 IgM/IgG; CMV, toxoplasmosis, syphilis, rubella serology.
- Chromosomal analysis: karyotype and microarray — chromosomal anomaly in approximately 15% of NIHF, higher with structural anomaly [8,9].
- Maternal investigations: thyroid function, haemoglobin electrophoresis (alpha-thal carrier), glucose-6-phosphate dehydrogenase (G6PD), anti-Ro/La antibodies (congenital heart block) [9].
- Fetal blood sampling (cordocentesis): if MCA-PSV >1.5 MoM and cause not identified — for haematocrit, blood group, Parvo PCR, viral studies [10].

Immune Hydrops and Rh Disease Management

Despite the dramatic reduction in Rh D alloimmunisation since prophylaxis programmes, immune hydrops due to anti-c, anti-E, and anti-Kell remains clinically relevant. MCA-PSV >1.5 MoM in a sensitised pregnancy is the indication for cordocentesis and, if confirmed anaemic, intrauterine transfusion (IUT) [19]. IUT via the umbilical vein at the placental cord insertion, guided by real-time ultrasound, can be performed serially from approximately 18 weeks and has dramatically improved survival to >90% in experienced centres. Serial MCA-PSV assessment every 1-2 weeks from 18 weeks is the monitoring standard in all sensitised pregnancies where IUT is being considered [20].

POST-DATES PREGNANCY — INTENSIFIED ULTRASOUND SURVEILLANCE**Definition and Rationale for Surveillance**

Post-dates pregnancy is conventionally defined as gestation beyond 41+0 weeks (post-term: $\geq 42+0$ weeks). The risk of perinatal mortality and morbidity rises progressively beyond 40 weeks — perinatal mortality at 43 weeks is approximately 4-7 times that at 40 weeks — driven by placental senescence, meconium aspiration syndrome, and cord compression from oligohydramnios [21]. Ultrasound surveillance from 41 weeks allows detection of the oligohydramnios, growth restriction, and biophysical deterioration that precede adverse outcome, providing an evidence base for the timing of induction [22].

Figure 9.5: Post-dates & Intrapartum Ultrasound — Key Assessments

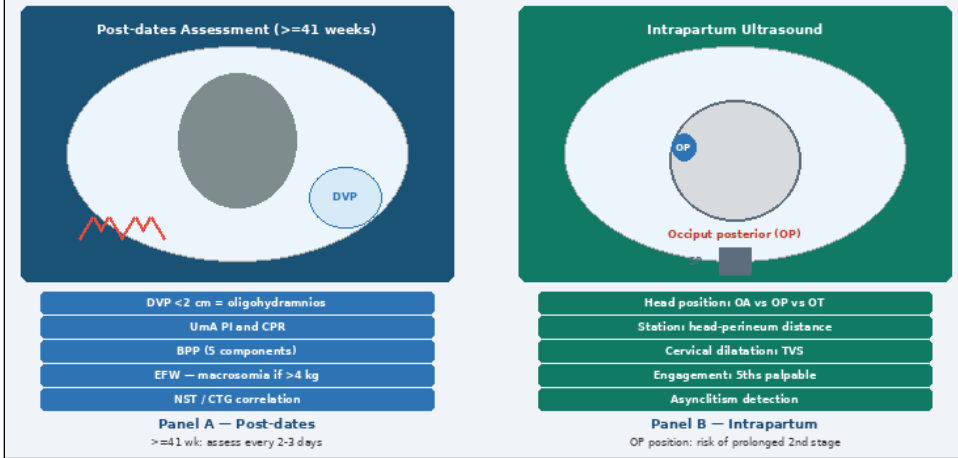


Figure 9.5. Post-dates and intrapartum ultrasound assessments. Panel A: Post-dates assessment — from 41 weeks, the key parameters are DVP (oligohydramnios < 2 cm is an indication for delivery), umbilical artery Doppler and CPR (brain-sparing in post-dates carries the same clinical implications as in FGR), modified BPP (NST + DVP), and EFW (macrosomia > 4000 g requires specific labour management planning). Panel B: Intrapartum ultrasound — head position assessment on transperineal or translabial scan; the fetal spine-to-sacrum relationship determines the occiput position (OA: spine anterior; OP: spine posterior); head-to-perineum distance measured from the outer bony limit of the presenting part to the perineal skin predicts the likelihood of successful instrumental delivery [3,5,6].

Checklist — Post-dates Ultrasound Assessment (41-42 Weeks)

- Amniotic fluid: DVP is the preferred method (less false-positive oligohydramnios than AFI). DVP < 2 cm = oligohydramnios — recommend delivery discussion. DVP 2-3 cm = borderline — repeat in 48-72 hours.
- Biophysical profile: modified BPP (DVP + NST) or full BPP (5 components). BPP $\leq 4/10$ at ≥ 41 weeks: recommend delivery.
- Umbilical artery and CPR: AEDF/REDF or CPR < 1.0 in post-dates context is a strong indication for delivery, regardless of BPP.
- EFW: macrosomia (EFW > 4000 g or > 95 th centile) — document and communicate to obstetric team for shoulder dystocia risk planning.
- Fetal presentation: confirm cephalic or malpresentation — especially important before induction of labour.
- Scan frequency: every 2-3 days if expectant management continued beyond 41 weeks. Do not allow more than 3-4 days between assessments in post-dates pregnancy [23,26].

INTRAPARTUM ULTRASOUND — FETAL HEAD POSITION AND LABOUR ASSESSMENT

Why Intrapartum Ultrasound Matters

Digital vaginal examination (DVE) for fetal head position assessment has been shown to be inaccurate in up to 50% of cases, with occiput posterior (OP) and occiput transverse (OT) positions particularly prone to misclassification [23]. Incorrect diagnosis of head position leads to failed rotational instrumental delivery, perineal trauma, and unnecessary caesarean section. Intrapartum translabial or transperineal ultrasound overcomes this limitation and provides objective, reproducible assessment of fetal head position, station, and asynclitism with a accuracy superior to clinical examination [24].

