Is There a Difference in Sagittal Alignment of Blount's Disease Between Radiographic and Clinical Evaluation?

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Abstract

Background A procurvatum deformity of the proximal tibia often is seen in patients with Blount's disease. If left untreated, it can lead to progressive angulation in the sagittal plane and altered contact stresses across the knee. **Questions/purposes** We asked the following questions: (1) Is the mean angle of procurvatum measured from full-length lateral radiographs of the tibia greater than that of procurvatum measured from clinical photographs of the affected lower extremity? (2) Is there a linear relationship between radiographically measured procurvatum and radiographically measured procurvatum?

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Methods We treated 72 patients surgically for Blount's disease between 1997 and 2012; of those, 29 patients were excluded from this analysis because they did not have adequate photographs or radiographs, leaving 43 patients (60% of the patients treated surgically; 47 limbs total), mean age of 13 years (range, 6–25 years), who underwent surgical realignment for Blount's disease were retrospectively evaluated at a median of 97 months after surgery (range, 24–170 months). Genu procurvatum was measured from full-length lateral radiographs of the tibia and clinical photographs of the affected lower extremity. We then assessed the relationship between radiographically measured procurvatum and clinically measured procurvatum using linear regression analysis.

Results The mean preoperative radiographically measured procurvatum (12.3°; range –3.1° to 55.2°) was larger than the clinically measured procurvatum (6.0°; range, –1° to 45°; $p = 0.024$). The mean postoperative radiographically measured procurvatum (4.2°; range –4.8° to 30.3°) was larger than the clinically measured procurvatum (2.1°; range, –2° to 20°; $p = 0.041$). Preoperatively and postoperatively, radiographically measured procurvatum and clinically measured procurvatum were well correlated (linear regression $p < 0.001$). After surgical realignment, the mean improvement in radiographically measured procurvatum (8.2°) was larger than that measured for clinically measured procurvatum (3.8°) ($p = 0.018$).

Conclusions In patients with Blount's disease, visual inspection of the extremity can underestimate the procurvatum deformity of the proximal tibia relative to the measurable deformity on radiographs. Furthermore, surgical correction of proximal tibial procurvatum does not lead to clinical hyperextension of the knee.

Level of Evidence Level IV, diagnostic study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

Blount's disease (tibia vara) is a developmental disorder affecting the posteromedial portion of the proximal tibial growth plate. Although it is essentially an oblique plane deformity, varus angulation of the proximal tibia is the most apparent clinical presentation in patients with Blount's disease. Other deformities including anterior angulation (procurvatum), internal rotation of the tibia, and limb shortening can develop as a result of the asymmetrical growth of the proximal tibia [18]. In children with Blount's disease, a procurvatum deformity of the proximal part of the tibia is typically noted, whereas the sagittal profile of the distal segments of the femur and tibia is usually within normal limits [7, 19].

Unrecognized and thus uncorrected multiplanar abnormalities of the proximal tibia can lead to residual deformities, which may lead to abnormal contact forces across the knee and growth plate and potentially contribute to premature arthritis and recurrent deformity, respectively [8, 17, 19]. Thus, a multiplanar correction of the proximal tibia using a proximal tibial osteotomy or guided growth techniques is the mainstay of managing such deformities in children with Blount's disease. However, it can be challenging to precisely determine the degree of flexion deformity at the knee based on clinical examination in such patients, especially those with large body habitus and scarring of the overlying skin and soft tissues with postoperative recurrent deformities. Although some authors have reported on the use of clinical photography as a means of documenting knee ROM [2, 15], there are no studies to our knowledge that have assessed the use of photography to measure fixed flexion deformity of the knee. Furthermore, the correlation of the radiographic finding with clinically apparent procurvatum deformity has not been previously reported. Such information would likely impact on the surgical correction that is attempted in patients with Blount's disease.

The primary purpose of our study therefore was to assess the magnitude of radiographic and clinical procurvatum deformity associated with Blount's disease. We also planned to examine the relationship between the magnitude of procurvatum based on a lateral radiograph of the tibia and procurvatum as measured on a clinical photograph in such patients and asked the following questions: (1) Is the mean angle of radiographically measured procurvatum greater than that of clinically measured procurvatum? (2) Is there a linear relationship between radiographically measured procurvatum and clinically measured procurvatum?

