Case Series

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Specific Anatomical Patterns of Septic Sequelae of Knee in Children: Possibility of a Vascular Etiopathogenesis

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Abstract

Background: The septic sequelae of knee following infantile infection is scantily described in literature. This case series depicts the various anatomical zones affected, the radiological presentation and proposes a vascular hypothesis for the sequelae.

Methods and results: Sequelae presented with three distinct radiological findings namely, unicondylar loss of lateral distal femur (n=4), hemicondylar loss of anterior portion of proximal tibia (n=3), and epiphyseal overgrowth and deficient tibial metaphysis of medial/ lateral side (n=4). The anatomical zones for above findings were seen approximately matching with the supply of specific genicular arteries around knee. On corroborating the early post infective radiographs and the sequelae radiographs, it was found that most patients had concomitant osteomyelitis, sometimes extensive.

Conclusions: We could recognize three distinct anatomical patterns of septic sequelae of knee following osteoarticular knee infection in infancy. An ischemic etiopathogenesis is suggested based on consistent radiological findings and the vascular supply zones. Most cases followed concomitant occurrence of septic arthritis and extensive osteomyelitis.

Keywords: Knee, Sepsis, Sequelae, Ischemia, Infants

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Introduction

Knee joint is one of the most common sites of hematogenous osteoarticular infection in infants [1]. The knee infection can either be septic arthritis of the joint and/or osteomyelitis involving distal femur or proximal tibia. Besides the direct destruction by pathogenic bacteria, toxins or host immune response, there can be other ways affecting articular surfaces and osseous tissue. The cartilage or tissue may suffer ischemia due to pressure tamponade effect of accumulated collections or from vessel spasm, shock, vasculitis or thrombosis [1, 2]. The post infective damage may be obvious soon or may be delayed for several years [3].

The septic sequelae of knee in children although known, but seldom investigated in detail. We observed several distinct patterns of sequelae following infantile infection which form the subject matter of this case series. The anatomical zone affected, the radiological presentation and the probable vessel responsible for the event are elucidated. For some patients, early post infective radiographs were available and the same were corroborated with the sequelae radiographs to better understand the etiopathogenesis.

Case series

Eleven patients (M:F= 3:8; affected limbs n = 11) who were diagnosed as septic arthritis of the knee joint with/without concomitant osteomyelitis of adjacent bones in infancy were included in the series (Table 1). The mean patient age at primary

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Table 1: Anatomical patterns of septic sequelae of knee and patient details

Pattern	Area involved	Radiological findings*	Probable vessel involved	Remarks
Unicondylar loss of distal femur, lateral side	Lateral half of femoral condyle	Loss of epiphysis and adjacent metaphysis of lateral femoral condyle. Sometimes a 'spur' is present at metaphyseal margin	Superior lateral genicular artery	4 patients[4i,4d,1p]
Hemicondylar loss of proximal tibia, anterior portion	Ossific nucleus proximal tibia	Anterior tibial condyle is deficient. Only small posterior portion is ossified	Tibial branch of middle genicular artery	3 patients[2i,2a,1d]
Epiphyseal overgrowth and deficient tibial metaphysis, medial/ lateral side	Medial / lateral proximal tibial metaphysis	Deficient medial/ lateral tibial metaphysis. Epiphysis grows into deficient tibial metaphysis. The physis line may be irregular and slanted. Uncovering of some portion of tibial metaphysis may be present	Medial side: inferior medial genicular artery Lateral side: anterior tibial recurrent genicular artery	4 patients[1m,3l,1i,1a,3d,2p]

Abbreviations: i- infantile sepsis; d- treated by drainage and antibiotics; a- treated by antibiotics only; p- polyarticular involvement; m- medial tibial metaphysis involvement; l- lateral tibial metaphysis involvement * Physeal bars may be associated

infection was 79 days (range, 2-300 days). Seven patients had neonatal sepsis. In 8/11 (73%) patients, the infection was managed by drainage and intravenous antibiotics. Others were managed by intravenous antibiotics only. In 3 patients, there was polyarticular involvement. All included patients had a minimum 2 years follow up post infection.

