Congenital dysplasia and dislocation of the hip

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to **JANE**

FOREWORD

It is my good fortune to contribute a foreword to this book written by Dr. Sherman Coleman. I hold high the author's qualifications. He has had a long and continuing interest in congenital dysplasia and dislocation of the hip, and few have the knowledge and expertise that he possesses in this area.

The excellence that one expects of Dr. Coleman is apparent in his approach to this complex subject. He has attempted to cover every conceivable phase and has established fairly definite guidelines. Indeed, almost every abnormality related to congenital dysplasia and dislocation of the hip in infants and adults is discussed in detail.

Many significant changes have occurred in the past two decades in the treatment of the unfortunate child who is born with this condition. In recent years we have seen the introduction of the innominate osteotomy of Salter as well as the pericapsular osteotomy of Pemberton. Other osteotomies that have been developed during the past two decades include the triple innominate osteotomy of Steel, the double innominate osteotomy of Sutherland and Greenfield, and the dial osteotomy proposed by Eppright and Wagner. The role of each of these osteotomies is described in detail. The author also clearly delineates the indications for salvage procedures such as the Chiari osteotomy, the shelf procedure of Wilson, and the Colonna arthroplasty.

There has existed for a great many years a compelling need for a textbook such as this. I confidently anticipate that this book will meet this need and serve as a guide for everyone interested in the subject of congenital dysplasia and dislocation of the hip.

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PREFACE

Over the past 30 years the perplexing and often distressing problems encountered in the diagnosis and treatment of congenital dislocation of the hip have become better defined and as a consequence more clearly understood. Correspondingly, the treatment of the condition has undergone major changes. The principles of diagnosis and treatment and the technical solutions to the many problems posed by this condition are better established now than at any time in the past. Our understanding of the clinical expressions of hip dysplasia in the infant, both during the newborn period and in the early weeks of infancy, and our improved programs for early detection have greatly reduced the number of problems caused by late diagnosis. It has been demonstrated that if hip dysplasia is recognized early and is appropriately treated, many of its worrisome sequelae are preventable. However, given the capricious nature of dysplasia and dislocation, there will always be the patient who has an atypical prenatal dislocation, a hip that does not respond favorably to conventional treatment, or a complex problem of iatrogenic origin that will challenge the expertise of any surgeon experienced in children's hip disorders.

The need for a book that discusses the early diagnostic features of this condition so that early recognition and treatment can be provided has become evident. The need for an extension of such a text to respond to the problems posed by the more complicated hip dislocation or by the ineffectively treated hip dislocation is equally obvious. The inevitable and uncontrollable variations in the disease process, as well as the unpredictable responses of patients to the various treatment modalities, suggest that the major problems associated with hip dysplasia and its sequelae will always exist. Thus an analysis of these issues and a logical synthesis of their solutions will continue to be necessary.

Because the clinical manifestations of congenital dislocation of the hip encompass not only the newborn period but also all ages from infancy through old age, I believe that it is appropriate to include the many ways in which the condition affects patients of all ages. The syndrome presents a complex though logical series of problems. Furthermore, each problem has its own unique set of characteristics, depending on the age of the patient, the past treatment history, the specific pathology of the hip, and many other highly individualized factors.

Ideally, the need for surgical treatment of congenital dislocation of the hip should eventually become a rarity, except for occasional difficult antenatal and teratologic dislocations, which will always remain a

challenge. However, the complete prevention of all sequelae of a problem that is both genetically and environmentally caused is unrealistic, even in the most medically sophisticated setting. The first and most important goal of this text is to deal with the diagnostic and therapeutic criteria of the neonate and infant with hip dysplasia and dislocation. Second, the scope and complexity of the condition, including the variations in which congenital hip disease may be present, are described. A review of the current surgical and nonsurgical approaches that are now available for treatment is covered next. Finally, some of the problems and complications that are unique to this condition are discussed, with suggestions of how to deal with such untoward occurrences.

