Original Article

Anthropometric analysis of the hip joint in South Indian population using computed tomography

Vetrivel Chezian Sengodan, Elangovan Sinmayanantham, J Saravana Kumar

Abstract

Background: Proximal femur has a significant functional modification on erect bipedal posture. Various proximal femoral parameters were analyzed in Western literature. This information was utilized in prosthetic designing. Implants designed for Western people are used in Indian patients undergoing hip surgeries such as internal fixation and replacement arthroplasty.

Materials and Methods: The study was done among 200 individuals (400 hips) with a normal hip joint after ethical committee clearance. Computed tomography scanning of proximal femur was done. Neck-shaft angle (NSA), neck width (NW), head diameter (HD), acetabular angle (AA) of sharp, horizontal offset (HO), vertical offset (VO), medullary canal diameter at the level of lesser trochanter (MD_{LT}), and acetabular version (AV) were measured. These parameters were tabulated and compared with various populations and statistically analyzed.

Results: The mean values were NSA 135°, NW 27 mm, femoral HD (HD) 42.5 mm, AA of sharp 35.5°, HO 37 mm, VO 46 mm, MD_{LT} 20 mm, and AV 18.64°. The values differ when compared with Western population. This study results differed when compared with other Indian studies done in Northern and Northeast Indian population. Significant differences noted in the parameters between sexes and between the sides of the hip joint.

Conclusion: This study indicates that there are significant differences in anthropometric parameters of proximal femur among the South Indian population compared with Western population. Even within the Indian population, the anthropometric parameters vary region to region.

Key words: Computed tomography, femoral stem, fracture implants, proximal femur
MeSH terms: CAT scan, hip prosthesis, intramedullary nailing, femur, anthropometry

Introduction

Proximal femur has a significant functional modification on erect bipedal posture. The morphology of the proximal femur, especially the relationship between proximal femur and the shaft of femur is an interesting subject in orthopedic literature. The geometry of the proximal femur is determined by genetic and environmental factors such as age, race, sex, and lifestyle.[1-3] Anthropometric dimensions described for proximal femur in Westerners might be quite different from those encountered among Indians.[1] Hence, the knowledge regarding proximal femur is important for understanding the biomechanics of the hip as well as surgical planning. Anthropometric analysis of the proximal femur will be useful in the management of the pathological conditions such as osteoarthritis of the hip, fracture neck of femur, and pertrochanteric fractures.

Fractures around the hip and osteoarthritis of the hip joint are relatively common in elders[4] and need ideal fixation for good functional outcome. Siwach and Dahiya compared the parameters of the femurs of Indian cadavers with those of Western and Hong Kong Chinese population.[1] They observed that the implants were oversized, and their angles and orientations have a mismatch, which can presumably lead to

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complications such as splintering and fractures.[1] Pathrot *et al*. using cephalomedullary nails suggested design modifications for Indian population with lesser neck width (NW).[5]

The aim of any surgical procedure in proximal femur is to obtain stable and well functioning hip joint. The common implants used in the proximal femur are dynamic hip screw, proximal femoral nail, cancellous screws, and replacement arthroplasty. Since the parameters of proximal femur morphometry for Indian population is lacking,[6] the data about proximal femur geometry for the Western population are utilized in prosthetic designing. With no other available option, the same implants designed for the Western population is used for Indian patients.

It is also vital to match the dimensions of the implant closely with those of native femur to prevent complications resulting from mismatch could be aseptic loosening, improper load distribution, and discomfort.[6,7] In uncemented hip, arthroplasty secondary biologic integration of a hip implant depends mainly on the quality of its primary stability.[6,8-10] Mismatch between bone and prosthesis will affect the bone ingrowth due to micromotion of the implants during the early postoperative period. It is also vital to design a prosthesis through which adequate loads can be transferred to the bone to prevent stress shielding.[6,11] This study is aimed to get more information about proximal femur geometry among South Indian population using computed tomography (CT).