Three distinct radiological patterns were observed in above patients which are described below:

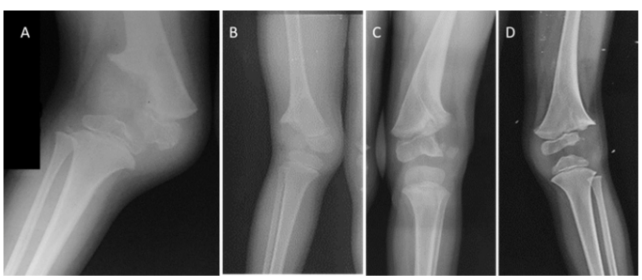

Figure 1: Unicondylar loss of lateral distal femur. In severe cases like 1A and1B, metaphyseal loss accompanied the epiphyseal loss. Protruded bony edge at the margin of metaphyseal loss ('metaphyseal spur') was seen in these cases. Angular deformity and epiphyseal irregularity can be appreciated in 1A. For less severe involvement, only epiphyseal loss was present (1C, 1D). However, a physeal bar at the margin of epiphyseal loss was present in these cases.

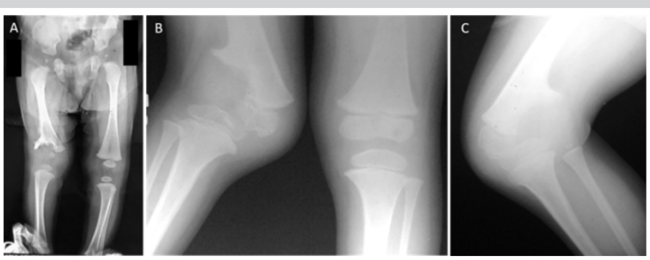

Figure 3: Early post infection radiographs were available for case 1A. This child suffered neonatal infection at age 15 days. The child had polyarticular involvement including right knee, left shoulder and elbow. Radiographs at 2 months (3A) showed chronic osteomyelitic changes in distal femur and well demarcated loss of lateral metaphysis and epiphysis even in early stages. The classical unicondylar loss pattern was well established by age 2.5 years (3B,C anteroposterior and lateral views).

1. Unicondylar loss of distal femur, lateral side (Figure 1): Four patients demonstrated this radiological pattern. The typical unicondylar loss pattern was a well circumscribed defect involving the lateral half of distal femoral epiphysis and adjacent metaphysis. The proximal margins of the metaphyseal defect had flared out a bit in form of a "spur" in some cases. Physeal bar was commonly associated with this lesion. The bar was typically found at the margin of epiphysis loss. Slight variations were observed in the radiographs depending upon the severity of involvement. Less severe forms manifested only predominant loss of lateral epiphysis and minor metaphyseal involvement (Figure 1 C, D). All unicondylar lesions followed a neonatal infection.

The affected anatomical zone approximately corresponded to

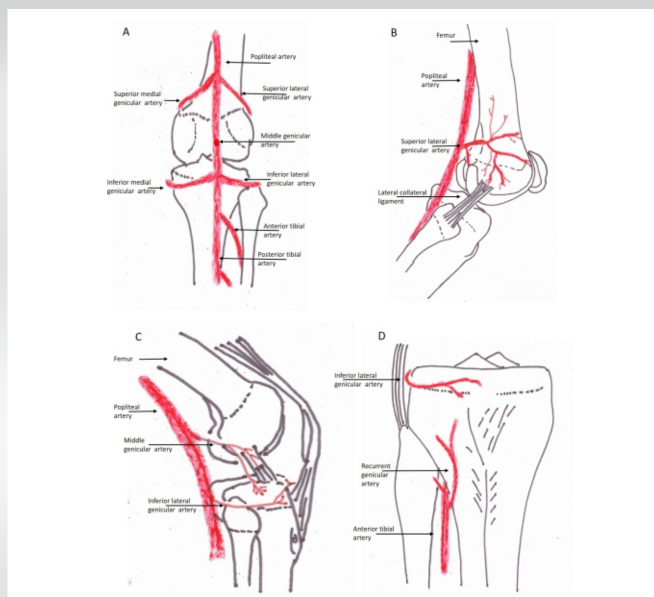

Figure 2: The distribution of genicular vessels around the knee joint (2A). The pattern of unicondylar loss of lateral distal femur approximately corresponds to the vascular zone of superior lateral genicular artery (2B). For hemicondylar loss of anterior portion proximal tibia, the probable vessel is middle genicular artery (2C). Deficient tibial metaphysis corresponds to inferior medial genicular artery or recurrent genicular artery.