Technique: Transperineal Ultrasound for Head Position

With the patient in the lithotomy position, the transducer is placed on the perineum in the sagittal plane (transducer marker towards the pubic symphysis) and angled to visualise the fetal spine [25]. The position of the fetal spine relative to the maternal pelvis determines the occiput position: fetal spine anterior (towards pubic symphysis) = occiput anterior (OA); fetal spine posterior (towards maternal sacrum) = occiput posterior (OP). The fetal orbit on transverse view provides an additional landmark — the orbit closest to the maternal abdomen corresponds to the occiput on that side [26].

Table 9.4: Intrapartum ultrasound parameters, techniques, and clinical significance. The head-perineum distance (HPD) and angle of progression (AOP) have been prospectively validated as predictors of successful vaginal delivery and instrumental delivery outcome — they provide objective decision support that digital examination cannot [6,28,29,30].

Parameter	Measurement Technique	Clinical Significance	References
Head position	Fetal spine direction relative to symphysis on transperineal sagittal view [3]	OP position: risk of prolonged 2nd stage, instrumental failure [5]	[3,4,5]
Head-perineum distance (HPD)	From outer skull table to perineal skin on transperineal sagittal [6,28]	HPD <35 mm predicts successful instrumental delivery [6,28]	[6,28,29]
Angle of progression (AOP)	Angle between pubic symphysis long axis and tangent to fetal head [6]	AOP >120 degrees predicts vaginal delivery within 1 hour [6]	[6,30]

Table 9.4 Continued...

Asynclitism	Lateral tilt of fetal head on coronal transperineal view [3]	Severe asynclitism associated with labour dystocia [5]	[3,5]
Cervical dilatation	TVS measurement of anterior lip and internal os aperture [20]	Objective alternative to digital examination in selected cases [20]	[20]

Clinical Pearl — The Angle of Progression: Predicting Vaginal Delivery

- An angle of progression (AOP) >120 degrees at full cervical dilatation predicts vaginal delivery within 1 hour with a sensitivity of approximately 80% and specificity of 85% [6,30].
- AOP <90 degrees at full dilatation are associated with a very low probability of spontaneous delivery and should prompt discussion of operative delivery before prolonged pushing causes fetal compromise [6].
- The AOP is measured on the transperineal sagittal view — angle between the line of the pubic symphysis long axis and the tangent line touching the leading edge of the fetal skull [6,30].

ULTRASOUND SAFETY — THE ALARA PRINCIPLE AND MEDICO-LEGAL FRAMEWORK**Biological Effects of Diagnostic Ultrasound**

Diagnostic ultrasound at the output levels used in clinical practice has an excellent safety record spanning five decades of widespread use, with no confirmed reports of fetal harm from properly performed diagnostic scanning [27]. However, this safety record applies to clinically indicated scanning by trained operators using appropriate output settings — it does not extend to prolonged commercial 'keepsake' scanning, scanning by untrained operators with uncontrolled output, or the use of Doppler modes inappropriately in the first trimester [28]. Two theoretical mechanisms of bioeffect exist: thermal effects (tissue heating from absorbed acoustic energy) and mechanical effects (cavitation, radiation force) [29].

Medico-Legal Obligations of the Obstetric Sonologist

The obstetric sonologist operates in one of medicine's highest-risk medico-legal environments. The standard of care is defined by published guidelines (ISUOG, AIUM, BMUS, ACOG) and by the reasonable practice of a competent specialist in the same field

[22,23]. Departures from guideline-defined minimum standards — failure to document chorionicity, failure to obtain standard cardiac views, failure to communicate an anomaly — are potentially indefensible in litigation [22]. The key medico-legal obligations specific to ultrasound practice are:

Checklist — Medico-Legal Obligations: Obstetric Ultrasound Practice

- Indication documentation: every scan must have a documented clinical indication. 'Routine' is not an indication — state the specific clinical question the scan is designed to answer.
- Examination completeness: every standard view must be documented as obtained or not obtainable (with reason). A scan that is not documented is a scan that was not done in the eyes of a court [22,23].
- Suboptimal scan: when standard views cannot be obtained (maternal habitus, fetal position, oligohydramnios), document this explicitly and recommend repeat scan or specialist referral. Never report a scan as 'normal' when mandatory views are missing [22].
- Anomaly communication: when an anomaly is identified, document that findings were communicated to a named senior clinician at a specified time. Do not rely on the report alone to trigger appropriate action.
- Informed consent for invasive procedures: documented, procedure-specific, including the procedure loss rate figure from current evidence. Verbal consent without documentation is legally insufficient [13,15].
- Image storage and report archiving: images must be stored with patient identifiers per institutional retention policy. The report is a legal document — it must be signed, dated, and filed in the medical record [22,23].

KEEPSAKE SCANNING — THE ETHICAL AND SAFETY CONCERN

Commercial keepsake ultrasound — scanning performed outside a clinical setting, without a clinical indication, for the purpose of creating bonding images or video — raises both safety and ethical concerns [30]. The concerns are: (1) safety — output levels and scan duration are not controlled by trained personnel; (2) false reassurance — parents shown a moving fetus may erroneously believe the scan has excluded anomalies; (3) delayed diagnosis — parents who have had a recent 'keepsake' scan may not present promptly for clinically indicated imaging; and (4) operator qualifications — these scans are not performed by qualified sonographers or sonologists [31]. Professional organisations including ISUOG, AIUM, and BMUS have issued statements discouraging keepsake scanning without a clinical indication.