Patients and Methods

Approval from our institutional review board was obtained before initiating this study. Using a surgical database in our division of pediatric orthopaedics, all patients with the

diagnosis of Blount's disease who had been treated by the senior author (SS) between 1997 and 2012 were identified. All of the following inclusion criteria had to be met before the patient was included in this retrospective study: (1) the diagnosis of Blount's disease was made on the basis of radiographic evidence of persistent or worsening genu varum with changes consistent with Blount's disease [11, 18]; (2) full-length lateral radiographs of the affected tibia were available; and (3) preoperative and/or postoperative clinical photographs of the lower extremity in maximal extension (side view) were available. Patients younger than 6 years old were not included because the deformity may be physiological genu varum. Patients were excluded from the study if they had a history of a lower extremity fracture of the affected extremity or did not have adequate clinical and radiographic records. Of the 81 patients with the diagnosis of Blount's disease, 72 patients were treated surgically. Of these 72 patients, 27 patients were excluded because they did not have adequate preoperative and/or followup clinical photographs. Two other patients who did not have initial radiographs were also excluded. Thus, 43 patients (60% of those treated surgically during the period in question) with a total of 47 affected limbs met the inclusion criteria, and they were evaluated at a median of 97 months after surgery (range, 24–170 months). All 43 patients (47 limbs) had preoperative and postoperative full-length lateral radiographs of the involved tibia. Twenty-eight (31 limbs) of 43 patients had both preoperative and postoperative photographs, four (four limbs) patients had only preoperative photographs, and 11 (12 limbs) patients had only postoperative photographs. Clinical charts and radiographic records were reviewed for this cross-sectional retrospective study. The demographic and radiographic findings noted at the final preoperative visit were used for preoperative data analysis. Included patients were not different from those excluded for insufficient followup in terms of age, time since surgery, sex, race, frequency of bilateral disease, or mean body mass index (Table 1).

All procedures were performed by the senior author (SS). An opening wedge osteotomy of the medial proximal tibia with gradual correction using an external fixator (Taylor Spatial Frame®; Smith and Nephew, Memphis, TN, USA) was performed. Patients were allowed to partially weightbear on the affected extremity postoperatively. Approximately 10 to 14 days after discharge from the hospital, full-length AP and lateral radiographs of the affected tibia were obtained and these were repeated every few weeks until satisfactory biplanar correction was identified. Evidence of consolidation at the osteotomy site was determined using radiographs. When at least three of the four cortices of the regenerate gap demonstrated corticalization on AP and lateral views, then consolidation was considered adequate for removal of the external fixator

Table 1. Demographic data

Demographics	Patients included	Patients excluded	p value
Number of patients (limbs)	43 (47)	29 (34)	
Mean age at surgery (years; range)	12.8 (6.0–25.1)	13.1 (6.5–26.1)	0.432
Mean followup (years; range)	6.9 (2.0–14.2)	6.0 (2.0–12.1)	0.264
Sex			0.436
Male	28 (65%)	22 (74%)	
Female	15 (35%)	7 (26%)	
Race			0.808
Black	28 (65%)	18 (62%)	
Others	15 (35%)	11 (38%)	
Bilaterality			0.470
Unilateral involvement	39 (91%)	24 (83%)	
Right	20 (51%)	14 (58%)	
Left	19 (49%)	10 (42%)	
Bilateral involvement	4 (9%)	5 (7%)	
Mean body mass index (kg/m ² ; range)	27.5 (17.0–45.1)	29.0 (18.0–45.9)	0.242

under general anesthesia. The patient was placed in a long-leg cast for 2 to 4 weeks postfixator removal and then progressed to full weightbearing without crutches.

