Echocardiographic Anatomy in the Fetus

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Springer

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To our parents, who paved the way of our lives

Preface

by Norman H. Silverman

Over the last two decades, the value of examining the fetal heart has moved from an experimental procedure of diagnostic curiosity to a front-line form of evaluating fetal cardiac health and disease. There have been numerous advances in the associated technology, including high-resolution imaging, the introduction of reliable color flow and pulse Doppler, and M-Mode and continuous-wave Doppler recordings in some instruments. Such advances continue, with the potential for 3D imaging using spatiotemporal image correlation (STIC) and full-volume fetal technology.

The techniques used by obstetric sonographers in all fields, including physicians from the fields of radiology, obstetrics, and pediatric cardiology, together with technologists who support and do most of the scanning, require a fundamental understanding of ultrasound as well as anatomy, physiology, and the various cardiac pathologies that occur in the fetus. This book addresses these fundamentals, providing correlations by means of diagrams and images of fetal cardiac morphology and pathology. The scans are quite unique, having been collected over several years by the principal author, Dr. Enrico M. Chiappa, from his laboratories in Italy, and provide exquisite echocardiography of normal and congenitally malformed hearts. These are complemented by the excellent pathological images of Dr. Andrew C. Cook and Dr. Gianni Botta, who provided high-quality images of normal and pathological fetal heart conditions, which are displayed as support for the echocardiographic images.

The organization of this book is oriented toward practitioners. The first section provides general guidelines for imaging the fetal body and heart, for segmental analysis, and for diagnosis. The second section takes a view-oriented approach, describing first the transverse views and then the longitudinal views of the fetal body and how each echocardiographic projection best displays a particular pathological entity. The third section contains essential information pertaining to the new technique of 3D/4D echocardiography and the role of the pathologist in heart disease, which expands further the value of this text for providing references and comparisons with standard imaging techniques.

The authors obviously gave a great deal of thought to this project – from the choice of images in the text, which include the clearest descriptions and labels, to the accompanying DVD, which contains complex moving echocardiographic images. The objective is to provide the reader with something greater than a static representation of the fetal cardiac morphology while retaining the ability to refer directly to morphological comparisons and consult with the text for greater detail. This work will have great appeal to physicians and technologists involved in obtaining and interpreting such images and will provide the obstetric, cardiological, and radiological communities with an excellent reference for comparing cases seen in their daily practice.

Preface

by Enrico M. Chiappa

The number of congenital heart diseases detected in utero is still low, even in countries with well-advanced screening programs. Only 20% of new cases of congenital heart disease come from traditional high-risk pregnancies. Ultrasound screening of all pregnancies is therefore necessary to improve the detection rate of congenital heart diseases and to manage them most effectively. However, prenatal screening studies have shown widely divergent results, with low detection rates in most cases. Several reasons have been advocated to explain why these programs seem to fail, and different solutions have been proposed to improve the success rate. There is a broad consensus that examiner skill plays a crucial role in this setting and that appropriate training is mandatory.

It is our belief that people responsible for fetal cardiology units in centers of excellence should invest resources to fully educate the personnel involved in prenatal ultrasound screening. To do this, a fundamental step is to improve, simply and comprehensibly, their knowledge about the anatomy of the fetal cardiovascular system. As Prof. Robert Anderson beautifully stated in a recent review [Anderson RH, Razavi R, Taylor AM (2004) Cardiac anatomy revisited. J Anat 205:159-177], one convention of the human anatomy is that all structures should be described in the setting of their anatomical position within the body and of the relationship of organs to each other. This convention has not always been strictly applied when describing the heart. In the past, the so-called Valentine approach has prevailed, that is, the convention of representing the heart isolated from the surrounding structures and balanced on its apex, with the atria above the ventricles. This approach generated confusion, particularly in the field of congenital heart disease, where the position of the heart and the location of the cardiac segments is variable. Therefore, as Prof. Anderson wrote: "students should be introduced to the anatomy of the heart as it lies within the body, as revealed with clinical tomographic images". To this purpose, the use of tomographic sections of isolated hearts, frequently used in textbooks of echocardiography, is only partially effective in prenatal ultrasound examination, where the views of the surrounding structures are much wider and the approaches to the fetal thorax more variable than in the postnatal setting.

We decided, therefore, to perform image sections of the whole fetal body to obtain tomographic views of the heart, thus showing the relationship between cardiac and extracardiac structures. As indicated in Chapter 21, tomographic sections of the fetal body were obtained in a limited number of fetuses under the gestational age of 20 weeks following informed consent of parents and in strict adherence with the Italian legislation on this subject. The idea to obtain these types of sections stemmed from almost 20 years of fundamental work by Alf Staudach [Staudach A (1989) Sectional fetal anatomy in ultrasound. Springer], with the advantages of computer technology in photographic and ultrasound images.

Rather than systematically describing congenital heart diseases in the fetus, the goal of this work is to provide a basic tool for understanding the normal and abnormal echocardiographic anatomy of the fetal heart. In this way, this textbook is complementary and not alternative to the more extensive publications on this subject.

The first section of this book describes the basic principles of diagnosis, illustrating assessment of the laterality of the fetal body, the visceroatrial arrangement, and the cardiac position. This order reproduces the logical sequence the examiner should follow when studying the fetal heart. In the second section, all echocardiographic projections in the fetus are described, from those most familiar to obstetric sonographers, to those usually obtained only by pediatric cardiologists. Particular emphasis is given to imaging the short-axis sections of the fetal body, which has recently proven to be a powerful method for complete examination of the fetal heart. The chapters pertaining to echocardiographic projection are in logical sequence in two series: the transverse views of the fetal thorax, presented from the bottom to the top, and the sagittal and parasagittal views, presented from the right side to the left side. The sequence of these planes in some ways imitates the changes of the scanning plane that can be obtained by the examiner tilting or translating the probe manually with traditional probes or electronically with modern 3D ultrasound.