REPORTING TEMPLATES: SPECIAL SITUATIONS

Template A: Post-dates Biophysical Surveillance Report

Field	Content
Clinical indication	Post-dates surveillance. GA: [X wk + Y d] by [CRL at dating scan / LMP]. Indication: expectant management at ≥ 41 weeks.
Fetal viability and presentation	Cardiac activity: present. Presentation: [cephalic / breech / transverse]. Engagement: [engaged / not engaged — fifths palpable: X/5].
Biometry	EFW (Hadlock): [X] g ([Xth] centile). AC: [X] mm. Note: EFW > 4000 g — macrosomia; shoulder dystocia risk assessment required.
Amniotic fluid	DVP: [X] cm. [Normal (≥ 2 cm) / Borderline (2-3 cm — repeat in 48-72 h) / Oligohydramnios (< 2 cm — recommend delivery discussion)].
Doppler	UmA PI: [X], EDF: [present/AEDF/REDF]. CPR: [X] ([normal/abnormal < 1.0]).
BPP	FBM [2/0], FM [2/0], FT [2/0], DVP [2/0], NST [2/0]. Total: [X]/10. [Normal (8-10) / Equivocal (6) / Abnormal (≤ 4)].
Conclusion & plan	[Normal biophysical profile — continue expectant management; repeat scan in [2-3] days / Oligohydramnios — recommend delivery discussion / BPP $\leq 4/10$ — immediate obstetric review for delivery / AEDF/REDF or CPR < 1.0 — same-day senior obstetric review].

Template B: Intrapartum Ultrasound Report

Field	Content
Clinical context	GA: [X wk + Y d]. Stage of labour: [active 1st / 2nd stage]. Indication for ultrasound: [failed descent / instrumental delivery planning / malpresentation query / other].
Fetal head position	Technique: [transperineal / translabial] ultrasound in [sagittal / axial] plane. Position: [OA / OT (R or L) / OP]. Confidence: [high / moderate].
Station / descent	Head-perineum distance (HPD): [X] mm. [< 35 mm predicts successful instrumental / 35-45 mm: intermediate / > 45 mm: unfavourable for instrumental]. Angle of progression (AOP): [X] degrees. [< 90 : very unfavourable / 90-120: intermediate / > 120 : favourable for vaginal delivery].
Asynclitism	[Absent / Mild / Moderate / Severe]. Laterality: [right / left synclitic tilt].

Template B: Continued...	
Fetal wellbeing	Cardiac activity: [present, rate X bpm / decelerations noted on CTG — document separately]. Liquor: [not formally assessed intrapartum / no significant fluid visible].
Conclusion	[Head position [OA/OP/OT] confirmed. HPD [X] mm / AOP [X]°: [favourable/unfavourable] for [spontaneous/instrumental] delivery. Findings communicated to [clinician] at [time]. Recommended: [expectant / rotation / instrumental delivery / caesarean section discussion]].

Template C: Invasive Procedure Report (Amniocentesis)

Field	Content
Pre-procedure	GA: [X wk + Y d]. Indication: [chromosomal analysis / microarray / infection / other]. Informed consent: [obtained — risks discussed including [X]% procedure-related loss]. Anti-D: [not indicated / given [dose] before procedure].
Pre-procedure ultrasound	Fetal cardiac activity: present. Placental site: [anterior / posterior / lateral]. Planned needle entry site: [describe — avoiding placenta where possible]. Amniotic fluid: DVP [X] cm.
Procedure	Needle: [20 / 22] gauge, [length] cm. Approach: [transabdominal, free-hand / with needle guide]. Passes: [X]. Fluid aspirated: [X] mL, [clear/bloodstained/turbid]. Sample sent to: [laboratory, date].
Post-procedure	Fetal cardiac activity: [present — HR X bpm]. No bleeding at entry site. No fetal bradycardia observed during procedure. Patient instructed to attend if [pain / bleeding / reduced fetal movement].
Complications	[None observed / Describe any complication: transient fetal bradycardia — resolved; small haematoma at entry site — monitored for 30 minutes].

Key Takeaways
<ol style="list-style-type: none"> 3D/4D ultrasound is a targeted complementary tool, not a routine replacement for 2D scanning. Its highest-yield applications are fetal face (cleft lip/palate), posterior fossa vermis (midsagittal reconstruction), corpus callosum, and cardiac outflow tracts via STIC [1,2]. Pulsed-wave spectral Doppler in the first trimester carries a TI of 1.5-2.5 — well above the recommended 0.7 safety threshold. Use M-mode for first-trimester cardiac assessment; reserve spectral Doppler for specific indications with minimum dwell time [21,24].

Key Takeaways

3. CVS can be performed at 11-14 weeks and provides the earliest chromosomal diagnosis, but confined placental mosaicism (1-2%) may require amniocentesis confirmation. The procedure loss rate is comparable to amniocentesis from experienced centres at approximately 0.22% above background [12,14,15].
4. The midsagittal vermian plane is the definitive view for posterior fossa assessment and cannot be reliably obtained in 2D axial scanning. When the 2D transcerebellar plane cannot confirm vermian integrity, 3D reconstruction or fetal MRI at ≥ 22 weeks is required before a confident posterior fossa diagnosis can be made [2,17].
5. Non-immune hydrops has a 30-50% perinatal mortality across all causes. The systematic investigation must include fetal echocardiography (arrhythmia), MCA-PSV (anaemia), chromosomal analysis, and maternal serology — identifying a treatable cause (SVT, Parvo B19 anaemia) changes the outcome dramatically [8,9].
6. In post-dates pregnancy, DVP < 2 cm (oligohydramnios) is an independent indication for delivery discussion at any point beyond 41 weeks — do not wait for biophysical deterioration when liquor is already critically reduced [23].
7. Digital vaginal examination misclassifies fetal head position in up to 50% of cases. Intrapartum transperineal ultrasound provides objective, reproducible head position assessment and should be used before all instrumental delivery attempts [3,4,5].
8. Head-perineum distance (HPD) < 35 mm at full dilatation predicts successful instrumental delivery; HPD > 45 mm is associated with instrumental failure and maternal/fetal morbidity. HPD should be measured before all instrumental deliveries [6,28,29].
9. Every suboptimal scan must be documented as such — with the reason and a specific recommendation for repeat or specialist scan. Reporting a scan as 'normal' when standard views are missing is a medico-legal risk and a patient safety failure [22,23].
Keepsake commercial scanning is not the same as clinical scanning. Ensure parents understand that a commercial scan does not constitute an anomaly assessment. Clinicians receiving patients who have had keepsake scans should not allow these to substitute for or delay guideline-mandated clinical scanning [21,24].

