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A new measurement method for the radiographic assessment of the proximal femur: the center-trochanter distance

Proksimal femurun radyografik değerlendirmesinde yeni bir ölçüm yöntemi: Merkez-trokanter uzaklığı

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Amaç: Proksimal femurun radyografik değerlendirmesi için geliştirdiğimiz yeni bir yöntem -femur başı merkezi ile trokanter uç noktası arasındaki dik uzaklığın ölçülmesi- tanımlanarak sunuldu.

Çalışma planı: "Merkez-trokanter uzaklığı" (MTU), femur diyafiz aksına dik çizilen ve femur başı merkezi (M) ve büyük trokanterin üst ucundan (T) geçen iki paralel çizgi arasında milimetre olarak ölçülür. Eğer M noktası T noktasına göre üstte ya da altta ise ölçülen uzaklık sırasıyla pozitif ya da negatif değer olarak ifade edilir. Bu yöntemi uygulamak amacıyla, kemiksel olgunlaşmasını tamamlamamış 200 kalçanın ve tamamlamış 600 kalçanın normal olarak değerlendirilen ön-arka direkt pelvis radyografileri üzerinde ölçümler yapıldı. Elde edilen aritmetik ortalamanın bir standart sapma (SS) altı ya da üstünde kalan değerler "normal", aritmetik ortalamanın iki SS altı ya da üstünde kalan değerler "patolojik" olarak kabul edildi. Yöntemin güvenirliği gelişimsel kalça displazisi nedeniyle ameliyat edilen ve uzun dönem izlemi olan 43 kalçada sınandı.

Sonuçlar: Kemiksel olgunlaşmasını tamamlamamış proksimal femurda -5 mm altı ve 15 mm üzeri, kemiksel olgunlaşmasını tamamlamış proksimal femurda -17 mm altı ve 7 mm üzerindeki MTU değerleri patolojik olarak değerlendirildi. Yöntemin gözlemci (kappa katsayısı 0.92 ve 0.81) ve gözlemciler (kappa katsayısı 0.88) arası güvenirliği mükemmel düzeyde bulundu.

Çıkarımlar: Merkez-trokanter uzaklığı, gelişimsel kalça displazisi ve Legg-Calvé-Perthes hastalığı gibi kalça patolojilerinde proksimal femurun radyografik değerlendirmesinde kullanılabilir.

Anahtar sözcükler: Femur başı/radyografi; femur başı nekrozu/radyografi; kalça/radyografi; kalça çıkığı/radyografi; Legg-Perthes hastalığı; referans değeri.

Objectives: We developed a new method -measuring the perpendicular distance between the center of the femur head and the tip of the trochanter- for radiographic assessment of the proximal femur.

Methods: The "center-trochanter distance" (CTD) refers to the perpendicular line drawn to the femoral shaft axis between two parallel lines that pass through the center of the femoral head (C) and the tip of the greater trochanter (T). The measured distance in millimeters is expressed as a positive or negative value depending on the location of the point C, that is, above or below the point T, respectively. Measurements were made on anteroposterior plain radiographs of 200 skeletally immature and 600 skeletally mature hips, all of which had been assessed as normal. Values that were found to be below or above the standard deviation of 1 and 2 of the mathematical means were regarded as "normal" and "pathological", respectively. The reliability of the method was tested in 43 hips that had been surgically treated for developmental dysplasia of the hip and had a long-term follow-up.

Results: The center-trochanter distance measured below -5 mm and above 15 mm in the skeletally immature proximal femora, and below -17 mm and above 7 mm in the skeletally mature proximal femora were regarded as "pathologic". The intraobserver (kappa coefficient, 0.92 and 0.81) and interobserver (kappa coefficient 0.88) reliability of the method was found to be excellent.

Conclusion: The center-trochanter distance may prove to be useful in radiographic assessment of the proximal femur in several hip disorders such as developmental dysplasia of the hip and Legg-Calvé-Perthes disease.

Key words: Femur head/radiography; femur head necrosis/radiography; hip/radiography; hip dislocation/radiography; Legg-Perthes disease; reference values.

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Antero-posterior direct pelvic radiography is an important diagnostic tool for various hip problems. Changes of both acetabulum and proximal femur can be seen easily in this kind of a graphy. Changes in shapes of femoral head and neck and angular deformities of the femoral neck can occur in consequent to the ischemic changes of proximal femur in the diseases like Legg-Calve-Perthes and developmental hip dysplasia.[1] It is known that in children, upper edge of the trochanter is seen at the same level or just at the distal of the center of the femoral head in plain graphy.[2] The normality of the relation between femoral head and the greater trochanter depend upon the absence of growth difference of both and the normality of the neck-body angle and the length of femur neck. This normal relation gives a positive strength to the hip abductors for maintaining the functional mechanics of the hip.[2,3] Thus, it may be put forward that the use of various measuring methods in antero-posterior pelvic graphy provides sufficient determinants in radiographic evaluation of proximal femur.