Materials and Methods

Two hundred patients both male and female in the age group between 20 and 70 years operated between 2012 and 2014 were included in the study group. Patients with normal hips on examination, who have undergone abdominal CT scan for other reasons, were evaluated after ethical committee clearance. Persons with preexisting hip pathologies such as osteoarthritis, rheumatoid arthritis, tuberculosis hip, old fracture or dislocations of hip, tumors of the hip and proximal femur, deformities of the lower limb, and spine were excluded from the study. Both the hip joints were analyzed. Multi slice toshiba helical CT scanner alexion Tsx-033A was used in our study. The position of the person during imaging was supine with both lower limbs in neutral rotation. The thickness of the CT slice was 2 mm. Superimpositions and motion artifacts were avoided. The neck-shaft angle (NSA), head diameter (HD), neck width (NW), acetabular angle (AA) of sharp, horizontal offset (HO), vertical offset (VO), medullary canal diameter at the level of lesser trochanter, and acetabular version (AV) were measured. Measuring process is optimized using the "full-screen" view, and the images were magnified to maximize resolution and accuracy.

Neck-shaft angle

It is the angle intersected between the long axis of the femur and the long axis of the neck of the femur [Figure 1a]. Femoral shaft axis is a line drawn by extending through two equidistant points from the mediolateral surface of femoral shaft in the center of the medullary canal. Neck axis is drawn by joining the two points equidistant from the superior and inferior surface of femoral neck.[11]

Head diameter

A perfect circle is drawn over the ideally spherical femoral head, and circle diameter is measured [Figure 1b].

Neck width

A perpendicular line to the neck axis at the narrowest part of the femoral neck is measured [Figure 1c].[5,12]

Acetabular angle of sharp

The angle intersected pelvic teardrop and a line edge of the acetabulum.[13] In the coronal sections of the CT scan images, a horizontal line is drawn through the teardrop and another line drawn from the tip of the teardrop to anterior edge of acetabulum. The angle formed between these two lines is defined as the acetabular angle of sharp [Figure 2a].

Horizontal offset

Horizontal offset or simply femoral offset is the horizontal distance from the center of rotation of femoral head to a line bisecting the long axis of shaft of femur.[14] Two lines were drawn - one along the center of femoral head, another along the middle of the femoral medullary canal [Figure 2b].

The measured distance between the two lines gives the HO.

Vertical offset

Vertical offset or femoral head position is the vertical distance from the center of femoral head to the tip of lesser trochanter [Figure 2b].[15]

Medullary canal diameter at the level of lesser trochanter

Mediolateral diameter of medullary canal measured at the level of middle of the lesser trochanter [Figure 2c].

Acetabular version

It is the angle measured between a line connecting both the posterior ischia and a line connecting the posterior lips of the acetabulum [Figure 3].[13]

The values were measured by two independent observers and were repeated after 2 weeks by the same observers to reduce the error of calculation.

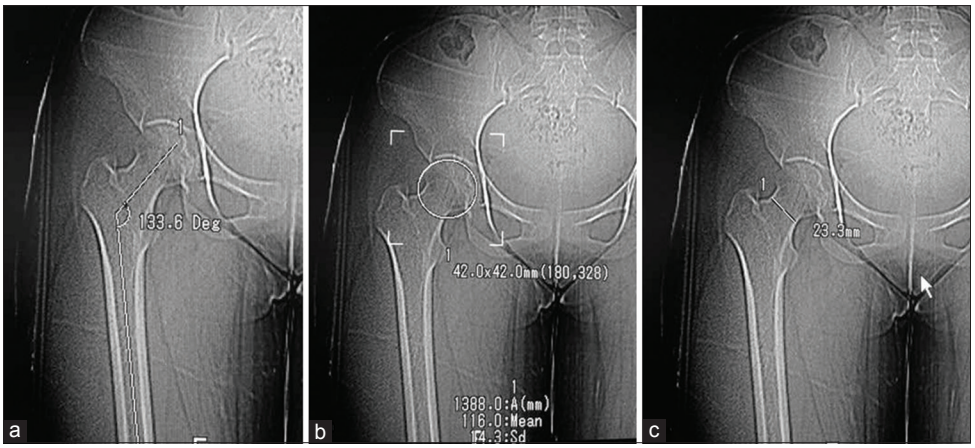

Figure 1: Sagittal CT scan of hip with thigh showing (a) Neck shaft angle (b) Head diameter (c) Width of the femoral neck