REPORTING, QUALITY ASSURANCE & MEDICO-LEGAL STANDARDS

The ultrasound report is the only permanent record of a clinical encounter that may have involved the detection — or the failure to detect — a life-altering diagnosis. In obstetric ultrasound, where the stakes encompass maternal life, fetal viability, and long-term neurodevelopmental outcome, the report is simultaneously a clinical document, a medicolegal instrument, and an audit trail. This final chapter addresses the standards that define a complete, defensible, and clinically useful report; the quality assurance systems that ensure those standards are consistently met across a department; the competency framework within which sonographers and sonologists are trained; and the medicolegal framework that governs the duties and liabilities of practitioners in this high-risk clinical environment

THE ANATOMY OF A COMPLETE OBSTETRIC ULTRASOUND REPORT

Why Report Quality is a Patient Safety Issue

Analysis of maternity negligence claims consistently identifies ultrasound reporting failures as a contributing factor in a substantial proportion of cases — including failure to identify anomalies, failure to document suboptimal examinations, failure to communicate urgent findings, and failure to recommend appropriate follow-up [1]. NHS Resolution data demonstrates that ultrasound-related claims account for a disproportionate share of the highest-value obstetric negligence settlements, with missed diagnoses of cardiac anomalies, vasa praevia, and ectopic pregnancy featuring repeatedly [2]. The correlation between report completeness and clinical outcome is documented in maternity safety investigations across multiple jurisdictions [3].

Eight Mandatory Header Elements

Checklist — Report Header: Eight Non-Negotiable Fields
<ul style="list-style-type: none">• Patient full name and date of birth — not initials; must be unambiguous identifiers.• Hospital/clinic number or unique patient identifier.• Date and time of examination — time matters for urgent findings and medico-legal timelines.• Gestational age at time of scan — state whether by CRL, LMP, or previous scan and the date of that reference.• Clinical indication — the specific clinical question the scan is designed to answer. 'Routine' is not an indication.

Checklist — Report Header: Eight Non-Negotiable Fields

- Operator name and professional registration number or grade (consultant sonologist, registered sonographer, registrar under supervision).
- Supervising clinician — if the scan is performed by a trainee or non-independently credentialed operator.
- Equipment: scanner manufacturer, model, and transducer frequency used [1,2,22].

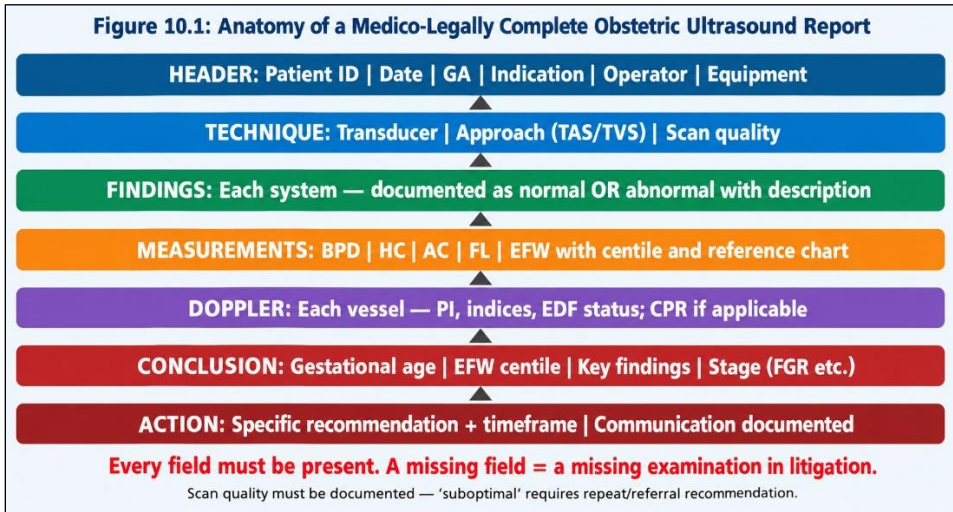
Figure 10.1: Anatomy of a Medico-Legally Complete Obstetric Ultrasound Report

Figure 10.1: Anatomy of a medico-legally complete obstetric ultrasound report — seven mandatory sections in sequence. Header: patient identification, date, gestational age, indication, operator, equipment. Technique: transducer, approach, scan quality. Findings: each system addressed individually. Measurements: with centile and named reference chart. Doppler: each vessel with PI and EDF status. Conclusion: integrated interpretation with EFW centile and clinical classification. Action: specific next step with timeframe and urgent communication documented. Absence of any section is a departure from the standard of care [1,2].

Documenting Scan Quality

Scan quality assessment is one of the most frequently omitted elements of obstetric reports, yet one of the most important medico-legally [4]. When a standard view cannot be obtained — due to maternal habitus, fetal position, oligohydramnios, or operator factors — the clinical implications are identical to identifying an abnormality: the clinician receiving the report must know that a mandatory view is missing and must understand what action is required [5].