The third section consists of two chapters. The first describes the essential use of modern 3D/4D ultrasound techniques to image the fetal heart, including new volume manipulation, such as spatial and temporal image correlation (STIC), and rendering, such as glass-body, minimum-transparent, and inversion modes. The second chapter emphasizes the importance of autopsy in providing information regarding anomalies of the fetal heart and describes optimal techniques for dissection and photography of the autopsic specimens. This section emphasizes the crucial role of the echocardiographic projections described elsewhere in this book, which maintain their fundamental role in the comprehension of new advances in ultrasound and the future application of MRI/CT in postmortem studies of the fetal heart. These two different chapters are incorporated in this section because the approach to volume data sets of 3D/4D sonography and to blocks of pathological specimens shows many similarities. The information displayed by either technique depends on the level at which the examiner cuts the cardiac volume, no matter if a digital tool or a pathologist's blade is used. Moreover, some image-rendering techniques are comparable with the fine-art photographic technique available to the pathologist to display with outstanding clarity the subtle details of congenital heart disease in fetal heart specimens.

The problem of image orientation was thoroughly discussed with cardiac morphologists Andrew C. Cook, Gianni Botta, and Robert H. Anderson from the very beginning of the editorial phase of this book. The reader will notice that some anatomical images of the transverse sections of the thorax do not "at first sight" match the echocardiographic images. We decided to maintain the echocardiographic images in their original caudocranial orientation, a standard that is accepted in MR and CT imaging, rather than flip them horizontally, which would reduce the resolution of the digital clips on the accompanying DVD. We decided, instead, to display a compass with every image, thus illustrating its orientation.

As to the abnormal heart, rather than fully describe a single congenital heart disease in different projections, the book and DVD describe how a specific projection appears in the normal heart and in some abnormal conditions. Although we understand that this is not sufficient for a comprehensive assessment of a specific disease, we believe this type of presentation reproduces the usual approach of the examiner, who is initially unaware whether the case being examining is normal or abnormal. The more the examiner understands the normal anatomy, the easier it is to recognize what is wrong.

Ultrasound assessment of the heart, whether in fetal life or postnatally, is based on moving images, and books therefore have limited value in teaching echocardiography. With recent advances in ultrasound systems, storing multiple digital frames and clips with superb image quality has become a reality. These advances have brought innovative applications to the clinical field and can be utilized as powerful multimedia presentations for teaching purposes. The accompanying DVD is such a tool. This is a complex DVD that includes more than 300 clips of normal and abnormal views of the fetal heart frames of each topic, with 11–13, representing a single cardiac cycle, each of which is displayed in a loop. The DVD in many respects is not simply a copy of the book. The text window contains essential information of the case being presented, and – in the four-chamber section in particular – a short unit describes the essential features of each specific congenital heart disease. We believe this presentation will be a highly useful tool for all those interested in the echocardiographic study of the fetal heart.

Acknowledgements

First of all, a special tribute to Prof. Robert H. Anderson, a giant in the field of morphology in congenital heart disease, whose teaching through the countless numbers of papers, books, lectures, and courses deeply impacts the practice of modern pediatric cardiology and cardiac surgery and, inevitably and unavoidably, the pages of this book.

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A special note of thanks to Andrew C. Cook, who gave Gianni Botta and me the valuable opportunity to learn from his passionate work as scientist coupled with his refined technique of dissection and photography of fetal heart specimens. Thanks also to Gianni Botta, a colleague and friend whose day-to-day collaboration provided the reciprocal opportunity for growth and understanding in the field of perinatal congenital heart diseases. I am indebted to Rabih Chaoui for agreeing to write the chapter on 3D/4D fetal echocardiography. We all recognize his substantial contribution to the knowledge of this technique through his fundamental papers published in the international literature.

We owe a special thanks to our esteemed colleagues who directly and indirectly contributed to this textbook: Tullia Todros, Mario Campogrande, Elsa Viora, Piero Gaglioti, Vlasta Fesslovà, Roberto Tumbarello, Roberto Conturso, Patrizia D'Ajello, Vincenzo Trengia, Marco Pagliano, Simona Sdei, Giuseppe Errante, Simona Bastonero, Maria Grazia Alemanno, Maria Brizzolara, Rosalba Giachello, Ruggiero Crocco, Alfio Oddo, Maria Renzetti, Giuseppe De Sanso, Vittorio Guaragna, Antonio Guelfi, Bruno Inaudi, Pierluigi Mazzucco, Alessandra Lesca, and Elena Gullino. Thanks to them and many others not mentioned, we had the opportunity to share clinical case experiences. Last but not least, I gratefully acknowledge Andrea Sciarrone for his valuable collaboration in the clinical field and his help in proofreading the references of this work.

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Our thanks to Sofia Redaelli (CNR Massa) and Eugenio Picano (CNR Pisa) Italian National Research Council (CNR) who helped make this book possible.

We are particularly indebted to Giuliano Kraft – efficiently supported in the final phase of this work by Tiziano Carducci – for the patience and strength he showed as time went on and it became apparent that the work was evolving beyond our expectations. Thanks to his creativity and professional ability in the digital world, he contributed brilliantly to the shape and construction of the complex structure of the accompanying DVD.

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Florence, August 2008 E.M. Chiappa

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PART I

Basic Principles of Diagnosis

CHAPTER 1 General Guidelines

Introduction

Congenital heart diseases are the most common congenital malformations, affecting six to eight per 1,000 live births [1-3], and their prevalence in abortuses has been shown to be even higher [4, 5]. Moreover, heart diseases are the leading cause of death among infants with congenital anomalies, causing nearly 20% of neonatal deaths and up to 50% of infant deaths due to congenital anomalies. Recent studies have demonstrated a positive impact of prenatal diagnosis in morbidity and mortality rates in specific groups of congenital heart disease [6-8]. Only 20% of congenital heart disease in the fetus occurs in high-risk pregnancies; therefore, routine screening of all pregnancies is necessary. Prenatal screening cannot be conferred solely to pediatric cardiologists because of the limited number of these specialists. The alternative, chosen in many developed countries, is to assess the heart in a simplified form – the four-chamber view – during routine "anomaly scan" at 18-20 weeks' gestation and to provide extra training for all obstetric sonographers. The anticipated potential of the four-chamber view to detect most of the severe cardiac anomalies has been disproved by discouraging false-negative rates of congenital heart disease in many screening programs utilizing this projection only [9-11]. Most forms of conotruncal anomalies, such as transposition of the great arteries, tetralogy of Fallot, truncus arteriosus, and double-outlet right ventricle, may appear completely normal in the four-chamber view. Some screening programs have demonstrated that the detection rate for congenital heart disease is significantly improved by an extended cardiac examination [12-16]. Therefore, there is a growing consensus that assessment of the ventriculoarterial connection should be included in the routine fetal anomaly scan [17, 18]. Detailed fetal echocardiography may identify most significant congenital heart diseases, but it is time consuming and requires special knowledge of the normal and abnormal cardiovascular system, which is not a requirement for every examiner. Most authors agree that to improve results in fetal echocardiography, efforts are needed to expand the skills of the operator involved with a clear and effective educational method. Positive results of training sonographers to recognize cardiac abnormality in the fetus have been proven [19, 20]. We believe the information provided in this work will be most useful to that end.

