

Significance of the Lateral Epiphysis of the Acetabulum to Hip Joint Stability

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Abstract

Normal development of the acetabulum is crucial to the growth and stability of the hip. Twenty-five New Zealand white rabbits (postweaning) weighing 1.5 to 2.2 kg were used. Both hips were exposed through an anterolateral approach. On the right hip, a fixed area of superolateral physeal cartilage was damaged with drills. Sham open reduction was performed for the left hip. Radiographic changes of the right hips were evident at 6 weeks. At 12 weeks, the right hip dislocated in a posterior and superior direction. The left hip remained normal. Histopathologic analysis correlated strongly with the radiographic findings. There were thinning of cartilage cells of the acetabulum, with disorganisation. The acetabular roof was poorly formed. The lateral acetabular epiphysis is vital to the development of the acetabular roof. Damage to this epiphysis may result in acetabular maldevelopment and subsequent hip instability. We tested the hypothesis that abnormality in this epiphysis can give rise to abnormal acetabular development.

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Introduction

Developmental dysplasia of the hip (DDH) remains one of the most difficult disorders to understand and treat in Paediatric Orthopaedics. The aetiology have not been clearly understood and therefore the management remains controversial.

Certain causative factors have been well established in patient with DDH including ligamentous laxity, response of female fetuses to maternal hormones, prenatal and postnatal positioning, and certain genetic factors.

The author believed that faulty genetic development lead to faulty acetabular development but the evidence to date is controversial. The acetabular roof is important to hip joint growth and stability.

The acetabular cartilage complex is a three-dimensional structure with three limbs (triradiate) medially and a cup-shaped structure laterally (Fig. 1). It is composed of very cellular hyaline cartilage. Normal acetabular growth and development occur through balanced growth of the proximal femur, the acetabular and triradiate cartilages, and the adjacent bones. In DDH, this fine balance may be disrupted.¹

The development of the fetal, neonatal and infant acetabulum is crucial to the growth and stability of the hip joint. In-depth studies on its development or maldevelopment might provide clues to the aetiologies and

pathogenesis of development hip dysplasia. Studies were done on the development of the acetabular roof in the fetal hip by arthrography and histology.² Others had investigated the role of the acetabular rim³ and the labrum^{4,5} on the genesis of acetabular dysplasia. Acetabular dysplasia induced by iatrogenic damage^{6,7} or fusion⁸ to the triradiate cartilage in experimental animals was also performed.

Only a few studies^{5,9-14} described the importance of the lateral acetabular epiphysis in the development of the hip joint. The effect of damaged and maldeveloped lateral acetabular physeal cartilage has not been previously investigated.

We believe that the lateral acetabular epiphysis, which forms part of the acetabular roof, exerts a strong influence on the growth and stability of the hip joint. We investigated this by studying the effects of iatrogenic damage to the lateral acetabular epiphysis on rabbit models. The experiments were designed to study how surgery on the lateral acetabular epiphysis might influence acetabular growth, as well as the contributions of this physis to the growth of the acetabular roof. The end point of our assessment was overt hip instability.

Materials and Methods

We used postweaning rabbits as our experimental model. Twenty-five New Zealand white rabbits weighing between

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1.5 and 2.2 kg were used. Anaesthesia was conducted with intravenous ketamine (5 mg/kg). Aseptic techniques were used throughout. Intramuscular ampicillin (25 mg/kg) and cloxacillin (25 mg/kg) were administered at induction of anaesthesia and continued once a day for a total duration of 3 days.

The rabbits were positioned in a lateral position (left lateral for right hip and right lateral for left hip). Antero-lateral approach was used in all cases to expose the hip joints. Care was taken to ensure meticulous haemostasis and soft-tissue handling. The origins of the rectus femoris were resected. The hip joint capsules were opened and the ligamentous teres divided. On the right hip of each rabbit, a fixed area of the superolateral physal cartilage between 12 and 1 o'clock was damaged iatrogenically using a 2-mm small burr (Fig. 2). A sham open reduction was performed over the contralateral left hip.

The joint capsule and rectus femoris were repaired

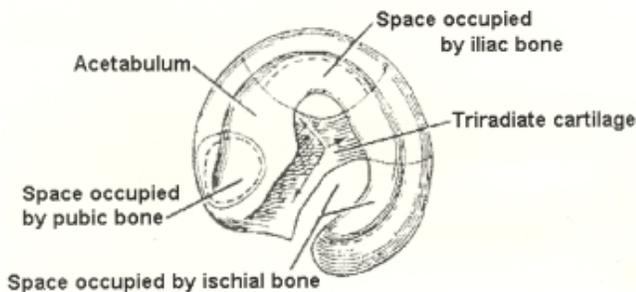


Fig. 1. Contribution of the three growth centres of the acetabulum.

