Abstract
Septic arthritis of the hip can have a serious impact on long term function. From minor changes to severe destruction of proximal femoral anatomy, the spectrum varies. The consequence is altered biomechanics of hip joint leading to pain, limp, instability, stiffness and gait abnormalities. Management of these sequelae has evolved over the years. Less severe sequelae are relatively easy to manage and have reasonably predictable results. Severe sequelae of septic hip, on the other hand pose a significant surgical challenge. Correction of limb length discrepancy, providing stable hips, and elimination of Trendelenburg gait with preservation of hip range of motion should be the main aims in the management of sequelae of the septic hip. Needless to say, even in this era of powerful antibiotics and advanced surgical techniques, early recognition of septic arthritis and timely intervention are of paramount importance in ensuring good long-term hip function.

Keywords: Sepsis; Hip; Sequelae; Choi classification.

Introduction
Septic arthritis of the hip leads to various sequelae in children and some are associated with significant morbidity. The complications associated with septic hip include premature closure of the capital femoral physis, avascular necrosis (AVN) of the femoral head, coxa vara, breva or magna, pseudarthrosis of the femoral neck, hip subluxation/dislocation, complete loss of the femoral head, abductor insufficiency, degenerative arthritis, acetabular dysplasia or ankylosis of the hip [1]. Accordingly, the child may be completely asymptomatic or severely disabled. The management of post-septic sequelae is equally challenging. The numerous classifications available and plethora of techniques described for management of sequelae hip clearly indicate that there is no standard treatment protocol and treatment needs customization according to disease profile and the patient’s need.
Pathogenesis of sequelae hips

The infective process damages the developing hip through several mechanisms including direct damage by toxins or through the immune response to infection; tamponade (ischemic) effect, and mechanical failure of pathological bone (Fig. 1). Sepsis destroys cartilage resulting in fibrous or bony ankylosis. The concomitant damage to capsule and stabilizers contribute to instability of the joint. The effect on the physis leads to long term changes in proximal femoral development. The proximal femoral physis contributes to approximately 30% of total femoral length. Complete physeal arrest in early childhood can lead to significant limb length discrepancy. Concomitant joint subluxation or dislocation adds to the amount of limb length discrepancy. Asymmetric physeal growth produces coxa vara, coxa valga or abnormalities of femoral version.

Septic emboli and vascular tamponade cause AVN of the femoral head. Risk of AVN of the femoral head is thought to be greater during the first year of life, because head is largely cartilaginous, although Vidigal reported that AVN is more severe in the older age group [2].

Another mechanism contributing to sequelae is the mechanical failure of pathological bone. The weakened femoral neck due to osteomyelitis may fracture leading to formation of pseudarthrosis. The failure may occur at the epi-metaphyseal junction (physeal slip) or more distally in the metaphyseal or trochanteric region [3].

Incidence and treatment trends

The outcome of hip sepsis depends on the extent, severity and duration of the disease process. Delay in treatment also leads to poor outcomes. Various studies report poor outcome or unsatisfactory results following septic arthritis in form of avascular necrosis, chondrolysis or loss of head in 9% to 66% cases [4]. With improvement and advancement of health care and surgical techniques, better outcomes have been reported in septic sequelae. A review of the most recent series describing sequelae of septic hip and their outcomes is included in Table 1 [5-9]. Several new procedures like osteochondroplasty, Ilizarov hip reconstruction and others have been introduced. Procedures where results were unsatisfactory or unpredictable like greater trochanteric arthroplasty have lost favour over time. The current trend favours individualization of treatment based on presence of femoral head, its profile and stability, nature and severity of symptoms and the patient’s functional demands.

Classification of post-septic hips

Various radiological classifications of septic sequelae are proposed to describe the late hip changes and guide treatment [6-9,13]. Hunka classified septic sequelae into 5 categories based on 10 patients over an 11-year period [7] (Fig. 2). Choi et al modified Hunka’s classification and classified septic sequelae based on experience of 34 hips of 31 patients [6] (Fig. 3 and 4). More recently, Forlin and Milani classified 41 hips in 37 patients based on relation between the femur and the acetabulum and sub-divided them according to the appearances of the proximal femur [8]. Johari’s classification is based on joint stability and the presence or absence of the capital femoral epiphysis [13].