Figure 4: Hemicondylar loss of anterior portion proximal tibia. Anteroposterior and lateral radiographs of knee in three patients. The loss of anterior half of tibial epiphysis was distinct and appreciated in lateral views (4B,D,F). The posterior tibial portion was spared and for this part, epiphysis could be appreciated in some patients (4D). Extensive bar formation was obvious in some patients (4B). Overall, the proximal tibia had an irregular appearance.

Figure 5: Early post infection radiographs were available for case 4A. The child suffered infection at age day 5. Originally manifesting as some periosteal reaction around proximal tibia and epiphysis (5A,B), later radiographs showed an extensive pan diaphyseal osteomyelitis (5C,D). The characteristic anatomical pattern was established by age 2.5 years (5E,F). 3D computed tomography scan images (CT scan) revealed the true extent of proximal tibial damage (5G, anterior, 5H, medial, 5I posterior and 5J, lateral views).

the supply of superior lateral genicular artery (Figure 2B) [4]. It is a branch of popliteal artery and arises on the posterior aspect of knee.

The early post infective radiographs revealed occurrence of concomitant osteomyelitis of the distal half of lateral femur (Figure 3).

2. Hemicondylar loss of proximal tibia, anterior portion: The lesion mainly involved the anterior (ventral) tibial epiphysis and physis with sparing of posterior tibia (Figure 4). For this spared region, the epiphysis portion was also present. Extensive bar formation was obvious in one patient (Figure 4B). Overall, the proximal tibia had an irregular appearance in radiographs. This characteristic pattern was evidenced in three patients.

The affected anatomical zone approximately corresponded to the ossific nucleus of proximal tibia [5, 6]. In most newborns, the ossific nucleus of the proximal tibia develops soon after birth. This centre provides growth and shapes the proximal tibial epiphysis. The region is predominantly supplied by middle genicular artery (MGA) (Figure 2C). Often a direct branch of popliteal artery, this vessel sometimes have common

Figure 6: Medial deficient tibial metaphysis and overgrowth of epiphysis (A,B anteroposterior and lateral views). Lateral most end of tibial metaphysis is seen uncovered. Post osteomyelitic non-union of tibial shaft is also obvious.

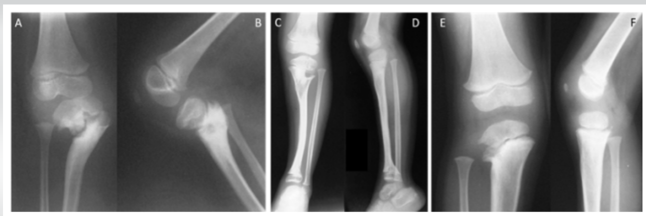

Figure 7: Lateral deficient tibial metaphysis and overgrowth of epiphysis seen in three patients (7 A,B; 7C,D; 7E,F). Physeal slant and metaphyseal uncovering is distinct in 7A,E.

origin with the lateral genicular artery. It enters the knee region at the level of the intercondylar notch, gives off branches to the posterior capsulosynovial structures, and the tibial epiphysis. The branch to tibial epiphysis penetrates the cartilaginous nucleus at the level of the intercondylar tubercles and supplies the central portion of the tibial epiphysis. The posterior portion of tibial condyle may get spared either being extra articular or because of profuse blood supply emerging from the adjacent popliteal vessel.

The early post infective radiographs revealed extensive infection involving epiphysis, metaphysis and diaphysis and evidence of extensive periosteal stripping near the proximal tibia (Figure 5).