Table 10.1: Scan quality categories and required report statements. An incomplete scan must never be reported as 'normal findings' — this is the most dangerous documentation error in obstetric ultrasound [1,2,8].

Scan Quality	Definition	Required Report Statement
Excellent	All standard views obtained; image resolution optimal [1]	'Scan quality: excellent — all standard views obtained.' [1]
Good	All standard views obtained; minor technical limitations [1]	'Scan quality: good — all standard views obtained.'
Limited	One or more views suboptimal but assessable [1]	'Limited — [view] suboptimal due to [reason]. Recommendation: [repeat/refer].' [1,2]
Incomplete	One or more mandatory views unobtainable [1]	'Incomplete — [view] could not be obtained. This is a mandatorily incomplete examination. Repeat / specialist referral required.' [1,2]

Medico-Legal Warning — The Most Dangerous Sentence in Obstetric Ultrasound

- 'No abnormality detected.' — written in a report where cardiac outflow tracts were not visualised, the fetal face was not assessed, or the spine was incompletely surveyed.
- This single sentence has been the central issue in dozens of high-value maternity negligence claims. It implies completeness where incompleteness exists [5,30].
- Correct wording when views are missing: 'The following views could not be obtained: [list]. This examination is incomplete in these respects. Repeat scan at [date/gestation] is recommended.' [1,2].

THE CONCLUSION: INTEGRATING FINDINGS INTO CLINICAL DECISIONS

The conclusion is the most clinically important section. It must integrate all findings into a single coherent clinical statement that directly answers the referring question [6]. A conclusion that lists measurements without clinical interpretation is not a conclusion — it is a data transfer. The conclusion must state: gestational age, EFW with centile, clinical classification (viable IUP, FGR Stage X, TTTS Stage X, etc.), and the specific recommended next step with timeframe [7].

Clinical Pearl — The Three-Sentence Conclusion Rule

- Sentence 1 (Findings): 'Single viable intrauterine pregnancy at [X wk + Y d] by biometry. EFW [X]g ([Xth] centile). UmA Doppler: AEDF. CPR <1.0.'
- Sentence 2 (Classification): 'Findings meet criteria for FGR Stage II (ISUOG/Delphi 2016) — EFW <10th centile + persistent AEDF.'
- Sentence 3 (Action): 'Urgent obstetric review required today. Delivery planning, antenatal corticosteroids if <34 weeks, and in-patient monitoring are recommended.'

IMAGE DOCUMENTATION — STANDARDS AND STORAGE

Eight Required Elements on Every Stored Image

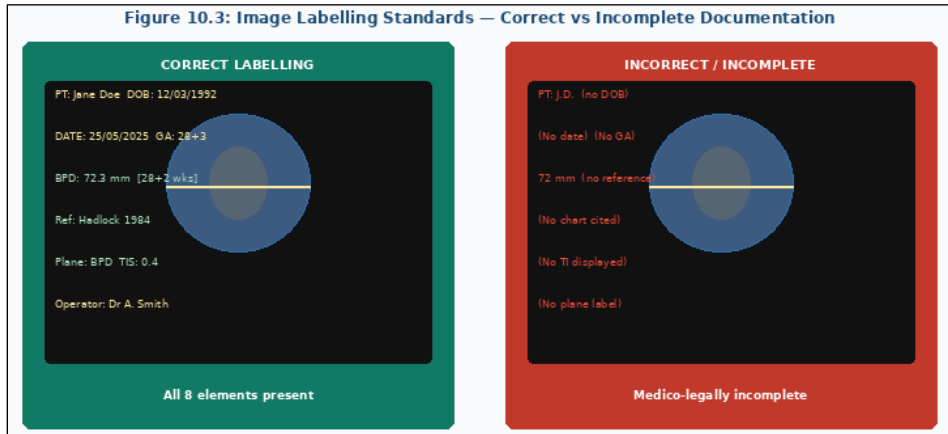


Figure 10.3: Image labelling standards — correct versus incomplete documentation. Left: a correctly labelled ultrasound image with all eight required elements — patient name and DOB, examination date, gestational age, measurement label, measurement value, reference chart cited, plane identifier, and thermal index (TI) displayed. Right: an incompletely labelled image missing date of birth, examination date, gestational age, reference chart, TI display, and plane label. An unlabelled or incompletely labelled image cannot support report measurements in legal proceedings [1,2,22].

Checklist — Image Labelling: Eight Required Fields on Every Stored Image

- Patient full name (not initials) — readable at the image storage resolution.
- Date of birth — distinguishes patients with identical or similar names.
- Date of examination — stored metadata alone is insufficient; date must appear on the image.
- Gestational age at time of scan — allows retrospective centile assessment if the report is challenged.
- Measurement label — unambiguous anatomical identifier (e.g. 'BPD', 'HC', 'UmA PI', not just calliper marks).
- Measurement value — stated on the image, not only in the report (images and reports may be separated in legal proceedings).
- Reference chart cited (for biometry) — which normogram the centile was derived from.
- Thermal index (TI) — displayed on all stored images, particularly Doppler modes; demonstrates safety compliance [21,24].

IMAGE RETENTION POLICY

Obstetric ultrasound images are clinical records subject to the same retention obligations as all medical records. In the United Kingdom, the standard retention period for obstetric records including images is 25 years from the date of the last entry — because a child born as a result of the pregnancy may bring a clinical negligence claim up to age 21 (the 3-year limitation period applies from the age of majority) [9]. Images stored only on removable media not backed up to a central archive do not meet the retention standard and represent an institutional liability [24].

QUALITY ASSURANCE IN OBSTETRIC ULTRASOUND

The QA Cycle

Quality assurance (QA) in obstetric ultrasound is the systematic process by which a department verifies that the scans it produces meet the clinical standards that justify patient and clinician trust [10]. A functional QA programme operates as a continuous cycle: defining standards, training, performing and documenting examinations, auditing, providing feedback, implementing changes, and redefining standards as evidence evolves [11].