Figure 1: Formation of septic sequelae of hip. A. Direct damage by infectious agent/toxins/body’s response. B. Tamponade (ischemic) effect. C. Mechanical failure of pathological bone.
Table 1: Sequelae of septic hip in children: most cited series in literature

<table>
<thead>
<tr>
<th>Study</th>
<th>Age at surgery (years)</th>
<th>Mean follow up (years)</th>
<th>Number of hips</th>
<th>Onset of disease</th>
<th>Type of sequelae</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hunka, et al., 1982</td>
<td>14.2</td>
<td>11.2</td>
<td>10</td>
<td>Before 18 months -9, after 18 months -1</td>
<td>Hunka type III - 2, Type IV A - 2, Type IV B - 3, Type V - 3</td>
<td>Type III - (2) (Unsatisfactory), Type IV A - 2 (satisfactory), Type IV B - 3 (satisfactory), Type V - 3 (satisfactory)</td>
</tr>
<tr>
<td>Choi et al., 1990</td>
<td></td>
<td></td>
<td>45</td>
<td>—</td>
<td>Choi type III A - 10, Type III B - 3, Type IV A - 14, Type IV B - 18</td>
<td>Type III A - Satisfactory - 90%, Type III B - Satisfactory - 66.66%, Type IV A - 1) 8/33% (7/12) satisfactory in Harmon procedure, 2) unsatisfactory in Colona arthroplasty, Type IV B - 1) Trochanteric arthroplasty - Below 6 years age - satisfactory in 71%, above 6 years age - unsatisfactory in all 2) Ilizarov hip reconstruction - Satisfactory in all, 3) Vascularized Iliac crest graft - unsatisfactory 4) Soft tissue release - unsatisfactory</td>
</tr>
<tr>
<td>Betz et al.*, 1990</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Type III - (3) (Unsatisfactory), Type IV B - 2 (satisfactory), Good -2 (Type V - 2)</td>
</tr>
<tr>
<td>Wada et al., 2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Type III A - Satisfactory - 71, Type III B - Satisfactory - 69, Good -2, Type V - 2</td>
</tr>
<tr>
<td>Furlin and Milani, 2008</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Type III A - 8/11 (satisfactory), Type III B - 2 had union, 2 - nonunion, Type IV - 2/6 (satisfactory), Type IV - 2/6 (satisfactory), Type IV - 2/6 (satisfactory)</td>
</tr>
</tbody>
</table>

* Except for Betz's study, the criteria used for clinical outcome is Hunka; for this series Harris hip score (HHS) was used.
A comparative analysis of the above classification systems is presented in Table 2. Choi’s classification is perhaps the most often quoted classification for post-septic hips.

Clinical presentation
A child with hip septic sequelae may be completely asymptomatic. The symptoms may be delayed due to late manifestations of infection e.g. growth arrest, acetabular dysplasia. The main presenting complaints are pain, limp, restriction of movements and instability. Pain may be due to instability, abnormal bony anatomy, ankylosis, incongruent joint surface or premature degenerative changes. Limping can occur because of coxa vara, dysfunctional abductor mechanism, pseudarthrosis, shortening, instability and pain. Restricted range of motion can result from multiple reasons viz. premature closure of the triradiate cartilage, acetabular dysplasia, avascular necrosis of the femoral head, soft tissue contracture, misshapen head and incongruency or ankylosis. Sometimes, multiple pathologies coexist and are together responsible for symptoms. With time, secondary changes may occur in the spine and distal joints.

Management
Various treatment modalities have been described to manage post-septic hip sequelae. The principal objectives of treatment and common ways of achieving them include:[15,16]
1. Improving head coverage - Abduction cast or brace, open reduction, femoral and/or pelvic osteotomy, osteochondroplasty
2. Limb length equalization - Shoe raise, contralateral epiphysiodesis, ipsilateral limb lengthening

<table>
<thead>
<tr>
<th>Table 2: Different classifications of sequelae of septic hip with reference to Choi’s classification*</th>
</tr>
</thead>
<tbody>
<tr>
<td>---</td>
</tr>
<tr>
<td>I</td>
</tr>
<tr>
<td>Minimal or no femoral head changes</td>
</tr>
<tr>
<td>II</td>
</tr>
<tr>
<td>Deformity of the femoral head with an intact physis</td>
</tr>
<tr>
<td>IIA</td>
</tr>
<tr>
<td>Deformity of the femoral head with premature fusion of the physis</td>
</tr>
<tr>
<td>IVA</td>
</tr>
<tr>
<td>Complete destruction of the proximal femoral epiphysis with a stable neck fragment</td>
</tr>
<tr>
<td>IIB</td>
</tr>
<tr>
<td>Complete destruction of the proximal femoral epiphysis with a small unstable neck fragment</td>
</tr>
<tr>
<td>IVB</td>
</tr>
<tr>
<td>Complete destruction of the head and neck to intertrochanteric line with dislocation of hip</td>
</tr>
</tbody>
</table>