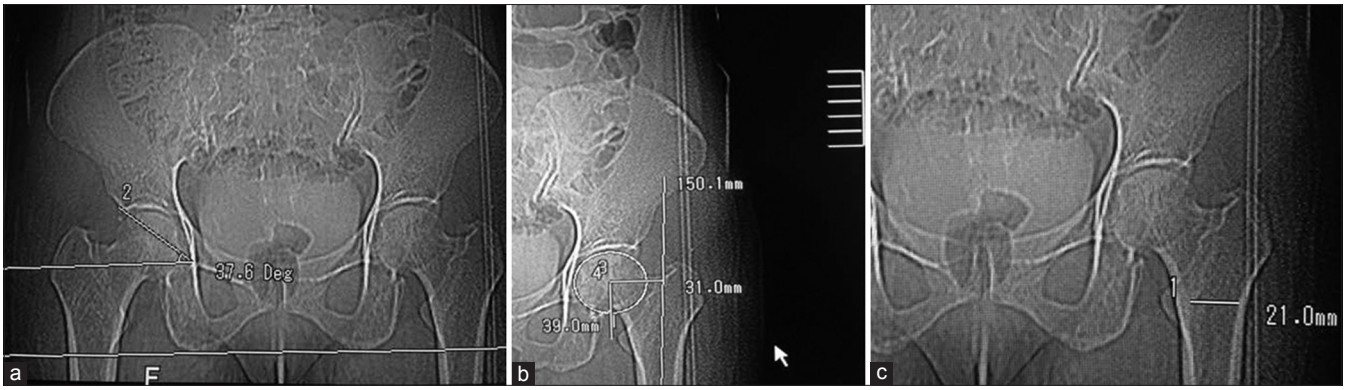

Figure 2: (a) CT scan pelvis with both hips showing acetabular angle (b) CT scan hip with hemipelvis showing horizontal and vertical offset (c) CT scan hip with pelvis showing medullary canal diameter at the level of lesser trochanter

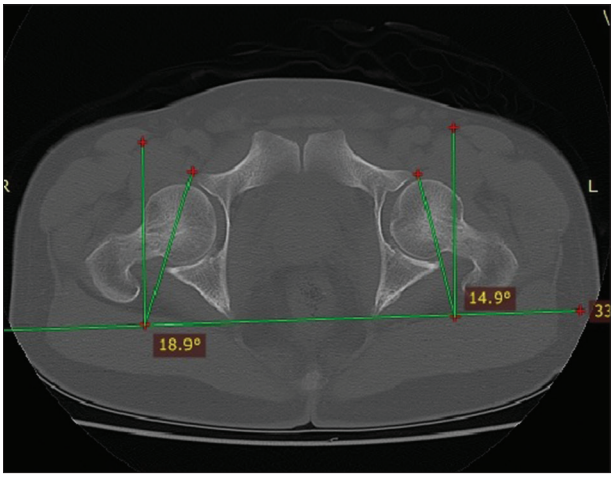

Figure 3: CT scan axial cut pelvis showing acetabular version

The values are tabulated, and the measured parameters are compared with Western population.

Results

Femoral head diameter

The mean of the value of the femoral HD in our study was 42.6 mm. The mean femoral HD among male and female was 44.2 and 40.9 mm, respectively. The values ranged from 38 to 50 mm among male and 36–46 mm in female. Between the right and left sides, the mean value was 42.48 and 42.68 mm, respectively. Statistical analysis was done; the *P* value was statistically significant. The femoral HD values between the two sides were compared.

Neck width

The mean value of the NW in our study was 27.5 mm. Among the male, it ranged from 19 to 37 mm, and for the female, it was from 20 to 33 mm. The mean value was 28.9 mm among male, and it was 26.1 mm among females. In the right side, the NW ranged from 19 to 37 mm, and on the left side, it was 20–35 mm. The mean value was 26.9 mm on the right side and it was 28.1 mm on the left side.