Preoperative radiographic assessment included evaluation of a full-length standing AP radiograph of both lower extremities including the hip and ankle with the patellae pointing forward as well as AP/lateral radiographs of the entire lengths of both tibiae. Deformity analysis was performed using the methodology described by Paley et al. [16, 17]. Sagittal plane analysis included measurement of the proximal posterior tibial angle. This is the posterior angle between the tangent along the tibial plateau and the anatomic axis of the tibia (formed by connecting the junction of anterior one-fifth and posterior four-fifths of the tibial plateau proximally and the midpoint of the tibial plafond distally) as measured on a full-length lateral radiograph of the tibia [16]. The reference value of proximal posterior tibial angle is 81° [12, 17]. Radiographically measured procurvatum for each limb was calculated in degrees as 81 minus the measured proximal posterior tibial angle (Fig. 1A). Thus, a positive value indicates radiographic procurvatum and a negative value indicates recurvatum. Frontal plane analysis included mechanical axis deviation and medial proximal tibial angle [16]. A pediatric orthopaedic surgeon (S-JK) who was not involved in the clinical care of these patients made all of the radiographic measurements. Intraobserver reliability was calculated by having the same individual measure 20 sets

of randomly selected radiographs a few weeks apart. The senior author (SS) independently measured the radiographic parameters for the same 20 patients noted. The radiographic parameters were tested for reproducibility using intraclass correlation coefficient (ICC). The ICC was 0.918 for intraobserver reliability and 0.904 for interobserver reliability.

Clinical photographs of the affected lower extremity were recorded for each selected patient with the involved knee in maximum extension. Care was taken using visual inspection to ensure that the leg was neither abducted nor adducted and in neutral rotation. The camera lens level was positioned parallel to the patient's knee. A physician assistant positioned the patient's knee in a maximally extended position and a photograph of the patient's lower extremity was taken using a digital camera (Kodak EasyShare C180, Tokyo, Japan). Angular measurements were made on a printout of the digital photograph to the nearest degree. A double-arm goniometer (arm length 30 cm; Biomet, Warsaw, IN, USA) was used with one arm placed along the anterior border of the thigh and the other arm of the goniometer along the anterior aspect of the lower leg [2] (Fig. 1B). Clinically measured procurvatum was documented for each limb as the direct measurement, in degrees, based on the reading from the goniometer. Thus, a positive value indicates radiographic procurvatum and a negative value indicates recurvatum. The measurement of clinically measured procurvatum was also tested for reproducibility using 20 randomly selected digital photographs. The ICC was 0.927 for intraobserver reliability and 0.912 for interobserver reliability.

For statistical analysis, we used SPSS Version 15.0 software (SPSS Inc, Chicago, IL, USA). Linear regression analysis was used to determine the relationship between radiographically measured procurvatum and clinically measured procurvatum. The t-test was also used to evaluate the difference between the mean angles of radiographically measured procurvatum and clinically measured procurvatum. A p value < 0.05 was considered significant.

Results

Clinical measurement underestimated procurvatum as measured on plain radiographs. The mean preoperative radiographically measured procurvatum (12.3°; range −3.1° to 55.2°) was larger than the clinically measured procurvatum (6.0°; range, −1° to 45°; p = 0.024). The mean postoperative radiographically measured procurvatum (4.2°; range, −4.8° to 30.3°) was larger than the clinically measured procurvatum (2.1°; range, −2° to 20°;

Fig. 1A–B (A) Lateral view of the left tibia demonstrates 35° of proximal posterior tibial angle with radiographically measured procurvatum of 46° (81°–35°). (B) Clinical photography shows measurement of radiographically measured procurvatum.

$p = 0.041$) (Table 2). Preoperatively, 42% (20 of 47) and 22% (eight of 35) of affected limbs demonstrated greater than 10° of radiographically measured procurvatum and clinically measured procurvatum, respectively. Postoperatively, greater than 10° of procurvatum was noted in 19% (nine of 47) of the limbs on radiographs and 7% (three of 43) of the limbs on clinical photography. All the tibias were in varus (medial proximal tibial angle less than 87°) preoperatively (Table 2).