*Approximate; based on available descriptions from original text.
3. Improving abductor insufficiency - Trochanteric arthroplasty, neck lengthening procedures (Wagner femoral neck lengthening, Hasler and Morscher’s modification of Wagner’s osteotomy, Papavasiliou technique, Kruminis modified Illizarov technique etc.), distal lateral transfer of greater trochanter, femoral and/or pelvic osteotomies
4. Providing stable hip - Closed/ open reduction, femoral and pelvic osteotomies
5. Restoring alignment - Femoral and/or pelvic osteotomies
6. Achieving union in pseudarthrosis - valgus osteotomy with or without fibular grafting
7. Salvage procedures- arthroplasty, fusion.
8. Special procedures for loss of head and neck (Choi type IV A and B)
   a. Albee, L’Episcopo and Harmon described similar procedures in younger children with severe sequelae of suppurative arthritis (Choi types IVA and B) [18-20] (Fig. 5). Albee arthroplasty was originally described for non-union neck femur by excising the head of femur and placing the denuded portion of greater trochanter into the acetabulum, thus creating a longer neck for better abductor function [18]. Modified Albee arthroplasty involves removal of greater trochanter and creating an incomplete greenstick fracture at base of medial fragment while maintaining the normal neck shaft angle between medial fragment and proximal femoral shaft [12]. It is said to restore near normal anatomy of hip, equalize limb-length discrepancy and prevent trochanteric overgrowth. However, proximal femoral portion may show poor remodelling, thus causing instability of hip joint with positive Trendelenburg test. There is also a theoretical risk of AVN.
   b. Greater trochanteric arthroplasty (Fig. 6). In Colona arthroplasty, fibromuscular layers over the greater trochanter are preserved by avoiding subperiosteal dissection [21]. The remaining neck portion is removed up to the femoral shaft. The greater trochanter is positioned into the hip joint. The abductors are reattached over the lateral aspect of the femur after maximum advancement. It can be combined with varus osteotomy of the femur. Greater trochanteric arthroplasty is a salvage procedure and decreases limb length discrepancy and pain, provides better hip function, gait and stability. Long term complications are subluxation due to gradual remodelling of the proximal femoral angulation, pain, avascular necrosis of proximal fragment, non-union, and stiffness. Choi et al introduced muscle pedicled trochanteric arthroplasty and preserved the vascularity of proximal femoral segment by not...
detaching the origin of vastus lateralis and intermedius [16].

c. Cheng used vascularized iliac crest graft in 7 children (8 hips) with Choi type IVB sequelae. Five hips showed graft resorption and only 3 cases showed graft remodelling [22].

d. Ilizarov hip reconstruction (Fig. 7) - Provides stability of hip, eliminates abductor lurch and corrects limb length inequality.

**Age consideration for surgical intervention**

Stable hips with deformed/ malaligned proximal femoral anatomy can be simply observed. Lateral extrusion of femoral head, abductor insufficiency and acetabular dysplasia should be treated by femoral varus/valgus with/without derotation osteotomy and pelvic osteotomies at an appropriate time. Concomitant soft tissue release should be done to improve mobilization of hip. Freeland et al advised surgery at or near skeletal maturity [23] whereas others [6,7,20] proposed age less than 2 years as appropriate for surgery. Closed reduction of dislocated hips with preserved head can be tried up to 2 years of age [13,17]. After 2 years, open reduction is recommended. Choi et al believe that open reduction reduction in children older than 6 years of age is not likely to be beneficial because of a high risk for stiffness and pain [16]. In older children, these hips should be treated similar to Type IVB.

Ilizarov hip reconstruction should be reserved for severe type of sequelae and should be undertaken in the adolescent years. Choi recommended pelvic support osteotomy even after 6 years of age, in failed reconstructive procedures in type IVA and in type IVB sequelae because it improves abductor mechanism, provide better muscle strengthening and a repeat pelvic support osteotomy can be performed at later age, if required [16]. He recommended abductor muscle strengthening exercise with shoe lifting in children who are candidates for later hip reconstruction pelvic osteotomy. Loss of pelvic support has been reported in young children as early as 12 months after the procedure due to remodelling [24]. Some authors therefore recommend Ilizarov hip reconstruction for skeletally mature adolescents and for young adults [24].

**Prognostic factors for sequelae**

Prognostic factors for septic sequelae are [1, 5, 8, 15, 16, 25, 26]:

1. Age at onset
2. Delay in hip drainage
3. Virulence of the causative organism
4. Prematurity
5. Associated osteomyelitis
6. Septic dislocation

Betz et al described poor outcomes in children where the hip sepsis occurred at less than 3 months of age and when there was a delay in drainage of greater than 4 days from the onset of sepsis [5, 8]. Non-staphylococcal organisms may be less destructive to the femoral head in infants [25].