The background of this project comes from two main considerations. First, whether in fetal life or postnatally, echocardiographic diagnosis is based on moving images. Consequently, books have limited value in teaching echocardiography, and the use of videotapes is time consuming and relies on inconsistent image quality. With recent advances in ultrasound systems, storing multiple digital frames and clips with superb image quality has become a reality. These advances have brought innovative applications into the clinical field and can be utilized in powerful multimedia presentations for teaching purposes. Second, imaged sections of cardiac specimens are usually compared with their corresponding echocardiographic views in textbooks of echocardiography. These sections are mainly obtained from isolated hearts because they are technically easier and less time consuming to obtain. Nevertheless, imaged sections of the whole body are better tools by which to understand the relationship between cardiac and extracardiac structures. This understanding is particularly necessary in fetal echocardiography, where the number of visible structures around the heart is much greater and the approaches to the fetal thorax are more variable.

For this project, we created a digital presentation, included in the DVD, in which images from tomographic sections of the whole fetal body are combined with dynamic echocardiographic images of normal fetuses and of some of the most common congenital heart defects. All projections are accompanied by schemes and full text for better understanding. We believe this collection will be a major tool for all those interested in studying the fetal heart.

Equipment

A thorough discussion of the principles of ultrasound in prenatal diagnosis is beyond the scope of this project, and the reader must refer to papers and books that extensively cover this subject [21-24].

General guidelines for instrumentation in fetal echocardiography recommend high-resolution ultrasound machines. Impressive progress has been made in ultrasound probe resolution over the past decade, thanks also to the very fast frame rate achieved by parallel processing in which the transducer transmits one line and receives two, resulting in a doubling of the previous rate (Fig. 1.1). Using modern probes, fetal echocardiography can now be performed transvaginally at 11-14 weeks gestational age and transabdominally at 12-15 weeks gestational age [25, 26]. Because of its effectiveness in identifying fetuses at risk for chromosomal and cardiac anomalies, nuchal translucency screening is creating an increasing population of fetuses in need of complete echocardiography [27-29]. Although diagnostic examination can be obtained at an early gestational age in selected cases, further scan between 18-22 weeks gestational age is recommended [30-32].

Transducer frequency should be as high as possible to obtain the best resolution. In the second trimester, a 5-8 MHz transducer is suitable in most cases. Nevertheless, a 3 MHz transducer may be required when deep penetration is necessary due to maternal overweight, an anterior placenta, polyhydramnios, or an unfavorable fetal position. Either sector or convex probes may be used, with advantages and disadvantages for each. Sector probes are the ones most preferred by cardiologists because they are designed to give the best performance in cardiac applications. Moreover, because of their diverging beam, sector probes are most useful when the acoustic window is limited. In the presence of polyhydramnios or increased thickness of the maternal wall, a sector transducer, thanks to its small footprint, can be placed into the umbilical cavity to get closer to the fetus and thus improve image quality. On the other hand, because of the divergent direction of the ultrasound beam from the probe surface, line density (and lateral resolution) decreases as depth increases.

Conversely, convex probes allow for a more ample angle of visualization, making orientation on the fetal body easier and guaranteeing a more homogeneous resolution over the whole area of investigation.

Because of the moving structures of the heart and the high heart rate in the fetus, the primary goal in ultrasound setting is to obtain a frame rate as high as possible. Cross-sectional imaging (Fig. 1.2a) is still the modality most commonly used to study the fetal heart. In this setting, a presetting with compressed gray scale, narrow ultrasound beam, single focus, and absent or very low persistence is recommended. For inexperienced obstetric sonographers, it is important to remember that such a presetting exists and must be selected because an obstetrical presetting employs a frame rate too low to reliably image the fetal heart. To avoid damage to the fetus, cardiac presetting

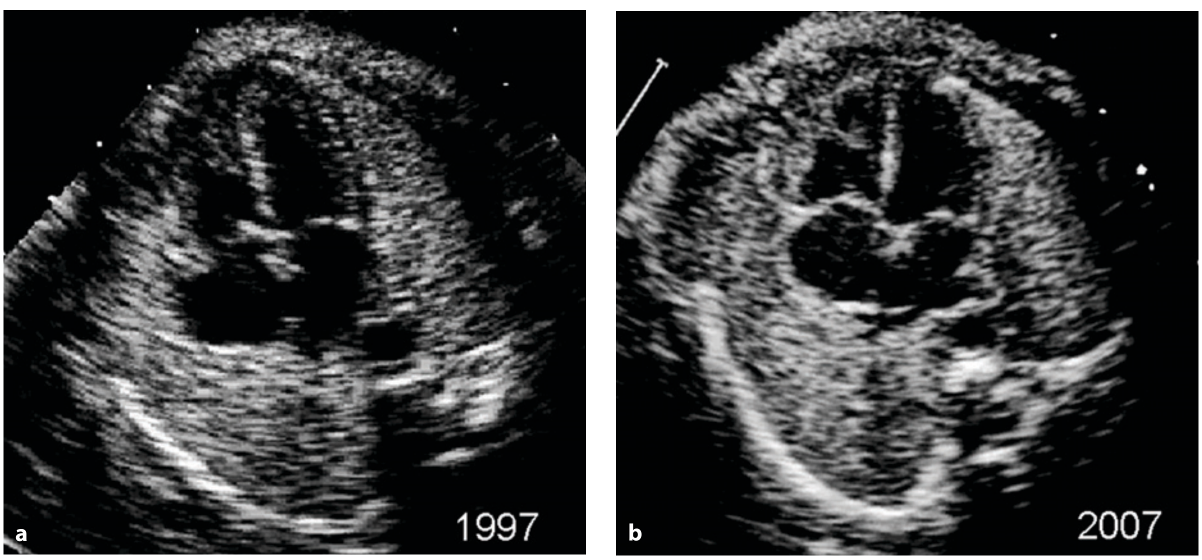

Fig. 1.1 • Ten years separates these two (**a**, **b**) four-chamber echocardiographic sections (**a** 1997; **b** 2007). The improvement in resolution of the new generation of probes is seen in the 2007 image, where a higher degree of anatomic detail is appreciated

should also be used to ensure that spatial temporal average power output for color and pulsed Doppler is less than 100 mW/cm^2.