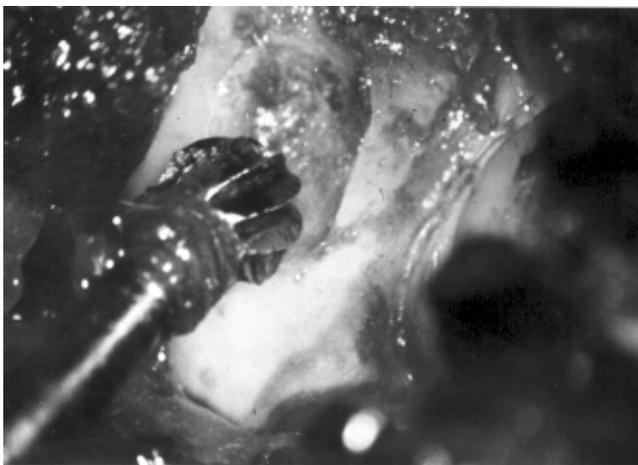


Fig. 2. Iatrogenic damage to the superolateral physal plate of the right acetabulum by a small burr.

meticulously with absorbable (Viracyl) sutures. The skin incisions were also closed with absorbable sutures. After surgery, all rabbits were allowed to move in their cages freely. They were given an ample supply of fluids and food.

Radiographic and histographic postoperative analyses of both hips were performed on the second postoperative day and 6 and 12 weeks after surgery. The radiographs were evaluated for acetabular development and hip stability. The acetabular indices for both hips were measured, and tested for statistical significance using the paired Student's *t*-test.

The rabbits were all killed at 12 weeks. The pelvis were harvested and the hip joints preserved with the surrounding soft tissues and capsules. The bones were decalcified. The specimens were stained using haematoxylin and eosin (H&E) and metachrome staining techniques. The gross and microscopic histologic specimens were subsequently assessed by an independent pathologist.

Results

Twenty-four of the 25 rabbits survived the entire study. The immediate postoperative radiographs were normal for both hip joints (Fig. 3a). However, at 6 weeks, there was evidence of acetabular abnormalities over the right hip (Fig. 3b). The right hip joints were starting to become unstable. On the contrary, the left hip remained stable with no changes seen over the acetabulum. At 12 weeks, prominent acetabular changes were noted over the right hip. The hip had dislocated in a posterior and superior direction. The left hip remained stable throughout. The acetabular index was also significantly higher ($P < 0.05$) for the right hip ($28 \pm 3^\circ$) compared with the left hip ($22 \pm 4^\circ$), using the paired Student's *t*-test.

Gross histopathologic analysis ($\times 28$) of the right hip joints revealed poorly formed and shallow acetabulum (Fig. 4a). There was maldevelopment of the acetabular roof in all cases. All the right femoral heads were dislocated. There was no evidence of osteoarthritis or osteonecrosis. In contrast, there were no abnormalities for the left hip joints (Fig. 4b).

Examination of the specimens under high-power fields ($\times 540$) revealed thinning of the cartilage cells of the right acetabulum, with poorly-organised cell layers. There were increased amounts of undifferentiated fibrovascular cells deep to the cartilaginous layer. There was poor formation of the right acetabular roof (Fig. 5a). In contrast, similar high-power examination of the left acetabulum revealed well-organised layers of cartilage cells of normal thickness. The acetabular roof was well developed (Fig. 5b).

The femoral head cartilage and the physal plate were not affected in both hip joints. No evidence of osteoarthritic changes was detected in both hip joints.



Fig. 3a. Immediate postoperative radiograph of the rabbit.



Fig. 3b. Radiograph of the same rabbit 6 weeks later. The right hip was beginning to show signs of instability.



Fig. 3c. Radiograph of the same rabbit 12 weeks after surgery. The right hip had completely dislocated.



Fig. 4a. Low-power magnification (x28) of the right hip shows obvious dislocation.



Fig. 4b. Low-power magnification (x28) of the left hip.