Due to advanced modalities of early detection of septic hip and better treatment, Lee et al described different prognostic factors from those previously described [26]. In his study, only the duration of symptoms before surgery was associated with a worse radiological prognosis. Both neonate and infant groups had no significant difference in prognosis. Delay of 5 days from onset of infection to treatment resulted in radiological unsatisfactory outcomes in 50% of cases. Poor clinical prognosis was not found to be associated with underlying disease, young age, concomitant osteomyelitis, infective organism and even with duration of delay in management.

Authors' preferred method of treatment for sequelae hip (Table 3)

The authors' preferred treatment protocol for various Choi types is presented in table 3.

Types IB, IIA and B, IIIA are treated according to the severity of deformity (Fig. 8,9,10).

For Type IIIIB, we take into consideration two factors: progressive coxa vara and child's age. If coxa vara worsens further than 90-100 degrees and the age is more than 4 years (neck profile sufficient to permit...
of fibular strut graft), intervention is considered (Fig. 11).
We usually intervene early in Choi IVA sequelae if a cartilage cap is present and prefer open reduction as true anatomical characteristics and head shape are visible only by direct visualisation of the femoral head. Post reduction stability can be judged simultaneously and if required, concurrent femoral and pelvic osteotomies can be added (Fig. 12).
For type IVB, the child is offered pelvic support osteotomy early if he/she has presented before age 6. The procedure provides hip stability and limb equalization. Even if the osteotomy remodels, the child has much better gait characteristics in early years of childhood. A repeat procedure, if required, can be offered at skeletal maturity. We do not hesitate to equalize limb length at any age (shoe raise/contralateral epiphysiodesis/ ipsilateral lengthening) because it aligns pelvis, prevents secondary compensatory mechanisms and reduces energy expenditure for walking.

**Conclusions**
Septic arthritis of the hip results in different sequelae according the region involved and severity of the original insult. Although the outcomes are variable and unpredictable, timely intervention in select cases can help achieve good joint stability, better proximal femoral anatomy and gait improvement. In other cases, reconstructive procedures may help in minimizing limb length discrepancy and in delaying the need for total hip arthroplasty or salvage surgery.


---

### Table 3: Authors’ preferred method of treatment for sequelae hip

<table>
<thead>
<tr>
<th>Choi type</th>
<th>Treatment</th>
<th>Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Observation or abduction cast/orthosis</td>
<td>Mottling, fragmentation or delay in ossification of the femoral head epiphysis</td>
</tr>
<tr>
<td>II</td>
<td>Femoral varus/valgus osteotomy</td>
<td>Coxa vara/valga/coxa magna</td>
</tr>
<tr>
<td></td>
<td>Acetabular procedure</td>
<td>Hip subluxation, acetabular dysplasia, coxa magna</td>
</tr>
<tr>
<td></td>
<td>Greater trochanteric epiphysiodesis</td>
<td>Trochanteric overgrowth</td>
</tr>
<tr>
<td></td>
<td>Neck lengthening procedures; distal trochanteric transfer</td>
<td>Severe coxa breva</td>
</tr>
<tr>
<td>IIIA</td>
<td>Femoral varus/valgus osteotomy, derotation, acetabular procedure</td>
<td>Coxa vara/valga with retroversion or anteversion</td>
</tr>
<tr>
<td>IIIB</td>
<td>Observation for coxa vara; femoral valgus osteotomy with bone grafting</td>
<td>Pseudarthrosis</td>
</tr>
<tr>
<td>IVA*</td>
<td>Open reduction combined with or without femoral and pelvic osteotomy</td>
<td>Presence of adequate cartilaginous cap over neck remnant and child is below 6 years of age</td>
</tr>
<tr>
<td></td>
<td>Supervised neglect; compensation for limb length discrepancy</td>
<td>Adequate cartilaginous cap absent</td>
</tr>
<tr>
<td></td>
<td>Pelvic support osteotomy and reconstruction</td>
<td>After 6 years age #</td>
</tr>
<tr>
<td>IVB*</td>
<td>Supervised neglect; compensation for limb length discrepancy</td>
<td>Child is below 6 years age</td>
</tr>
<tr>
<td></td>
<td>Pelvic support osteotomy and reconstruction</td>
<td>After 6 years age #</td>
</tr>
</tbody>
</table>

* trochanteric arthroplasty has fallen into disfavour because of unpredictable results
^ limb length discrepancy can be associated with any sequelae type
# may require a repeat procedure, if performed early