The possibility of image magnification using the zoom allows for better definition of the size and structure of the fetal heart, whereas the cine loop now makes it possible to record a long series of consecutive digital images that can be immediately reexamined as single frames. This function is particularly useful for identifying structural or flow anomalies that may be overlooked should the images be evaluated in real time only. With recent instrumentation, storing digital clips on the hard disk of the built-in computer is possible. Instruments equipped with cine-loop and digital-clip storing capabilities provide a user-friendly system in which moving clips and still-frame digital images are readily accessible for review – a powerful means for off-line analysis and case discussion that is largely superior to professional videotape recorders.

When investigating the fetal heart, the use of Doppler is complementary to the morphological study with the cross-sectional technique. To allow an accurate flow evaluation, the insonation angle should be as parallel as possible to the estimated flow direction under study. The estimated error of flow velocity is negligible for insonation angles less than 20-30°. Routine use of color flow mapping (CFM) (Fig. 1.2b) is helpful to assess the symmetry of ventricular filling and to detect significant regurgitation of the atrioventricular valves related to major congenital heart defects. CFM facilitates positioning of the sample volume of pulsed Doppler in the region of interest. On CFM evaluation, the color box should be kept as small as possible, with maximum scale velocity around 50-90 cm/s in arterial districts and 7-20 cm/s in venous districts. On pulsed Doppler (Fig. 1.2c), the sample volume must be kept small (2-4 mm), with a wall filter at 150-300 Hz for arterial vessels and 50-100 Hz for venous vessel. Pulsed Doppler tracings should be obtained during periods of fetal apnea to avoid the flow waveform modifications produced by respiratory movement. Continuous Doppler is considered optional but may be necessary to assess precisely the peak velocity of high-velocity jets, such as those in tricuspid valve regurgitation in pulmonary valve atresia with intact ventricular septum (Fig. 1.2d).

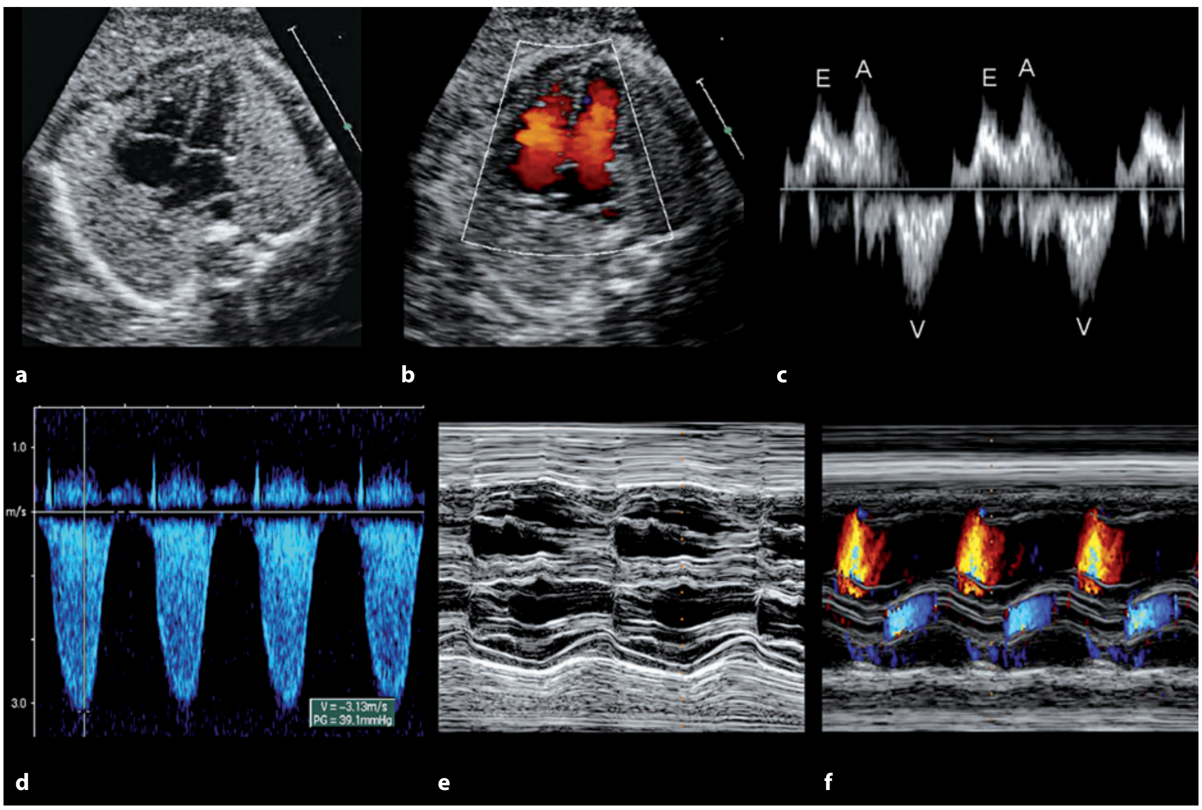

Fig. 1.2 • Some of the most common applications of echocardiography in the fetal heart: cross sectional (**a**), color flow mapping (**b**), pulsed Doppler (**c**), continuous Doppler (**d**), M-mode (**e**), and color M-mode (**f**)

Due to the high frame rate and time resolution, M-mode tracing (Fig. 1.2e) is the most accurate method to provide information on wall thickness, ventricular diameter, and shortening fraction. However, the application of M-mode in the fetus is limited because M-mode measurements require an ultrasound beam orientation that is difficult and sometimes impossible to obtain. Color M-mode color (Fig. 1.2f) combined with pulsed Doppler has been demonstrated to be an invaluable tool in assessing fetal arrhythmias.