Figure 10.2: The quality assurance cycle for obstetric ultrasound departments — six stages: define standards, train and assess competence, perform and document, audit and review, feedback and improve, implement changes. Left: QA process metrics including measurement reproducibility, inter-observer agreement, report completeness, and image quality scoring. Right: outcome metrics including detection rate benchmarking, missed anomaly review, turnaround time, and patient feedback. No stage of the cycle is optional [17].

DETECTION RATE BENCHMARKING

The most clinically meaningful QA metric for an anomaly service is the detection rate for major structural anomalies compared against published national and international benchmarks [12]. The UK NHS FASP publishes minimum acceptable detection rates for eleven conditions in the national programme [6]. The EUROCAT register provides population-level detection rates across European centres [4]. Departments whose detection rates fall below these benchmarks must initiate structured case review, targeted training, and where appropriate, accreditation review [13].

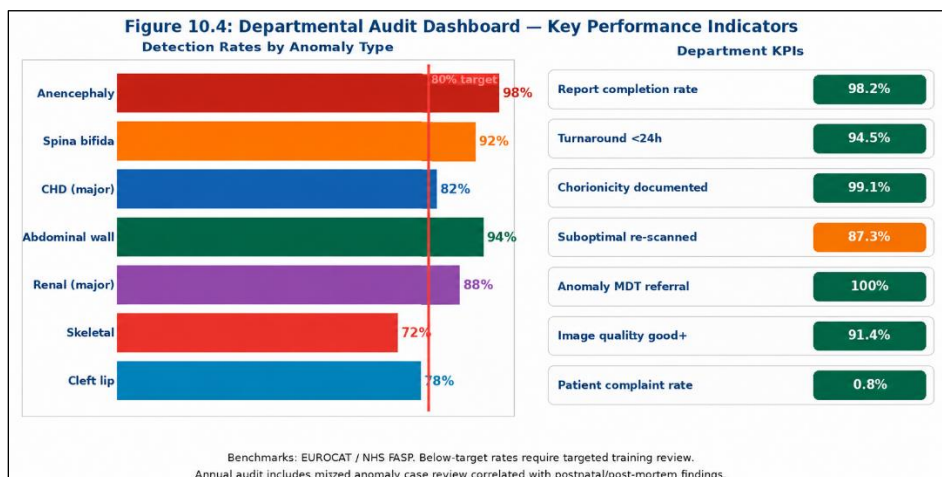


Figure 10.4: Departmental audit dashboard — detection rates by anomaly type against the 80% benchmark (red line) and departmental KPIs. Anencephaly and abdominal wall defects approach the theoretical maximum; skeletal dysplasias and cleft lip consistently underperform — motivating targeted training in these areas. KPIs provide a comprehensive operational picture including report completion, turnaround time, chorionicity documentation, and suboptimal scan re-scan rates [4,6,17].

Checklist — Departmental QA Minimum Annual Programme

- Detection rate audit: calculate detection rate for all major structural anomalies; compare against FASP/EUROCAT benchmarks; present to clinical governance.
- Missed anomaly case review: structured review of all cases where an anomaly identified postnatally or at post-mortem was not diagnosed prenatally; categorise as missed (scan not done), technical miss (visible but not identified), or inherently undetectable.
- Report completeness audit: random sample of 50 reports per operator per year; assess against the eight-element checklist; document and address deficiencies.

Checklist — Departmental QA Minimum Annual Programme

- Image quality scoring: random sample of 20 image sets per operator per quarter; score against the eight-element image labelling checklist.
- Inter-observer reproducibility: biometry comparison on 20 shared cases per year; document mean differences and coefficients of variation.
- Equipment maintenance log: document scheduled preventive maintenance, probe integrity checks, and any output level anomalies identified [1,17].

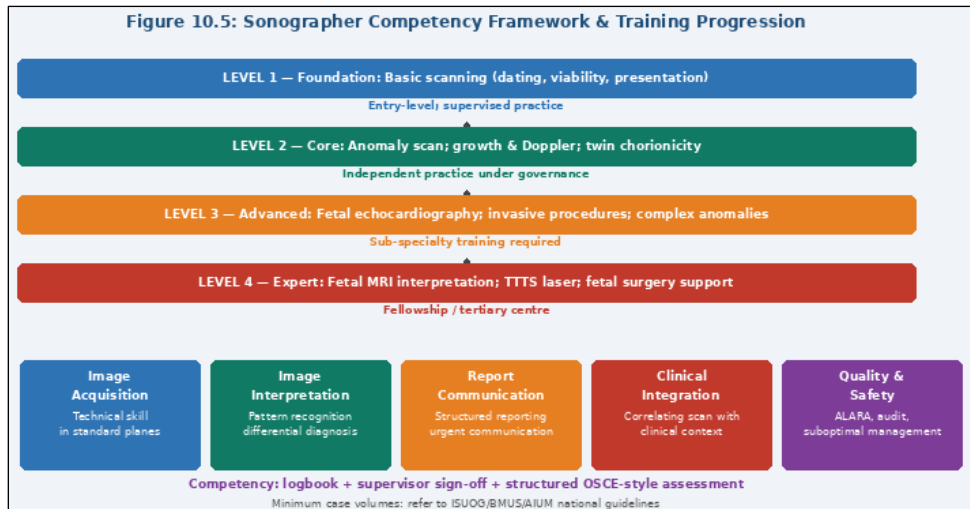
COMPETENCY FRAMEWORK AND TRAINING PATHWAYS**Levels of Competency**

Figure 10.5: Sonographer competency framework — four levels progressing from foundation (basic viability and dating) through core (anomaly scan, growth, Doppler, twin surveillance) to advanced (fetal echocardiography, invasive procedures) to expert (fetal MRI, laser guidance, fetal surgery). Five competency domains underpin all levels: image acquisition, image interpretation, report communication, clinical integration, and quality and safety. Independent practice requires supervisor sign-off of minimum case volumes and structured assessment at each level transition [16].