Discussion

A genetically determined balanced growth of the acetabular and triradiate cartilages, as well as a well-located and centred femoral head is required for normal hip joint development and stability.¹ Both the acetabular and femoral head components are derived from the same primitive mesenchymal cells.^{15,16}

The os acetabuli was described as the highest and most lateral border of the superior lip of the acetabulum.⁹ It was also noted that the os acetabuli had various shapes and

sizes, and might not always fuse completely.⁹ At puberty,⁷ the epiphysis appeared on the acetabular margin, occurring concurrently with the fusion of the triradiate cartilage. The new growth centres were located at the edge of the acetabulum and would usually fuse between the ages of 18 and 23 years.

Thick cartilage, from which a secondary ossification centre, the os acetabulum, develops in early adolescence, separates the acetabular cavity from the pubic bone.¹⁴ This os acetabulum was described by Ponseti^{13,14} as an island of bone within the acetabular cartilage adjoining the pubic bone. He also termed it the lateral physeal plate of the acetabulum. Its contribution to the development of the acetabulum and the continuity of the fibrocartilaginous labrum was recognised. The lateral acetabular epiphysis was also described to be homologous to other epiphyseal



Fig. 5a. High-power magnification (x540) of the right hip.

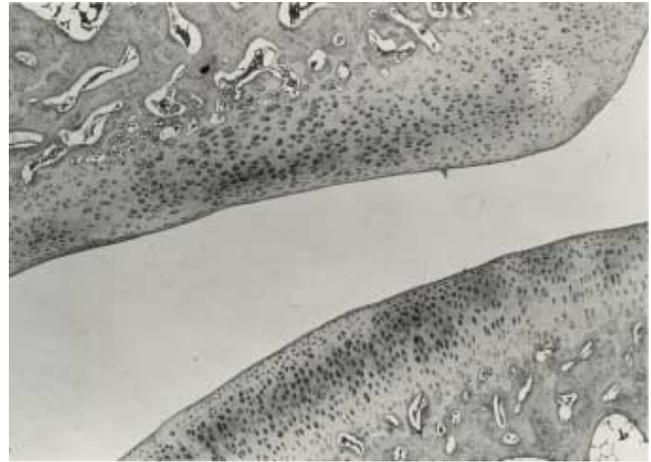


Fig. 5b. High-power magnification (x540) of the left hip.

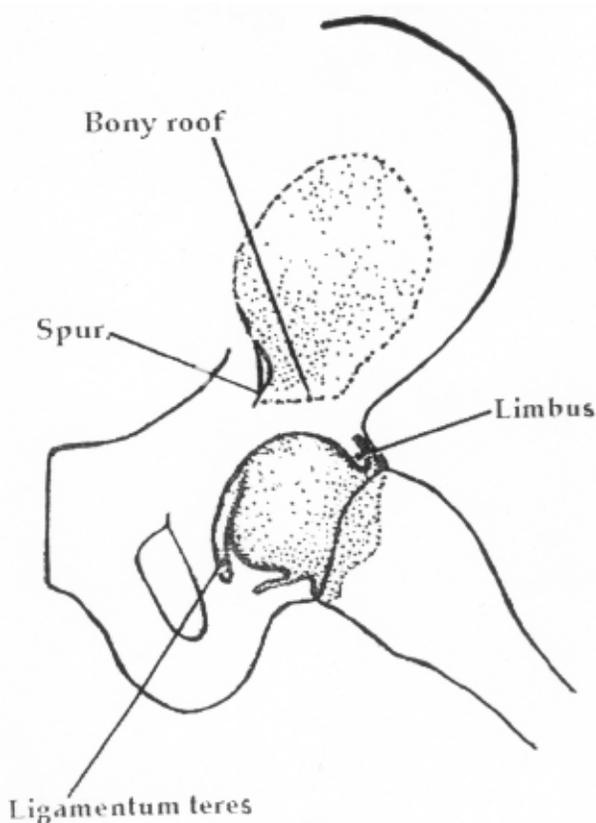


Fig. 6. Location of the limbus in relation to the bony roof of the acetabulum.

cartilages of the skeleton.¹⁰ O'Hara,⁵ in his study of the effects of limbectomy in infants, noted the importance of preserving the limbus (Fig. 6) to the normal development of the lateral physal cartilage.

Ossification of the acetabulum in rats^{10,11} and humans¹²

was studied, and their observations were similar in many ways. The superior acetabular bone or the acetabular epiphysis in rats were secondary centres of ossification constant in terms of position, times of origin and fusion. In humans, these os acetabuli or acetabular epiphyses developed at about 8 years of age and would fuse with the ilium at the age of 18 years old.