Up to now two methods are defined to evaluate the relation between femur head and great trochanter in a plain anteroposterior graphy. Edgren[4] has defined "articulotrochanteric distance (ATD)" for precisely measuring the distance between the joint surface of femur head and the tip of greater trochanter at a pelvic graphy. The numeric value obtained is read as positive if the joint surface of the femur head is above the tip of greater trochanter and is read as negative if vise-versa. This parameter is used to assess the radiographic results in various studies.[2,5-8] Kalamchi ve MacEwen[3] have assessed the position of the tip of the great trochanter according to the center of the femur head and have defined it as positive if the trochanter is at distal of the center of the femur head, neutral if they are on the same level and negative if the trochanter is at proximal of the center of the femur head. The use of this parameter to evaluate the radiographic results in several hip pathologies is seemed quiet limited.

In this study, it is aimed to define a new, easy and objective measuring method names as "center-trochanteric distance (CTD)" in radiographic assessment of proximal femur, to reveal its normal and pathologic border range and to investigate its reliability.

Patients and methods

Central trochanter distance is the distance between to parallel lines which are perpendicular to the vertical axis of diaphysis of femur passing through the center of femur head (C) and the tip of the great trochanter (T), in terms of millimeter (figure 1). C point is determined by positioning a transparent pattern including concentric rings on the contours of femur head. If C point is above T point, the distance measured is defined as positive (figure 1a) and if C point is below T point, the distance measured is defined as negative (figure 1b).

First phase of the study was formed by determining the normal and pathological values. Radiographic results of the patients who admitted to the orthopedics and traumatology outpatient clinic or hospitalized in the same clinic of a certain hospital for this purpose. Anteroposterior pelvic graphies which were taken for various purposes

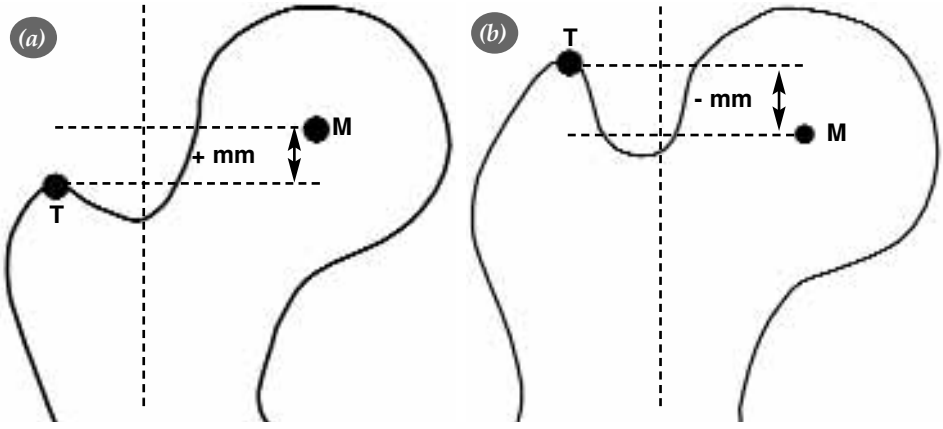

Figure 1. (a, b) Schematic view of the center-trochanter distance. C: Center of femur head T: Tip of the greater trochanter.

Table 1. Measurement results of 800 normal hips.

	Number of hips	Mean ± SD (mm)	Distribution (mm)
Immature proximal femur	200	4.8±4.8	-7 ve 17
Mature proximal femur	600	-5.2±6.1	-25 ve 13

and were classified as normal were separated aside. Two legs and knees were at extension, patella were facing frontally and focusing distances were 110 cm in all these films. First group was consisted of 200 proximal femurs of 100 children (50 females, 50 males, average age 9.2 ± 2.7 year-old) who were immature in terms of bone structure with visible growth plaque lines of apophysis of great trochanter and epiphysis of proximal femur.

Second group was consisted of 600 proximal femurs of 300 adult patients (150 females, 150 males average age 39.1 ± 16.2) who were mature in terms of bone structure with invisible growth plaque lines of apophysis of great trochanter and epiphysis of proximal femur. All measurements were done by the second author as defined before. Same pencil and ruler were used in all measurements. After calculating mean values of the measurements, the values remaining one standard deviation upper or lower than the arithmetical mean were defined as "normal", two standard deviations upper or lower than the arithmetical mean were defined as "pathological" and values in between one and two standard deviation were defined as "controversial".