3. Epiphyseal overgrowth and deficient tibial metaphysis, medial/lateral side: Three patients had deficiency of lateral tibial metaphysis and one had medial involvement. A portion of tibial metaphysis immediately below the physis was deficient leading to overgrowth and tilt of the ipsilateral epiphysis (Figure 6, 7). In severe lesions, there was widening of the physis

Figure 8: Early post infection radiographs for medial deficient tibial metaphysis (A,B anteroposterior and lateral views). Evidence of extensive diaphyseal osteomyelitis, pathological fractures and slipping of proximal tibial epiphysis was present

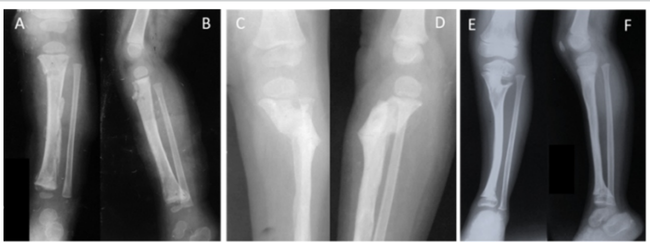

Figure 9: Early post infection radiographs for lateral deficient tibial metaphysis for case 7C,D. Again extensive diaphyseal osteomyelitis and pathological fractures were present (9A,B). The osteomyelitis healed with a large metaphyseal defect and malunited pathological fracture of tibial shaft (9C,D). The fracture however quickly remodeled and by age 3 years, a lateral tibial defect was obvious (9E,F).

opposite to the tilt and uncovering of the peripheral metaphyseal bone. The proximal tibial physis became inclined instead of horizontal in such patients. Two patients had additional anterior sagittal tilt along with the coronal misalignment. Physeal irregularity was also obvious in two patients.

The approximate vascular mapping for this type of lesion corresponded to the recurrent/ inferior medial genicular vessels supplying proximal tibia [7, 8] (Figure 2D). These genicular branches originate from the popliteal artery at the back of knee and course anteriorly. The affection of recurrent genicular artery (a branch of anterior tibial artery) seems responsible for the lateral metaphyseal defects. The articular cartilage supported by epiphyseal/capsular vessels probably escapes the septic insult and proliferates. Inferior lateral genicular vessels may additionally support the lateral tibial epiphysis. The inferior medial genicular artery is the probable vessel for the medial metaphyseal defect. As is obvious from the illustrated early post sepsis radiographs from two patients, these lesions usually follow extensive diaphyseal osteomyelitis with probable interference of both periosteal and intramedullary blood supply (Figure 8, 9).

Discussion

Vascular etiopathogenesis for sequelae of septic arthritis and osteomyelitis in children is long known, especially for the hip joint [9-11]. It has been reported that there is acute decline in the perfusion of the region following an infection [9]. The reasons for vascular hypoperfusion can be many: increased intra-articular hydrostatic pressure resulting from purulent exudate, or septic vascular thrombosis caused by accompanying osteomyelitis [11]. In addition, the septic shock and comorbidities may enhance the region's ischemia. In severe cases, the resulting avascular necrosis may be responsible for gross damage e.g. loss of femoral head.

The current medical literature is largely focussed on the hip joint infection and its sequelae [12]. Knee joint involvement although common, has seldom been elucidated in such detail. Lately, there have been extensive studies on the vascular supply of distal femur in relation to osteochondral flaps and genicular artery embolization for knee osteoarthritis [4, 13, 14]. We recognized several distinct anatomical patterns of septic sequelae knee which could possibly be related to a vascular origin.