This book is sufficiently broad in scope that it should provide a practical guide to the diagnosis and care of common problems in congenital hip disease that are encountered by pediatricians, general family physicians, and orthopedic surgeons from other areas of expertise. It is not primarily directed to the attention of the experienced hip surgeon who is already familiar with much that I have written. Nor do I expect that all will fully agree with the principles presented or the experiences on which they are based, for each builds on his or her own experience, which very possibly will differ.

Any effort that is designed to satisfy such broad objectives requires more than simple factual knowledge and clinical experience; it requires the selfless participation of the several hundred patients afflicted with congenital dislocation who have entrusted me with their care. These people have provided me with an irreplaceable source of clinical and factual information. This includes the cooperation and continuing support of the many medical and paramedical personnel who are involved in their care. Such a volume is also built on the invaluable exchange of ideas that has taken place among my teachers, colleagues, and students. But even more, it requires the tolerance and devotion of my understanding and patient wife and family, whose personal lives were often inconvenienced by the demands made to produce this book. To all these individuals I want to extend my deep gratitude. Special thanks are due my son, Dr. S. Michael Coleman, and some of my residents, including Drs. Howard A. King, Kenneth D. Johnson, and Peter M. Stevens, for their research efforts on several of the chapters. I also want to thank Mrs. Ruth C. Henson, Mrs. Kathryn A. Morton, and Mrs. Tarza L. Peterson for their editorial assistance in composition, bibliography, and secretarial support. Thanks are also due Mr. Julian Maack, who was responsible for producing all of the original illustrations as well as adaptations.

Sherman S. Coleman

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CONTENTS

CHAPTER 1

Embryology and anatomy of the hip joint

EMBRYOLOGY

To comprehend the etiology and pathogenesis of congenital hip dislocation, it is necessary to understand the development of the human hip joint. Many detailed and comprehensive studies of the developing hip have been reported. Bardeen's[4] investigations, beginning in 1901, represent some of the early, more sophisticated studies on this subject. Subsequently, the contributions of Strayer,[28] Badgley,[1] Laurenson,[17] Gardner and Gray,[12] Watanabe,[32] and others have helped to expand and further our understanding of hip joint development. With these concepts about the normal development we can better envisage some of the problems and conditions that result from the pathologic development of the hip. In this chapter only a synopsis of the embryogenesis and morphogenesis of the hip will be described; more detailed information can be obtained by referring to the references at the end of the chapter.

General considerations

The prenatal development of the hip has been arbitrarily divided into the embryonic and fetal periods. The *embryonic period* involves the first 2 months after fertilization. At 2 months of gestation the embryo measures about 30 mm in crown-rump length; it is during this period that the limb buds are formed by differentiation from a blastemal mass. The limb buds ultimately become the definitive appendages. During the embryonic period the circulation to the limb is established and the hip joint becomes completely formed in cartilage, with an identifiable femoral head, acetabulum, capsule, synovial membrane, and ligamentum teres.

The *fetal period* begins at the conclusion of the embryonic stage and continues through the final prenatal development at term. It is during this time that the complex developmental characteristics of the human hip take place and the features of the hip that relate to antenatal dysplasia and dislocation are established.

Embryonic development of the hip. Early investigators* demonstrated that the anlage of the skeleton consists of un-

*See references 2 to 4, 8, 14, and 15.

differentiated cell masses. Bardeen[2,4] showed that during the third week of embryonic life the limb buds become filled with mesenchyme, the origin of which is uncertain but was thought to be from the parietal layers of the unsegmented mesoderm. Strayer[29] later believed that this mesenchymal tissue possesses multipotential characteristics and contains all the elements necessary for the development and growth of the joint, with the exception of the blood vessels and nerves, which appear later. These concepts, although not universally accepted, seem to have the support of the majority of investigators.