Second phase of the study was formed by examining the reliability of the defined method in surgically operated hips due to development hip dysplasia. For this purpose, 43 radiograhic results of 29 patients (mean age 21 year-old, distribution 13-29) which were taken after approximately 20 years of fallow-up (distribution 13-28 years) were investigated. None of the hips were dislocated. Measurements were done twice with 2 weeks intervals independently by the first two authors. Same pencil and ruler were used in all measurements. Hips were classified into "normal", controversial" or "pathological" subgroups in accordance with the definitions done before, after the observers measured CTDs in millimeters. Intraobserver and interobserver measurement variations were defined as the difference between the two measurements of one observer and the difference between two measurements of two observes, respectively. Intraobserver and interobserver compliance about the relations of head-trochanter in terms of measured CTD value was calculated by kappa statistics.

Results

Range values from normal hips

Values between 0-10 mm were defined as "normal, between -1 and -5 mm were defined as "controversial" and values lower than -5 mm and higher than 15 mm were defined as "pathological" in accordance with the previously defined formula in proximal femur group of immature bone structure. 97% (n=193) of the 200 measurements in this group was in ±2 SD range. In proximal femur group of mature bone structure, values between -11 and 1 mm were defined as "normal", between 2-7 mm and between -12 and -17 mm were defined as "controversial", values lower than 17 mm and higher than 7 mm were defined as "pathological". 575 (96%) of 600 measurements in this group were in the range of mean ±2 SD (table 1).

Reliability of interobserver and intraobserver measurements from treated hips

Mean intraobserver and interobserver measurement differences were 1.0±0.9 mm (distribution 0-4 mm) and 1.7±1.5 mm (distribution 0-8 mm), respectively. When center-trochanter distance measurements were classified as normal, controversial and pathological in accordance to the classification defined before, the compliance ratio (kappa coefficient) of first and second author was 98% (0.92) and 95% (0.81), respectively. Interobserver compliance ratio (kappa coefficient) was found to be 97% (0.88). All kappa values calculated were indicating a perfect compliance. [9]

Discussion

Any radiograpical or clinical evaluation system is valuable if its precision and reliability are proved. But, the reliability of an evaluation system should be

determined before evaluating of the results of the treatment method or before being a guide for treatment.[10] Several defects of previously defined radiographic evaluation method for the relation of femur head and trochanter have led the authors to develop a new evaluation system. Although the articulotrochanteric distance is used extensively, its intra and interobserver measurement consistency has not been assessed, yet. Also, normal and pathological range values of this measurement method in both children and adults have not been determined, yet. This prevents the standard classification of hips as normal or pathological. The classification system of Kalamchi and MacEwen[3] for head-trochanter relation covers mainly the patients whose bone maturation is completed. For this reason, use of this method in adults is controversial. Also, it can be considered as a subjective method because of lack of numeric values. Besides, intraobserver reliability is moderate [11] On the contrary, in our study, normal and pathological ranges of CFD in both children and adults were determined and also, intra and interobserver reliability were found to be perfect. The center of the femur head is known to be the center of femoral rotation.[2] As femur head is an anatomical and biomechanical point, we believe that considering the center of femur head as a reference for radiographical evaluation of trochanter – head relation would be more appropriate. It can be told that a significant decrease in center-trochanter distance may originate from an excessive growth of great trochanter, decreased neck-diaphysis angle or decrease in length of femur neck and it can be told that a significant increase may originate form the increase in neck-diaphysis angle and/or the increase in the antroversion of femur neck.

In clinical practice, it may be possible to determine the pathological changes of proximal femur, to establish a treatment approach and to evaluate of the results of chosen method after CTD measurement similar to the measurements of ATD. In our opinion CTD has two disadvantages beside its advantages. In excessively deformed and flattened femur head, the exact determination of the center of the head might not be as easy as it used to be with a normal femur. This problem can be solved by considering the acetabular concavity center as the center of the femur head. That is why, when acetabulum and femur head are thought to be two circles within each other, the center of acetabulum can be accepted as the center of femur head.[12] On the other hand this solution is not valid for subluxated or dislocated hips. Besides, the use of CTD in children younger than 5 years old is limited due to the fact that determining the center of femur head can fail in this age group. [1]

In conclusion, CTD can be accepted as an objective, anatomical and simple measuring method for radiographical assessment of proximal femur. This method has perfect intra and interobserver reliability. Center trochanteric distance is an appropriate method for the radiographic assessment of proximal femur in several hip diseases like DHD and Legg-Calve-Perthes disease.

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