Major Planes of the Body and Heart

The major planes of the body are the sagittal, coronal, and transverse planes (Fig. 1.3) as detailed in the following:

- The *sagittal plane*, also called the median plane, runs in a true anteroposterior direction. When traced through the median axis, the body is divided into right and left halves.
- The *coronal plane*, also called frontal plane, is a long-axis plane of the body perpendicular to the sagittal plane. When it is traced through the central axis, it divides the body into anterior and posterior halves.
- The *transverse plane*, also called the horizontal plane, is a short-axis plane of the body perpendicular to the sagittal and coronal planes. It divides the body into superior and inferior portions.

The long axis of the heart in postnatal life lies in a plane that runs from the left hypochondrium, where the cardiac apex is located, to the right shoulder. In the adult, it is typically inclined 45° to each major

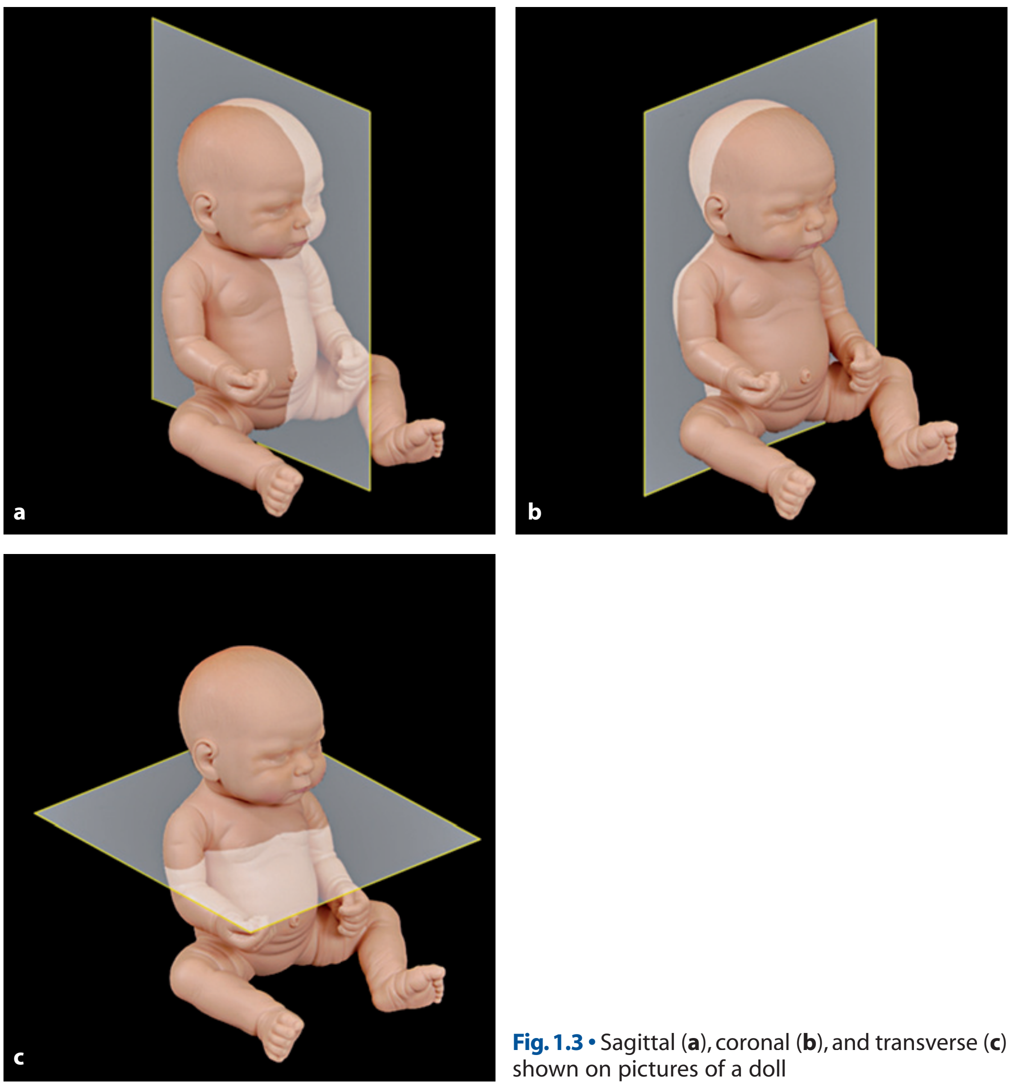

Fig. 1.3 • Sagittal (**a**), coronal (**b**), and transverse (**c**) planes of the body shown on pictures of a doll

body plane. However, inclination of the cardiac long axis relative to the transverse plane may change with the positions of the diaphragm. In the fetus, the heart is more horizontal than in postnatal life because the lungs are deflated and the liver is relatively large. Therefore, the cardiac long axis sits on a plane nearly parallel to a transverse plane of the fetal body. On the contrary, the short axis of the heart, which is perpendicular to the long axis, is almost parallel to the sagittal plane of the fetal body (Fig. 1.4).

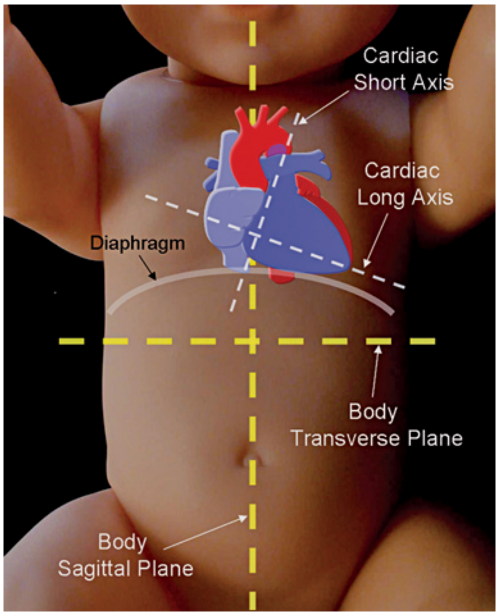

Fig. 1.4 • Long and short axis of the fetal heart and body are simulated on a picture of a doll

By convention, two major planes can be distinguished along the long axis of the heart: the four-chamber plane and the two-chamber plane. The first plane is perpendicular to the inlet and trabecular ventricular septum, whereas the second plane is parallel to it (Fig. 1.5a). The short-axis plane includes a series of parallel planes, all perpendicular to the long axis of the heart. Classically, the short-axis plane at the level of the mitral valve and the level of the papillary muscles of the left ventricle are considered (Fig. 1.5b).