Table 10.2: Minimum case volumes by competency level (ISUOG framework). Volume is the floor, not the ceiling — competency is assessed by quality and supervisor sign-off, not volume alone [16].

Level	Examination Type	Minimum Cases (ISUOG)	References
Level 1 — Foundation	Early pregnancy / viability / dating	100 supervised scans [16]	[16]
Level 2 — Core	Second-trimester anatomy survey	200 scans; 50 anomalies [16]	[16]
Level 2 — Core	Third-trimester growth and Doppler	100 scans; 20 Doppler [16]	[16]
Level 3 — Advanced	Fetal echocardiography	100 cardiac scans; 25 CHD [16]	[16]
Level 3 — Advanced	Invasive procedures	50 procedures under supervision [16]	[16]
Level 4 — Expert	Complex anomalies; TTTS management	Fellowship-level; no fixed minimum [16]	[16]

CONTINUING PROFESSIONAL DEVELOPMENT

Competency in obstetric ultrasound requires maintenance through regular practice, case review meetings, participation in departmental audit, approved CPD courses, and periodic competency re-assessment [15]. Practitioners who have not performed a specific scan type (e.g. fetal echocardiography) for more than 12 months must re-establish competency under supervision before performing it independently [16].

MEDICO-LEGAL FRAMEWORK — DUTY, BREACH, AND CAUSATION

The Standard of Care

In clinical negligence law, the standard of care in a specialty is defined by the practice of a 'responsible body of practitioners' — the Bolam test [10,24]. For obstetric ultrasound this means the practice defined by current published guidelines from ISUOG, AIUM, BMUS, ACOG, and national programmes such as FASP [17]. The landmark UK Supreme Court judgment *Montgomery v Lanarkshire Health Board* [2015] established that patients must be told about 'material risks' that a reasonable person in their position would want to know [18]. In the ultrasound context, when an anomaly or uncertainty is identified, the patient must be informed in a manner that allows autonomous decision-making — including referral for a second opinion [19].

Medico-Legal Warning — The Communication Duty After Montgomery

- Identifying a potential anomaly and documenting it only in the report — without ensuring timely communication to the patient and referring clinician — does not discharge the communication duty established by Montgomery [10].
- When a serious anomaly is suspected, same-day verbal communication to a named senior clinician — documented by name and time in the report — is the minimum standard [5,23].
- Do not rely on the report reaching the right person through routine administrative channels [5,23].

Common Sources of Ultrasound-Related Litigation

Table 10.3: Common sources of ultrasound-related maternity litigation and prevention. Each category maps directly to a clinical protocol in Chapters 2-9. Documentation of adherence to these protocols is the primary defence against a negligence claim [5,30].

Claim Category	Common Scenario	Prevention / Mitigation
Missed cardiac anomaly	HLHS/TGA not detected; cardiac views not documented [5,30]	Four-view cardiac protocol documented; echo for NT ≥ 3.5 mm [5]
Missed ectopic pregnancy	Adnexa not surveyed; PUL not managed per protocol [30]	Systematic adnexal survey documented; PUL algorithm followed [5]
Missed placenta praevia	Placental site not documented; no repeat TVS arranged [30]	Placental distance to IOS in mm documented; repeat TVS booked [5]
Missed vasa praevia	Cord insertion not documented; no colour Doppler IOS [30]	Cord insertion documented; IOS colour Doppler in high-risk cases [5]
Incorrect chorionicity	MCDA labelled DCDA; TTTS surveillance not initiated [5,30]	T-sign/lambda documented at 11-14 weeks for every twin [5]
Gestational age error	Wrong reference chart; hyperflexed CRL measurement [30]	Reference chart stated; CRL technique documented [5]
Delayed FGR diagnosis	AC centile not plotted; Doppler not performed despite SGA [30]	EFW centile plotted; Doppler for all EFW <10 th centile [5,29]

DUTY OF CANDOUR

When a clinically significant finding is missed on ultrasound — discovered postnatally, intraoperatively, or at autopsy — the practitioner and institution have a legal and ethical obligation to disclose this to the patient under the Duty of Candour [20]. This requires: a sincere apology (not admission of liability), an explanation of what happened, information about any investigations being undertaken, and an offer of support [21]. Failure to comply is a regulatory offence for institutions and grounds for fitness-to-practise investigation for individuals [22].

ARTIFICIAL INTELLIGENCE IN OBSTETRIC ULTRASOUND

Current Applications and the Verification Principle

Current AI applications with regulatory approval or advanced clinical validation include automated biometry measurement (BPD, HC, AC, FL) with performance comparable to experienced operators in optimal conditions, automated fetal plane detection, automated EFW calculation, and signal processing for obese patients [3]. AI-assisted anomaly detection — particularly for cardiac anomalies and NTDs — is an area of active research but has not yet achieved the sensitivity and specificity required for independent clinical use [23].

The critical principle for practitioners integrating AI tools is that AI is a decision-support aid, not a decision-making authority. An AI-generated measurement or classification must be verified by the human operator before acceptance into the clinical record — the practitioner, not the algorithm, is responsible for the report [24].

Clinical Pearl — The AI Verification Principle

- When an AI tool provides a biometric measurement: verify against your clinical assessment before accepting it. AI algorithms can fail in non-obvious ways — a plausible BPD measurement from an oblique plane is still wrong.
- Document: 'Biometry measurements verified by operator against [AI tool name]' or 'Biometry measurements taken manually; AI tool not used.' Never document AI-generated values as operator-verified without verification [3,24].
- AI tools CE-marked or FDA-cleared as medical devices are regulated — limitations are documented in the Instructions for Use. Read the IFU before clinical deployment [3].