At 4 weeks of gestation the embryo is about 5 mm in crown-rump length and the limb buds, which consist of densely packed cells with multipotential capacity, can be seen as folds along the ventrolateral aspect of the body. At this stage the hip shows little differentiation; however, the knee joint, feet, and toes already show some early evidence of development.[32]

When the length of the fetus is 10 mm (5 to 6 weeks), the os innominatum blastema begins to separate into three masses, representing the ilium, ischium, and pubis. At the 12-mm stage (6 weeks) the femoral shaft begins to show precartilage cells and assumes a somewhat "club-shaped" appearance (Fig. 1-1). Centrally, the cartilage of the femur grows by interstitial cell proliferation, and, at the periphery, the growth is appositional, as the cells and matrices are laid down in successive layers. At 6 weeks of gestation the femoral shaft is composed of the most differentiated cartilage cells,

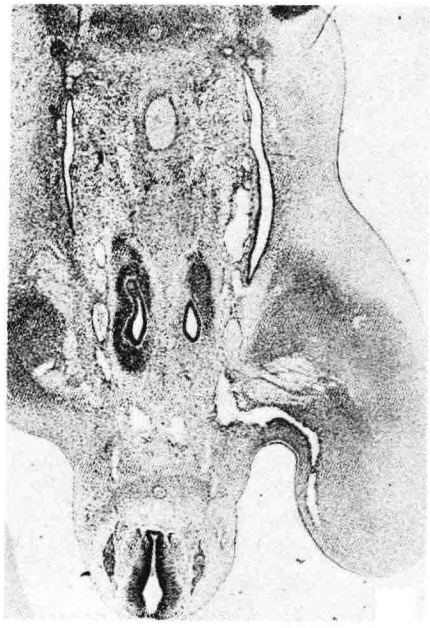

Fig. 1-1. At 6 weeks of gestation (fetal length, 12 mm) the lower limb appendage has developed precartilage cells in the region of the acetabulum and the femur. (From Strayer, L. M.: The embryology of the human hip joint, Yale J. Biol. Med. **16:**13, 1943.)

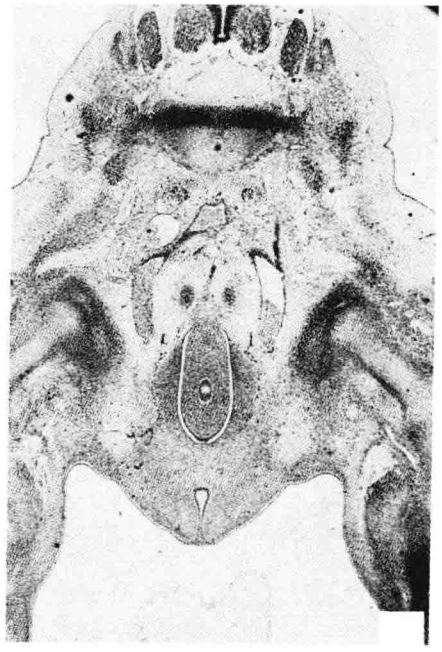

Fig. 1-2. At 7 weeks of gestation (length, 15 mm) the femur and acetabulum become better defined and the femoral head assumes a globular shape. (From Strayer, L. M.: The embryology of the human hip joint, Yale J. Biol. Med. **16:**13, 1943.)

with the head of the femur, the distal femur, and the trochanters appearing progressively less differentiated in that order.

Strayer[29] observed that, after the 12-mm blastemal stage previously described, each skeletal primordium (that is, the femur and os innominatum) passes through three or more stages of development. These are called the blastema, the precartilage, the cartilage, and the fetal bone stages. He found the femur of a 17- to 20-mm embryo to be a typical example of this developmental process. In this primitive stage the femoral shaft is composed of cartilage cells, the ends are made up of precartilage cells, and the greater trochanter is composed of cells resembling blastema.