Basic Probe Manipulations

In general, echocardiographic study of the fetal heart requires small probe manipulations. In fact, because of the small size of heart and the relatively large distance from the application point of the probe, small movements of the transducer produce great changes in the scan plane.

In ultrasound examination, the section plane can be modified by three fundamental manipulations of the probe: rotation, angulation, and translation (Fig. 1.6):

- With rotation, the scan plane is changed by turning the transducer clockwise or counterclockwise while maintaining the footprint in a fixed position.
- With angulation, the scan plane is modified by tilting the probe in the cranial, caudal, right, or left direction. In this case also, the application point of the probe is maintained relatively fixed.
- In translation, the scan plane is left unchanged while its application point is changed by sliding the transducer on the skin.

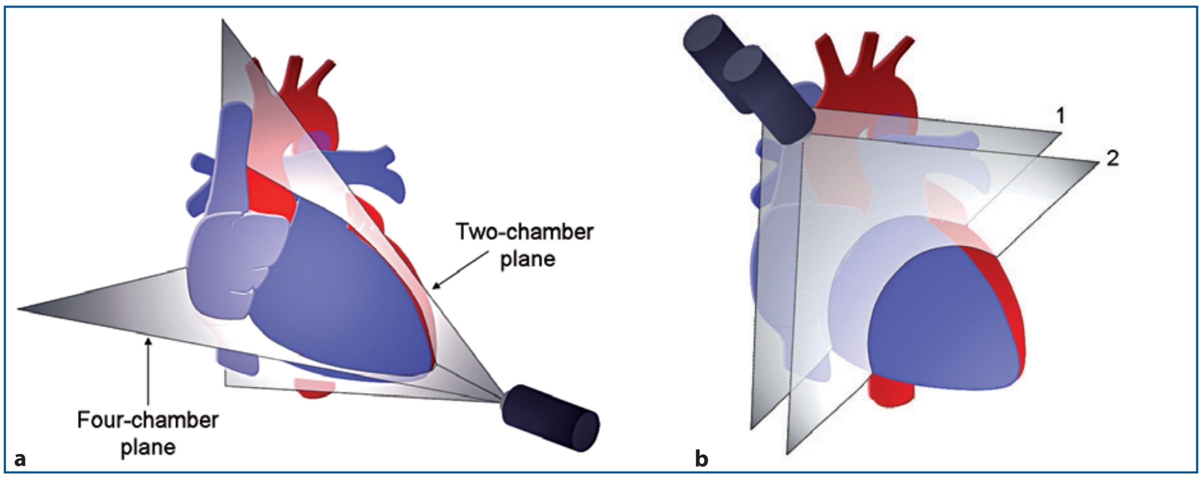

Fig. 1.5 • The two planes along the long axis of the heart are shown on a heart diagram, simulating an apical approach with the probe (**a**). The two basic short-axis planes of the heart are shown on a heart diagram: at the level of the mitral valve (or the base of the heart) (*1*) and at the level of the papillary muscles (*2*) (**b**). (See more in the respective chapter)

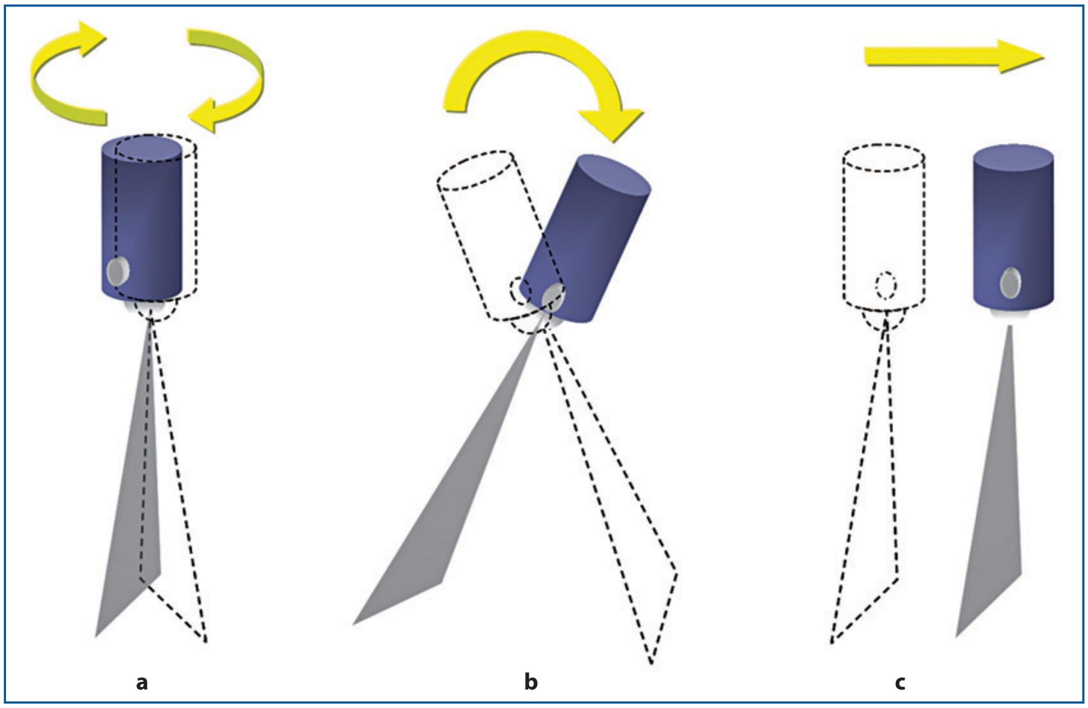

Fig. 1.6 • Diagram showing the three basic manipulations of the probe: rotation (**a**), angulation (**b**), and translation (**c**)