REPORTING TEMPLATES: QUALITY AND GOVERNANCE

Template A: Universal Quality Checklist for Anomaly Scan Audit

Table 10.4: Universal quality checklist for anomaly scan audit. Score: 15/15 = fully compliant; 13-14 = minor deficiency — log and feedback; <=12 = significant deficiency — formal remediation required. Run on a random sample of 10 reports per operator per quarter [1,2,17].

S. No.	Quality Element	In Report?	On Images?
1	Patient full name and DOB	Y / N / N-A	Y / N / N-A
2	Date and time of examination	Y / N / N-A	Y / N / N-A
3	Gestational age and dating method	Y / N / N-A	Y / N / N-A
4	Clinical indication stated	Y / N / N-A	N-A
5	Operator name and grade	Y / N / N-A	N-A
6	Scan quality documented	Y / N / N-A	N-A
7	All standard views documented (or non-visualisation stated)	Y / N / N-A	Y / N / N-A
8	Biometry: all four measurements with centile and named chart	Y / N / N-A	Y / N / N-A
9	Doppler: PI and EDF for each vessel assessed	Y / N / N-A	Y / N / N-A
10	Placental distance to IOS in mm (TVS if applicable)	Y / N / N-A	Y / N / N-A
11	Amniotic fluid: DVP in cm	Y / N / N-A	Y / N / N-A
12	Clinical conclusion: EFW centile + classification	Y / N / N-A	N-A
13	Specific action with timeframe	Y / N / N-A	N-A
14	Urgent finding: communication documented by name and time	Y / N / N-A	N-A
15	Thermal index (TI) displayed on Doppler images	N-A	Y / N / N-A

Template B: Suboptimal Scan — Mandatory Report Wording

Field	Required Content
Scan quality	'This examination was [limited / incomplete] due to [maternal body habitus / fetal position — spine anterior / oligohydramnios / other]. This is a [partially / substantially] incomplete examination.'
Views obtained	'The following standard views were obtained and are within normal limits: [list each system and finding].'

Template B: Continued....	
Views not obtained	'The following mandatory views could not be obtained: [list — e.g. left ventricular outflow tract, fetal upper lip, thoracolumbar spine axial views].'
Clinical significance	'The clinical significance is: [e.g. major cardiac anomaly cannot be excluded / fetal cleft lip cannot be excluded / spinal defect cannot be excluded].'
Recommendation	'Repeat anomaly scan is recommended at [gestation / date]. If repeat scan remains incomplete, referral to a fetal medicine unit is recommended. This result must NOT be communicated to the patient as a normal result.'
Communication	'The incomplete nature of this examination has been communicated to [clinician name] at [time] on [date].'

Key Takeaways

1. The report is the only permanent record of the examination. Its completeness and accuracy are patient safety issues and the primary line of defence in clinical negligence litigation [5,30].
2. A scan reported as 'normal' when mandatory views are missing is the most dangerous documentation error in obstetric ultrasound — it has been the central issue in dozens of high-value negligence claims [8,30].
3. Every report must contain all eight header elements, a scan quality statement, system-by-system findings, measurements with named centile chart, Doppler indices for each vessel assessed, a clinical conclusion with EFW centile and classification, and a specific timed action recommendation [1,2].
4. Every stored image must display all eight labelling elements — including the thermal index for Doppler images. Unlabelled images cannot support report measurements in legal proceedings [21,24].
5. Detection rate benchmarking against FASP/EUROCAT standards is the most clinically meaningful QA metric for an anomaly service. Departments below the 80% benchmark for any condition must initiate structured case review and targeted retraining [6,17].
6. Montgomery (2015) imposes a patient-centred communication duty — practitioners who identify a potential anomaly or uncertainty must ensure that information reaches the patient in time to allow autonomous decision-making, not merely that it reaches the report [10,24].
7. Chorionicity documentation failure in twin pregnancy is a high-frequency, high-consequence litigation scenario. The T-sign or lambda sign must be documented at 11-14 weeks for every twin pregnancy [5,30].

Key Takeaways: Continued...

8. AI tools are decision-support aids, not decision-making authorities. Every AI-generated measurement or classification must be verified by the human operator before acceptance into the clinical record [3,24].
9. Duty of Candour is a legal obligation — when a clinically significant finding is missed and later discovered, disclosure to the patient is mandatory, not optional [24].
Competency in obstetric ultrasound is maintained, not merely achieved. Practitioners who have not performed a scan type for more than 12 months must re-establish competency under supervision before independent practice [16,24].

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CHAPTER 5

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CHAPTER 6

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CHAPTER 8

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CHAPTER 9

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CHAPTER 10

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ABOUT THE BOOK

Obstetric Ultrasound: Principles, Clinical Practice and Diagnostic Precision

is a practical, clinically oriented guide to the principles and application of obstetric sonography across pregnancy. It takes readers from ultrasound physics, equipment optimisation and standard scanning technique to early pregnancy assessment, second-trimester fetal anatomy, growth and Doppler surveillance, placental and amniotic-fluid evaluation, multiple pregnancy, cervical assessment, preterm birth, fetal anomalies and special clinical situations. The book also addresses structured reporting, quality assurance and medico-legal standards, with systematic protocols, measurement guidance, diagnostic checklists and abundant ultrasound images to support consistent, accurate and clinically meaningful practice. Designed for radiology and obstetrics residents, practising radiologists and obstetricians, sonographers, fellows and other healthcare professionals involved in antenatal imaging, this book bridges fundamental concepts with real-world clinical application, helping readers improve diagnostic confidence and patient care in obstetric ultrasound.

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