Bardeen[4] and Strayer[28] both found that the initial skeletal primordium of the hip joint consists of densely packed, multipotential, primitive mesenchymal cells. Gardner and Gray[12] in 1950 concurred with these observations and also added evidence that showed that the general form and major components of the hip are present before the joint space actually develops. In Bardeen's[3] detailed studies of the embryogenesis and morphogenesis of the hip, he concluded that the development of the acetabulum takes place by means of the fusion of the cartilaginous primordia of the ilium and ischium and that these in turn fuse with the smaller and the more slowly developing pubic primordium. He observed that the proportional amounts of each pelvic cartilage contributing to development of the acetabulum were the same as for those ultimately contributed by the corresponding portions of the innominate bone in the adult; namely, two fifths ischium, two fifths ilium, and one fifth pubis. During this acetabular formation, which can be observed as early as 6 to 7 weeks of gestation (length, 15 mm), the femoral head can be seen to develop in situ as a globular structure within the primitive cartilage of the hip joint.

When the fetus is 15 mm long, or at approximately 6 to 7 weeks of gestation, the femoral head and acetabulum show further signs of differentiation. The femoral head becomes globular in shape and the femoral shaft also begins to acquire a slightly convex shape (Fig. 1-2). At length 17 mm (7 weeks of gestation) a definite interzone develops between the femoral head and the acetabulum, and when the fetus has reached 20 mm in length (7½ weeks of gestation) this interzone differentiates into three layers. The middle layer or zone represents the first evidence of the synovial membrane, and the outer layers represent the perichondrium of the acetabulum and femoral head.[12] Also, at 20 mm of length the muscle groups are outlined and the femoral neck has formed a recognizable angle of inclination with the shaft of the femur.[32] This angle varies from 130 to 160 degrees.

When the length of the fetus is about 30 mm (8 weeks), at the conclusion of the embryonic stage, there is noticeable deepening of the acetabulum and the greater trochanter becomes evident. By this stage the cartilage has become hyaline in nature. Also, the ligamentum teres and other capsular structures have become vascularized; the labrum glenoidale (limbus) also shows signs of development at the periphery of the acetabulum (Fig. 1-3).

Fetal development of the hip. The *fetal period* begins at 8 weeks of gestation when the fetus measures approximately 30 mm in crown-rump length; it is during this time that all the definitive development of the hip joint occurs, leading to the final fetal or prenatal development at term.

When the length of the fetus is about 30 mm (8 weeks) the hip joint space begins to form as a small, slitlike cavity lined by flattened cells. Strayer[28] postulated