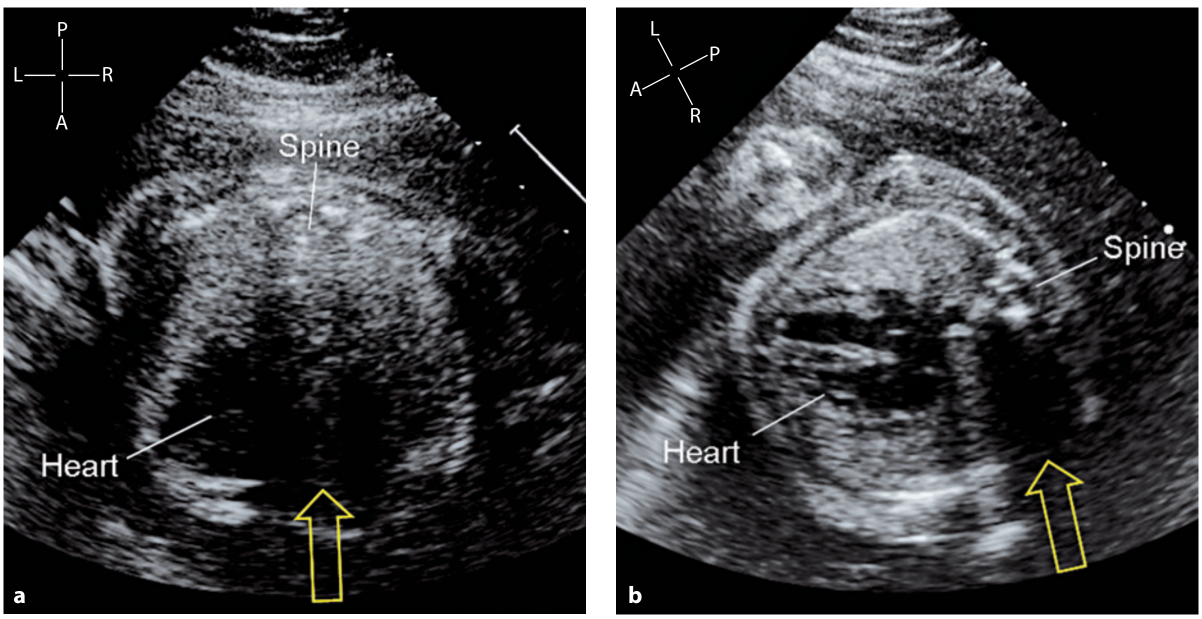

Fig. 1.7 • Four-chamber view in the same fetus with unfavorable anterior presentation of the spine. The shadow of the spine (**a**) (*yellow open arrow*) masks the heart, which is barely visible. The heart is brought out of the shadow (**b**) (*yellow open arrow*) by translating the probe to the left side of the spine. A four-chamber view of reasonable quality is obtained from the posterior part of the left hemithorax

Translation of the scan plane is more difficult to learn but is particularly useful in prenatal ultrasound examination because it provides a similar projection from different scanning angles. This allows, for example, the targeted organ to be brought out of the shadow of proximal structures (Fig. 1.7).

Translation of the scan plane may also improve the definition of cardiac structures by allowing examination

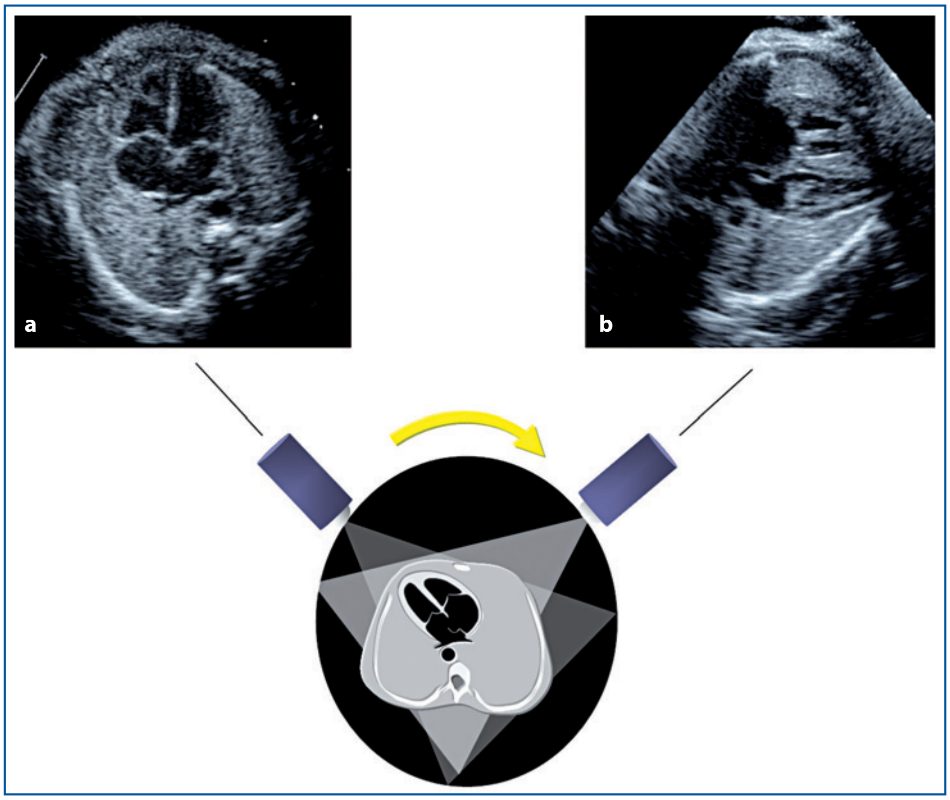

Fig. 1.8 • Diagram simulating a transverse section of the fetal thorax at the level of the four-chamber view within the amniotic cavity (*black area*). The apical four-chamber view (**a**) can be changed to a transverse four-chamber view (**b**) by translating the probe (*yellow arrow*) on the mother's abdomen while maintaining the section plane unchanged

with axial instead of lateral resolution (Fig. 1.8). In fetal echocardiography, similar projections of the heart can be obtained from different positions of the transducer because the lungs do not represent an obstacle to imaging, as they are filled with fluid and not air. This allows projections through the rib cage, even from the back, which are unobtainable postnatally (Fig. 1.7). Nevertheless, projections from the back produce attenuation of the ultrasonic energy, particularly in the third trimester when bony structures of the thoracic cage absorb most of the ultrasound energy.

In general, the best definition of cardiac structures is achieved through the fetal abdomen. If initially unfavorable, fetal presentation may change for the better by translating the scan plane or by turning the mother on her side, having her empty a full bladder, or having her take a little walk. Sometimes, the examination must be postponed for hours or a few days.