The effects of damaged and maldeveloped os acetabulum or lateral acetabular epiphysis on hip growth and stability have not been previously investigated. Our findings in this study clearly demonstrated that damage to the lateral acetabular epiphysis would result in maldevelopment of the acetabulum and subsequent hip instability.

Our radiographic findings are similar to actual clinical scenarios of DDH. Radiographs of the hips of the rabbits revealed a poorly formed and shallow acetabular roof, with a significantly raised acetabular index. All the affected hips had dislocated by 12 weeks of study. The histopathologic findings are also similar to the study by Ponseti¹³ on the histologic morphology of the acetabulum in congenital dislocation of the hip.

We believe that the lateral epiphysis of the acetabulum is vital to the development of the roof of the acetabulum. Poor development of the roof may result in hip subluxation and dislocation. We postulate that damage to the lateral acetabular epiphysis in the intrauterine environment or after birth may cause DDH. In clinical practice, ultrasonography of the hip joint can be utilised to follow up the cartilaginous roof of the acetabulum in neonates and infants.

Surgery performed on the paediatric hip or pelvis must avoid damage to the lateral epiphysis of the acetabulum. The labrum should also be preserved, as it may influence the growth of the lateral acetabular epiphysis. Inadvertent damage to the lateral acetabular epiphysis may lead to acetabular maldevelopment and hip instability.

DDH is one of the leading causes of osteoarthritis of the hip. Based on our postulation of lateral acetabular epiphysis damage as one of the aetiologies, attention should now be paid to how we might prevent this from occurring. In doing so, these patients may be spared total hip arthroplasty in their later years.

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REFERENCES

1. Weinstein S L. Development hip dysplasia and dislocation. In: Morrissy R T, Weinstein S L, editors. *Lovell and Winter's Pediatric Orthopaedics*. Philadelphia: Lippincott-Raven, 1997:903-50.
2. Laurensen RD. Development of the acetabular roof in the fetal hip: an arthrographic and histological study. *J Bone Joint Surg Am* 1965; 47:975-83.
3. Negri C, Tricarico A, Lorio L. The importance of the acetabular rim in the genesis of congenital hip dysplasia: experimental research. *Ital J Orthop Traumatol* 1977; 3:219-25.
4. Kim Y H. Acetabular dysplasia and osteoarthritis developed by an eversion of the acetabular labrum. *Clin Orthop* 1987; 215:289-95.
5. O'Hara J N. Congenital dislocation of the hip: acetabular deficiency in adolescence (absence of the lateral acetabular epiphysis) after limbectomy in infants. *J Pediatr Orthop* 1989; 9:640-8.
6. Delgado-Baeza E, Sanz-Laguan A, Miralles-Flores C. Experimental trauma of the triradiate epiphysis of the acetabulum and hip dysplasia. *Int Orthop* 1991; 15:335-9.
7. Garay E G, Baeza E D, Hierro A S. Acetabular dysplasia in the rat induced by injury to the triradiate growth cartilage. *Acta Orthop Scand* 1988; 59:516-9.
8. Gepstein R, Weiss RE, Hallel T. Acetabular dysplasia and hip dislocation after selective premature fusion of the triradiate cartilage: an experimental study in rabbits. *J Bone Joint Surg Br* 1984; 66:334-6.
9. Brailsford J F. *The radiology of bones and joints*. London: J & A Churchill, 1935:180-7.
10. Harrison T J. The growth of the pelvis in the rat: a mensural and morphological study. *J Anat* 1958; 92:236-60.
11. Harrison T J. The influence of the femoral head on pelvic growth and acetabular form in the rat. *J Anat* 1961; 95:12-24.
12. Perna G. Sulla ossificazione dell' acetabulum e sul significato del tuberculum supracotyloideum nell' uomo [in language?]. *Chir Org Mov* 1922; 6:485-568.
13. Ponseti IV. Morphology of the acetabulum in congenital dislocation of the hip: gross, histological and roentgenographic studies. *J Bone Joint Surg Am* 1978; 60:586-99.
14. Ponseti IV. Growth and development of the acetabulum in the normal child: anatomical, histological and roentgenographic studies. *J Bone Joint Surg Am* 1978; 60:575-85.
15. Lee J, Jarvis J, Uhthoff H K, Avruch L. The fetal acetabulum: a histomorphometric study of acetabular anteversion and femoral head coverage. *Clin Orthop* 1992; 281:48-55.
16. Strayer L M Jr. Embryology of the human hip joint. *Clin Orthop* 1971; 74:221-40.