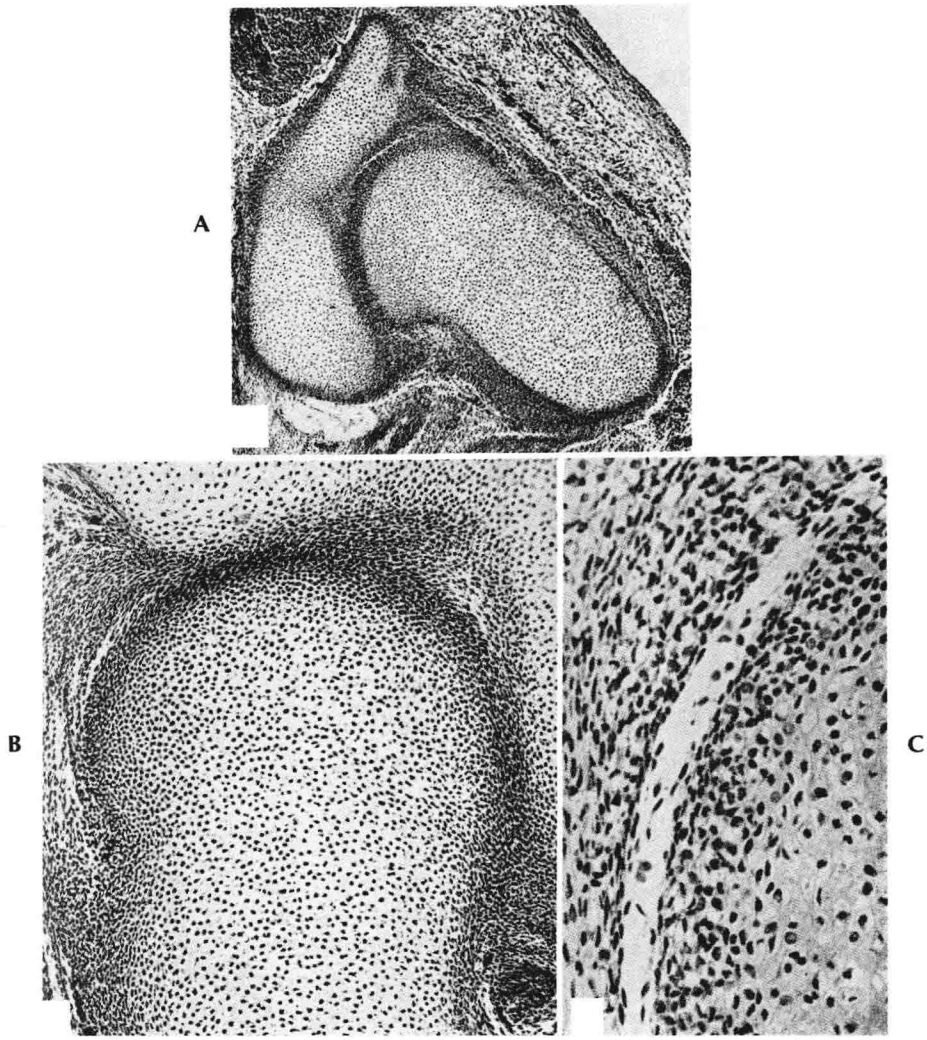

Fig. 1-3. Slightly later, at 8 weeks of gestation (length, 30 mm), an interzone develops between the femoral head and acetabulum, **A.** The perichondrium of these two structures is defined, the labrum glenoidale is beginning to develop, **B,** and the cartilage becomes slightly hyaline in character, **C.** (From Gardner, E., and Gray, D. J.: Prenatal development of the human hip joint, Am. J. Anat. **87**:163, 1950).

that the joint cavity develops as a degenerative and mechanical process because he observed degeneration and cell splitting along the joint margins as the embryo grew from 37 to 45 mm (8 to 9 weeks) in size. He also proposed that the developing neuromuscular mechanism had a significant effect on the joint development and that abnormalities in the neuromuscular system could cause adverse changes in hip growth and development. At 30 to 40 mm an ingrowth of blood vessels invades the deepened acetabular fossa, and synovial-like tissue develops around the reflection of the developing labrum glenoidale or limbus. The acetabulum more clearly shows the iliac, pubic, and ischial cartilages entering into the formation of the acetabulum.[12] The femoral head also reveals a definite fovea capitis femoris, and the ligamentum teres is well defined (Fig. 1-4).

Strayer[29] observed that the development of the acetabular elements is accompanied by lateral growth and proliferation of the labrum. He believed the growth of the limbus to be "the most important mechanism concerned with deepening of the acetabulum." Hence he believed that the labrum and its normal growth are critical in lending stability to the hip during its fetal development.

At 11 weeks the fetus is approximately 50 mm in length. The hip joint has been completely formed, and the femoral head presents a spherical contour; it is approximately 2 mm in diameter.[32] The head shows signs of vascularization, predomi-