Axial and Lateral Resolution

The axial resolution is the shortest distance between two points lying on the same insonation axis, which the ultrasound system is able to represent as separate. The lateral resolution refers to the shortest distance between two adjacent points that an ultrasound system is able to represent as distinct. In virtually all cross-sectional ultrasound systems, the axial resolution is better than the lateral resolution. This implies that structures that are orthogonal to the ultrasound beam will be better represented than structures that are parallel. The four-chamber view provides one of the best examples to explain this concept. This view can be obtained in apical or transverse orientation. Despite showing sections of the fetal thorax across identical structures, the apical and transverse four-chamber views provide different information. In fact, in the apical approach, the moderator band, the atrioventricular valves, and the venoatrial connection are better represented; in the transverse approach, ventricular-wall thickness, ventricular transverse diameter, and foramen ovale morphology and function are more precisely assessed. Conversely, in the apical approach, it is difficult to identify the endocardial borders of the heart chambers and assess precisely ventricular-wall thickness and transverse diameter of cardiac cham-

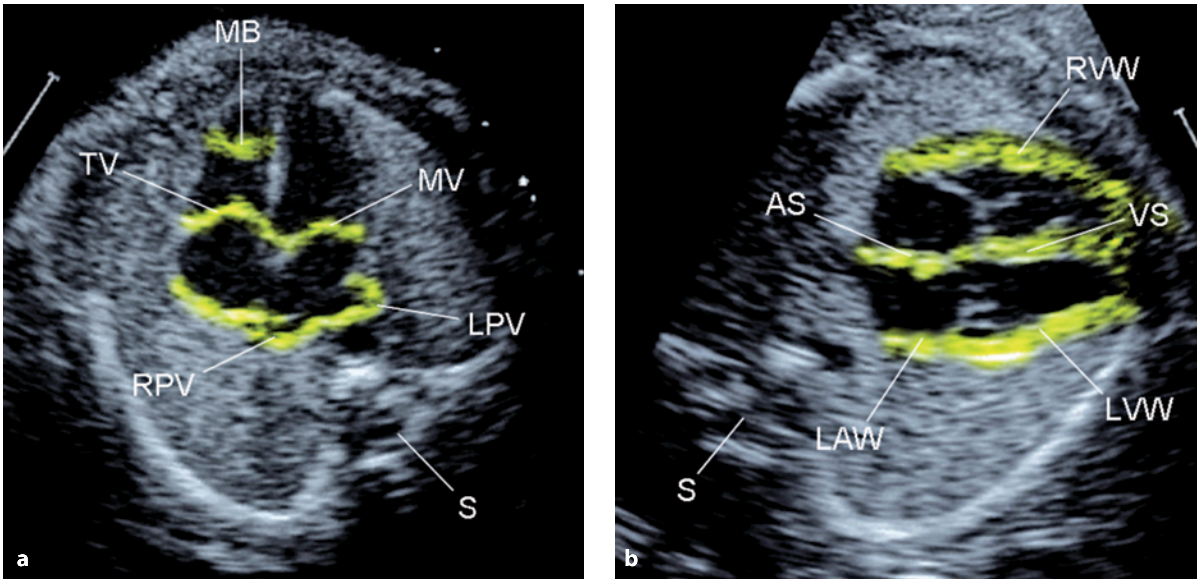

Fig. 1.9 • Normal four-chamber view in apical (**a**) and transverse (**b**) approach. The *yellow highlighted areas* indicate structures that are better defined in each view. *AS* atrial septum, *LAW* left atrial wall, *LPV* left pulmonary vein, *LVW* left ventricular wall, *MV* mitral valve, *RPV* right pulmonary vein, *RVW* right ventricular wall, *TV* tricuspid valve, *S* spine, *VS* ventricular septum

bers, whereas in the transverse approach, the moderator band and atrioventricular valves are usually undefined (Fig. 1.9). These differences are even better appreciated on moving images than in still frames.

Method for Comprehensive Cardiac Evaluation

As already stated, most authors agree that the routine fetal anomaly scan should include assessment of ventriculoarterial connection, and this can be achieved by different methods. Some authors favor incorporating the views of the two so-called ventricular outlets [16, 17]. Others suggest using a series of short-axis sections of the fetal thorax for complete cardiac examination [33-36].

In complete assessment of the fetal heart, the experienced examiner should understand the echocardiographic anatomy so thoroughly that he or she uses the standard views not as ends in themselves but only as reference points during a scan sequence, including a series of parallel sections from bottom to top, from side to side, and from front to back. However, demanding such knowledge from all obstetric sonographers for routine examination is highly unreasonable. Our teaching experience over the past 10 years has shown us that beginners or first-level sonographers can understand and more easily assess the fetal heart using transverse or sagittal views of the fetal body; that is, by orienting the scan plane orthogonal or parallel to the long axis of the fetal body (Fig. 1.10). This is because the long axis of the fetal body is a reference line easier to identify than the major axis of the fetal heart.

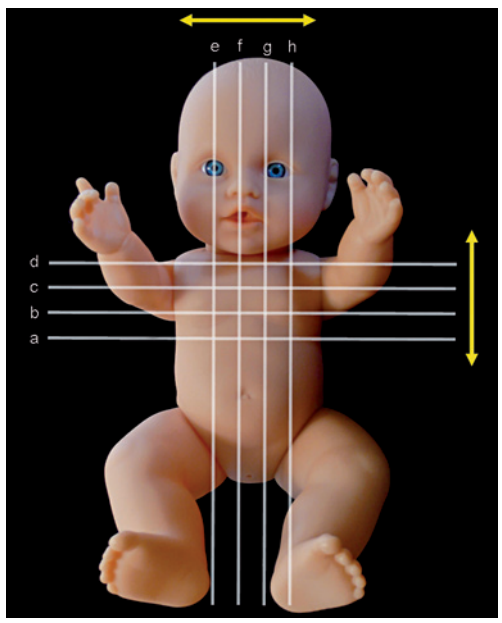

Fig. 1.10 • *White lines* on the picture of a doll simulate a consecutive series of sections with which one can investigate the fetal body along the transverse plane, from bottom to top (*a-d*), and along the sagittal plane, from right to left (*e-h*)

In particular, the transverse sections of the fetal upper abdomen and thorax have gained a growing