Radiographically measured procurvatum and clinically measured procurvatum were well correlated for the entire cohort, including measurements made preoperatively and postoperatively (linear regression analysis, $p < 0.001$) (Fig. 2A). Based on subgroup analysis, there remained a significant relationship between radiographically measured procurvatum and clinically measured procurvatum among patients evaluated preoperatively ($p < 0.001$) (Fig. 2B) and postoperatively ($p = 0.001$) (Fig. 2C). After surgical realignment, the mean change (Δ) in radiographically measured procurvatum (8.2°) was greater than in clinically

Table 2. Overall sagittal and frontal plane deformities at both initial presentation and latest followup

Assessment	Mean value (range)	95% confidence interval
Procurvatum on routine radiographs		
Initial	12.3° (range, −3.1° to 55.2°)	8.1°–16.6°
Recent followup	4.2° (range, −4.8° to 30.3°)	2.1°–6.2°
Procurvatum on clinical photographs		
Initial	6.0° (range, −1° to 45°)	2.3°–9.6°
Recent followup	2.1° (range, −2° to 20°)	0.5°–3.6°
Mechanical axis deviation (mm)		
Initial	70.5 (range, 58.9–92.2)	60.5–80.5
Recent followup	20.4 (range, −2.2 to 35.9)	7.4–33.4
Medial proximal tibial angle		
Initial	71.2° (range, 60.1°–79.7°)	63.1°–79.3°
Recent followup	88.8° (range, 73.2°–103.1°)	75.2°–102.4°
Posterior proximal tibial angle		
Initial	68.7° (range, 25.8°–84.1°)	63.4°–71.9°
Recent followup	76.8° (range, 50.7°–85.8°)	73.8°–77.9°

measured procurvatum (3.8°) ($p = 0.018$). There was a significant relationship between radiographically measured procurvatum (Δ) and clinically measured procurvatum (Δ) ($p = 0.001$) (Fig. 3).

Discussion

Children with Blount's disease are reported to have a frontal plane deformity [1, 13]. However, as a result of the asymmetrical growth resulting from involvement of the posteromedial portion of the proximal tibial growth plate, an oblique plane deformity of the tibia with lateral angulation, internal rotation, and anterior angulation (procurvatum) develops [18]. Natural history studies of Blount's disease have suggested that progressive procurvatum deformity can lead to gait abnormality, leg length inequality, and premature arthritis of the knee [9, 10, 22]. However, it is difficult to precisely determine the degree of procurvatum at the knee based on clinical examination alone and such clinical assessment may be different from the procurvatum deformity noted on radiographs. In the present study, we found that clinical examination underestimates procurvatum relative to radiographic analysis but that the two are well correlated.

Our study has some limitations. First, this was a retrospective, cross-sectional case series of modest size with multiple variables. Furthermore, a large number of patients (more than one-third) was excluded because they did not have adequate photographs or radiographs. However, comparing the demographics and other important clinical

Fig. 2A–C Scatterplot of regression analysis demonstrates the relationship between radiographically measured procurvatum (Procurvatum R) and clinically measured procurvatum (Procurvatum C). (A) Scatterplot of regression analysis shows preoperative and postoperative relationship ($p < 0.001$); (B) scatterplot of regression analysis shows preoperative relationship ($p < 0.001$); and (C) scatterplot of regression analysis shows postoperative relationship ($p = 0.001$).

Fig. 3 Regression analysis graph shows the relationship between the change (Δ , preoperative minus postoperative) in radiographically measured procurvatum (Procurvatum R) and in clinically measured procurvatum (Procurvatum C) after surgical realignment ($p = 0.001$).

parameters between the included patients and those excluded for insufficient followup suggests those groups were similar, which tends to offset this limitation (Table 1). Second, there is a possibility for measurement error when assessing sagittal plane deformities using radiographs and clinical photography. Because the majority of children with Blount's disease are obese [3, 14, 20, 21], the excess tissue in the limb can affect measurement. Because we made clinical measurement based on the anterior portion of the lower limb, given the overhanging skin around the posterior thigh and calf in these patients, it is likely that a goniometric measurement using the mid-thigh and midleg axis would lead to an even greater underestimation of the true magnitude of the proximal tibial procurvatum deformity. Furthermore, it is plausible that the longstanding procurvatum deformity of the proximal tibia in these children can lead to compensatory changes in the adjacent soft tissues such as stretching of the