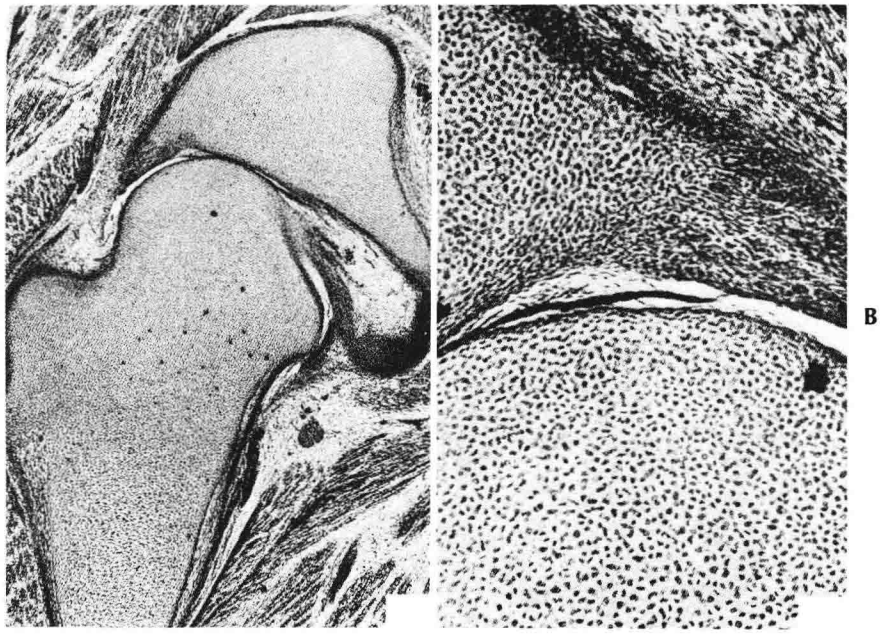

Fig. 1-4. At 9 weeks of gestation (length, about 40 mm), the joint cavity has begun to form, with synovial-like tissue reflected about the limbus, and the ligamentum teres becomes defined, **A.** The cartilage has become hyaline in nature and the perichondrium is well developed on both sides of the joint, **B.** (From Strayer, L. M.: The embryology of the human hip joint, Yale J. Biol. Med. **16:**13, 1943.)

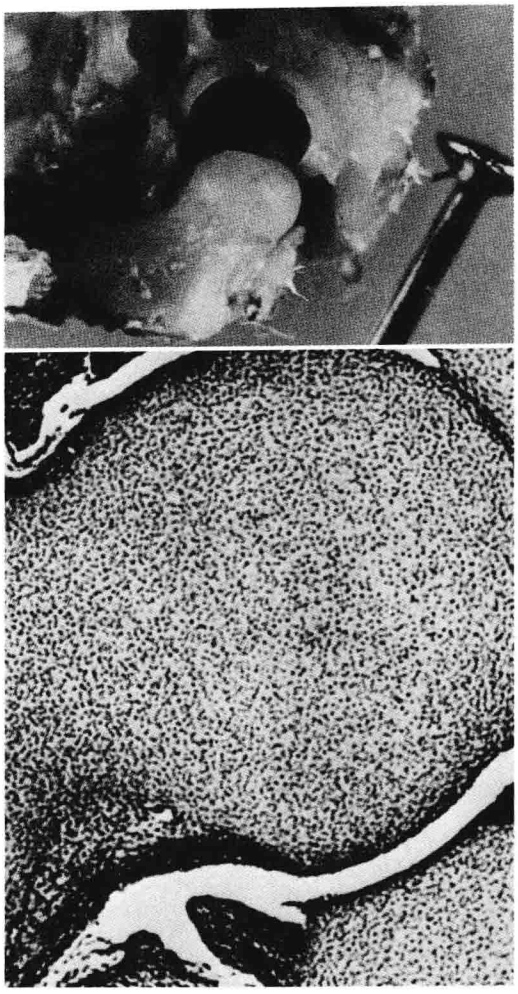

Fig. 1-5. The femoral head can be manually dislocated from the acetabulum at about 11 or 12 weeks of gestation (length, 50 mm). This is shown well in **A.** The size of the femoral head is shown in relationship to the head of a pin. The joint space at this time is completely formed, **B.** (From Watanabe, R. S.: Embryology of the human hip, Clin. Orthop. **98:**8, 1974.)

nantly by vessels from the perichondrium of the neck and also by a few vessels entering from the trochanteric fossa and the ligamentum teres.[12] The lines of cleavage have now formed at the joint, and, at this time, the head is covered by well-defined hyaline cartilage. Also at this point, because the femoral head is now separate from the acetabulum, it is possible for the head to be manually dislocated from the acetabulum (Fig. 1-5).[32]