Our reasons for hypothesizing vascular etiopathogenesis for these sequelae were many: Firstly, similar anatomical patterns were found in multiple patients. Not only this, these patterns have also been described by previous authors, especially the unicondylar loss distal femur, lateral side [2, 15-21] and hemicondylar loss, proximal tibia [21]. Secondarily, the region affected in these sequelae corresponded approximately to the vascular zone of a particular vessel. The unicondylar loss lateral femoral condyle, hemicondylar loss proximal tibia, and deficient tibial metaphysis could respectively be traced to superior lateral genicular artery, middle genicular artery and recurrent genicular artery/ inferior medial genicular artery [4-8]. Thirdly, the occurrence of above-described lesions was not explained by any other theory. For example, the unicondylar loss of lateral femoral condyle, is variably described as a consequence of osteomyelitis or septic arthritis of the knee region [2, 15-21]. Strong et al put forward the concept of metaphyseal infection spreading to the epiphysis through the transphyseal blood vessels [21]. The above theory however could not explain the sparing of the medial femoral articular cartilage while the whole joint was infected. To explain the 'unicondylar' involvement, Tercier et al postulated the synovial septum ('loculation') hypothesis wherein the opposite condyle was shielded from the proteolytic effect of bacteria [20]. The transynovial septae could however be demonstrated only in about 15% knees. The 'loculation' hypothesis again could not explain the unicondylar damage as once the infection migrated into epiphysis and metaphysis, there are no absolute barrier to the spread to infection. Fourthly, several other corroborative evidence support the vascular hypothesis. Signson et al reported that the destructive changes, typically seen due proteolytic activity of sepsis, were not evident in the epiphysis and adjacent metaphysis in the unicondylar femoral lesions [19]. This could only be explained by acute occlusion of the vessel preventing further invasion by bacterial and host responses and therefore the involved region had very clear demarcation margins. Additionally, partial regrowth of the affected region has been demonstrated overtime in several series [2]. This is theoretically possible with dissolution of thrombus, regeneration of newer vessels or formation of collaterals from the surrounding vasculature.

There can be slight differences in the radiological presentation of the lesions depending upon the extent of primary involvement, duration since infection and the revascularization status. However, a close look at early post infective radiographs revealed a common finding of concomitant osteomyelitis, sometimes extensive, in all these sequelae. The osteomyelitis and the accompanying periosteal stripping probably disrupted the alternative source of vascular supply to the regions. With further septic insult to the remaining terminal genicular vessels, complete ischemia of the region followed and resulted in occurrence of typical lesions.

The main technique through which the vascular territories have been commonly mapped are dye studies in cadavers followed by surgical dissection or high resolution imaging [22]. The infantile nature of post infective vascular insult may preclude determination of exact sequence of events at that time and the sequelae manifests only several weeks/months later. The vascular hypothesis however may pave way for several preventive interventions. Same as hip joint arthritis, the decompression of knee effusion may be considered a surgical emergency. To avoid stretch on posterior knee capsule and vessels, a splintage in flexed knee position is suggested till joint decompression is undertaken. Medical measures such as management of shock, coagulopathy and hydration may also help.

The vascular etiopathogenesis may also potentially help when sequelae are already established. The management of many of the described sequelae has always been an uphill task [20]. In some patients, the recurring deformity associated with these lesions had required upto 6 osteotomies or multiple complex surgeries [2, 20, 21]. Surgical advances have now made possible pedicle based osteochondral flaps [4, 13, 14]. Since the vascular anatomical areas are relatively well defined, suggestions are made for early reconstruction of these lesions using the newly developed modality.

Our study had limitation of mainly using plain radiographs to delineate the septic sequelae of knee. Although arthrogram and advance imaging may reveal the anatomical patterns more precisely, plain radiographs remains the most common modality for initial diagnosis and follow up. Being based on a retrospective radiological review, the clinical manifestations and future course of the lesions was not available. We could however highlight the consistent radiological findings for these patients. Moreover, early post infective radiographs pointed out the concomitant osteomyelitis and the probable periosteal disruptions. It is prudent to add that occurrence of concomitant septic arthritis and osteomyelitis is already red flagged with poor prognosis because of more severity and prolonged course with higher levels of acute phase reactants, CRP and ESR compared to plain septic arthritis or acute hematogenous osteomyelitis [1, 23, 24]. Our series added more reasons for a careful prognostication and need for long term follow up in these dual infections.

Conclusion

We could recognize three distinct anatomical patterns of septic sequelae of knee following infection in infancy. An ischemic etiopathogenesis is suggested based on consistent radiological findings and the vascular supply zones. Most cases followed concomitant occurrence of septic arthritis and extensive osteomyelitis.

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Declaration of patient consent : The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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