posterior capsule of the knee or recurvatum deformity of the distal femur. Given the retrospective study design, we were unable to reliably assess the potential contributions of such compensatory mechanisms. It was difficult to quantify the soft tissue laxity of the knee. In addition, although the lack of sagittal plane deformity in patients with Blount's disease has been previously reported [19], lateral radiographs of the ipsilateral femur were not evaluated for this study. Third, Blount's disease is neither a frontal nor a sagittal plane deformity, but rather an oblique plane deformity. However, most clinicians [5, 7, 19] still assess this deformity clinically and radiographically in frontal and sagittal plane based on convention. As such, the purpose of our study was to compare only the sagittal profile based on clinical examination versus radiographic examination in these patients.

In the current study, we found that in patients with Blount's disease, the mean angle of procurvatum based on full-length radiographs of the tibia was higher than measurements based on clinical photographs (12.3° versus 6.0°). Thus, the magnitude of procurvatum deformities around the proximal tibia that are based on radiographs can be greater than that noted on visual inspection. Underestimated and thus uncorrected such procurvatum deformities can eventually result in residual and progressive deformities as a result of abnormal contact forces across the knee and adjacent growth plates. Finally, in severe cases, they potentially contribute to growth suppression, limb shortening, and premature arthritis [19]. In clinical practice, the procurvatum or recurvatum of the knee is typically assessed either visually or with a handheld goniometer. Despite the simplicity and minimal cost, the accuracy of measurements obtained using a handheld goniometer is dependent on the accurate alignment of the arms of the measuring device between bony landmarks, which are often visualized rather than marked [4] perhaps compromising accuracy [6]. Furthermore, palpation of bony landmarks around the hip and knee regions can prove difficult, especially in obese patients and those with overlying soft tissue scarring or defects. Additionally, movement of the overlying skin may alter the perceived position of the underlying bony landmarks. Both goniometer alignment and landmark identification have been shown to contribute to measurement error [6]. In our patient cohort, although we attempted normalization of the sagittal alignment (proximal posterior tibial angle of 81°) of the proximal tibia, mean radiographic procurvatum of 4.2° and clinical procurvatum of 2.1° still remained at the latest followup. Several possible explanations may have contributed to this finding. First, we tried to avoid clinical hyperextension of the knee; overcorrection was not attempted, and we may have inadvertently accepted slight radiographic undercorrection in the sagittal plane. Second,

because a large number of our patients were skeletally immature, procurvatum deformity might have recurred after surgery. Finally, given the difficulty in adequately positioning and visualizing the proximal tibia resulting from the overlying external fixator, the assessment of the sagittal profile of the proximal tibia during the distraction phase of treatment may have been compromised.

Our results showed that radiographically measured procurvatum and clinically measured procurvatum were well correlated both preoperatively and postoperatively. We also noted excellent measurement reliability for assessing sagittal plane deformity using both techniques. We believe that supplementing the patient's medical record with documentation of the knee deformity using a photographic trial provides greater assessor transparency compared with simply documenting the maximum knee extension using visual inspection or goniometric measurement by a single observer. However, further analysis using a more robust prospective study design involving a larger cohort of patients would be needed to verify our impression. In the present study, despite a strong linear relationship between the two measurement techniques, the mean change in radiographically measured procurvatum (8.2°) was significantly greater than in clinically measured procurvatum (3.8°) after surgical realignment. Because the mean change in clinically measured procurvatum is less than that of radiographically measured procurvatum, we believe that radiographic full correction will not lead to clinically relevant recurvatum.

In summary, although clinical and radiographic measurement of procurvatum in patients with Blount's disease was well correlated, clinical measurement underestimates the magnitude of the radiographic deformity of the proximal tibia. This is important because unrecognized and thus uncorrected multiplanar abnormalities of the proximal tibia can lead to residual deformities and other sequelae. Moreover, based on preliminary data, correcting the procurvatum deformity based on the radiographic measurement does not lead to clinical hyperextension of the knee. We recommend that a comprehensive multiplanar deformity analysis including clinical examination and radiographs should be routinely performed when evaluating a patient with Blount's disease.

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