Neck-shaft angle

The mean value of the NSA in our study is 135.4°. Among male and female, the range of NSA was 128°–147° and 122°–145°. The mean value was 136.7° in male and 134.18° in females which was statistically significant. The right side it was from 122° to 147° and 124°–147° on the left side. The mean value was 134.60° on the right side

and it was 136.26° on the left side. Statistical analysis was done; the *P* value was statistically significant.

Horizontal offset

The mean value of the HO was 37.6 mm. Among males, it ranged from 35 to 45 mm and for the females 33–40 mm. The mean value for the males was 39.84, and for the females, it was 35.40 mm. In the right side, the HO range was 33–44 mm, and on the left side, it was 33–45 mm, and the mean value was 37.78 on the right side, and on the left side, it was 37.47 mm.

Vertical offset

The mean value of the VO was 46.89 mm. Among males, it ranged from 40 to 65 mm and for the females 35–56 mm. The mean value for the males was 49.99 mm, and for the females, it was 43.80 mm. In the right side, the VO range was 35–65 mm, and on the left side, it was 40–61 mm, and the mean value was 47.41 on the right side, and on the left side, it was 46.38 mm. Statistical analysis was done; the *P* value was statistically significant.

Acetabular angle of sharp

The mean value of the AA is 35.5°. Among males and females, the range of AA of sharp was the same and was 24°–42°. The mean value among male and female was 35.33° and 35.73°. Among the right and left sides, the range was 24°–42° and 26°–42°. The mean value among the right and left sides was 35° and 36.07°.

Medullary canal diameter at lesser trochanter

The mean value of the medullary canal diameter at the level of lesser trochanter (MD_{LT}) in our study was 20.2 mm. Among males and females, range was 13–30 and 13–27 mm, respectively. The mean value among male and female was 20.65 and 19.75 mm. Among the right and left sides, the range of values was 13–29 and 13–30 mm. The mean value among the right and left side was 20.65 and 19.76 mm. Statistical analysis was done; the *P* value was statistically significant.

Acetabular version

The mean value of the AV in our study was 18.64°. Among males and females, range was 10°–33° and 11°–33°. The mean value among male and female was 17.84° and 19.45°. Among the right and left sides, the range of values was 11°–33° and 10°–29°. The mean value among the right and left side was 18.05° and 19.25°. Statistical analysis was done; the *P* value was statistically significant.

Discussion

The Indian subcontinent comprises a vast collection with different morphological, genetic, cultural, and linguistic characteristics, while much of this variability is indigenous, a considerable fraction of it has been introduced through large-scale immigration into India in historical times.[13] Knowledge of the anatomical parameters of the bony components of the hip joint is very essential, as it will help better understanding of the etiopathogenesis of diseases such as primary osteoarthritis of the hip joint.[13]

The lifestyle and the social customs of the Indian population differ from that of the Western population. The hip joints of the Indian population would be evolutionally different from their Western counterparts since our population is more apt to floor level activities with increased external rotation of the hip.[13] CT has helped in the detailed study of the hip joint.[13]

For anthropometric studies, Husmann *et al*. and Noble *et al*. used plain radiographs in their study,[8,16] whereas CT scan was used by Rubin *et al*.[17] and Mahaisavariya *et al*.[18] According to Rubin *et al*., CT scan values were more accurate than plain radiographs.[17] In a study by Rubin *et al*. (Swiss population), the femoral HD was 43.4 mm.[17] A study among the Caucasian population by Noble *et al*., the femoral HD was 45.9 mm.[16] In our study, the femoral HD was 42.58 mm (range 38–50 mm) which was less than the Western studies.

Femoral HD value among South Indian population was less while comparing our study with a similar study done in New Delhi by Rawal *et al*.[6] [Table 1]. Femoral neck forms an angle with the shaft which is usually 135° ±7° in the normal adult. Functional significance of this angle is that the displacement of femoral shaft away from the pelvis facilitates freedom of hip joint motion.[20]

Regarding the NSA, our study results were compared with Western studies.[6,16,17] The NSA of the Western studies was less than our study results. Our study was also compared with other Indian studies.[6,13] The NSA among South Indian population was more than Rawal *et al*. study done in New Delhi [Table 1], whereas it was less than Northeastern study done by Saikia *et al*. The neck stem angle of the standard femoral prosthesis in arthroplasty is 131°. The mean NSA in our study is 135°, when these differences are not restored while performing total hip arthroplasty, we may not get the normal hip biomechanics.