At this same 50-mm stage, Badgley[1] reported that femoral anteversion measures approximately 5 to 10 degrees and that the acetabular inclination averages 40 degrees in the sagittal and 70 degrees in the vertical plane. These values have subsequently been affirmed by Wata-

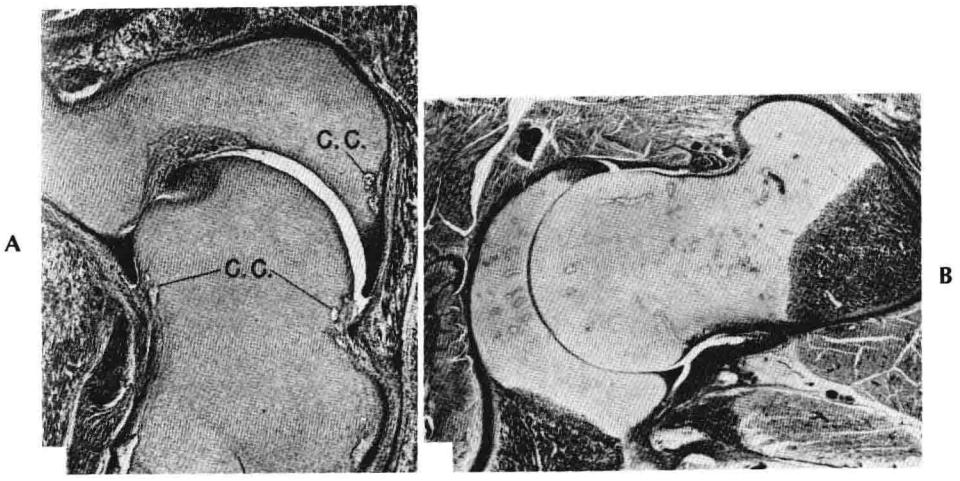

Fig. 1-6. At 13 weeks of gestation (length, 70 mm), the capsular structures become better defined and the acetabular roof more completely covers the femoral head, **A.** The zona orbicularis is also evident, and the cartilage of the head and neck and trochanters, along with the acetabulum, are well vascularized, **B.** (From Gardner, E., and Gray, D. J.: Prenatal development of the human hip joint, Am. J. Anat. **87**:163, 1950.)

nabe.[32] However, these fetal calculations of the various directional planes of the acetabulum appear subject to considerable uncertainty from the standpoint of accuracy because of difficulty in establishing a critical point of reference. I believe, therefore, that this particular aspect of hip joint development does not deserve further discussion. The vasculature of the capsule and the synovial membrane have also become well developed at the 50 mm stage, and the pattern now largely resembles that of the adult hip.

When the length of the fetus is 70 mm, the roof of the acetabulum extends over the femoral head and the vascularity of the entire hip becomes more pronounced. Also at the 70-mm stage of development (12 to 13 weeks of gestation), the fibrous capsule becomes thickened as a result of the further development of collagenous fibers, which help form a well-defined zona orbicularis (Fig. 1-6). By 14 weeks of development, the crown-rump length of the fetus is approximately 90 mm. Because of the increasing length of the limbs, the hips and knees seem to become forced into greater flexion and the left lower limb usually overlaps the right.

At the sixteenth week of gestation (length, 120 mm), a demonstrable enlargement of the femoral head and the trochanters is evident. At this stage the musculature about the hip is fully developed and active hip motion can be observed. The vasculature has matured and the main source of supply to the femoral head is by way of the epiphyseal and metaphyseal vessels. The vessels of the ligamentum teres, which contribute to the femoral head, are very small and insignificant at this age. Moreover, as Gardner and Gray[12] have shown, the arteries of the round ligament contribute very little to the blood supply of the developing femoral head until late in childhood.

At 20 weeks of gestation the fetus averages 170 mm in length and has completed one half of its prenatal development.