The NSA among male was more than female and was statistically significant in our study [Table 2], similar to Rawal *et al*.[6] study done in New Delhi. This study revealed that there should be relative degree of difficulty in fixing the same femoral stem to a male and female patient during total hip arthroplasty to restore the natural mechanics of the joint by considering both extra and intramedullary parameters of the femur.

Available cephalocervical diaphyseal angles in proximal femoral nail are 130° and 135°. In our study, NSA ranges from 122° to 147°. Hence, a routine proximal femoral nail may not replicate the original NSA following surgical fixation in all patients.

The AA was first described by sharp.[13] AA is frequently used to determine the presence of acetabula dysplasia. The values of more than 43° are considered dysplastic.[11] In our study, the angle was 35.5° [Table 3]. Stuberg and Harris[21] found mean AA of 32.2° and 32.1° in males and females, respectively. Nakamura *et al*.[22] observed mean of 38° in the Japanese population. When comparing the AA of our study with the study done by Saikia *et al*.[13] in Northeast India, the AA was less among the South Indian population compared to Northeast Indian population [Table 1].

Maintaining the leg length (VO) and HO helps to preserve proper hip biomechanics and improves overall postsurgical patient satisfaction in total hip replacement.[23,24] The horizontal and vertical femoral offsets in our study were 37.62 (range 35–45 mm) and 46.89 mm (40–65), which were much lower than the values observed by Western studies of Rubin *et al*.,[17] Husmann *et al*.[8] Our study results when compared with a similar Indian study done in New Delhi by Rawal *et al*.[6] revealed that the HO and VO are less among South Indian population [Table 1].

Table 1: Comparative analysis of the morphometry of the hip joint reported in different studies

Parameters	Present study (Indian), *n*=400 (mean)	Rawal *et al*.[6] (Indian), *n*=98 (mean±SD)	Ravichandran *et al*.[19] (Indian), *n*=578 (mean)	Saikia *et al*.[13] (Indian), *n*=104 (mean±SD)	Rubin *et al*.[17] (Swiss), *n*=32 (mean±SD)	Husmann *et al*.[8] (France), *n*=310 (mean±SD)	Mahaisavariya *et al*.[18] (Thai), *n*=108 (mean±SD)	Noble *et al*.[16] (Caucasian), *n*=80 (mean)
Femoral head diameter (mm)	42.6	45.41±3.66	-	-	43.4±2.6	-	43.98±3.47	45.9
Neck width (mm)	27.5	-	30.99	-	-	-	-	-
Neck-shaft angle (°)	135.4	124.42±5.49	126.55	139.5±7.5	122.9±7.6	129.2±7.8	128.04±6.14	125.4
Horizontal offset (mm)	37.6	40.23±4.85	-	-	47±7.2	40.5±7.5	-	-
Vertical offset (mm)	46.9	52.33±7.19	-	-	56.1±8.2	57.3±8.1	48.94±4.95	-
Acetabular angle of sharp (°)	35.5	-	-	39.2±4.9	-	-	-	-
Medullary canal diameter at the lesser trochanter (mm)	20.2	-	-	-	27.9±3.6	-	-	-
Acetabular version (°)	18.6	-	-	18.2±5.6	-	-	-	-

SD=Standard deviation

Table 2: Gender analysis of the various parameters of the hip joint in our study

Parameters	Male (*n*=100)			Female (*n*=100)			*P* (significant values underlined)
	Mean	Range	SD	Mean	Range	SD	
Femoral head diameter (mm)	44.1	38-50	2.45	40.9	36-46	2.06	<0.0001
Neck width (mm)	28.9	19-37	2.84	26.1	20-33	2.30	<0.0001
Neck-shaft angle (°)	136.7	128-147	3.77	134.1	122-145	4.11	<0.0001
Horizontal offset (mm)	39.8	35-45	2.04	35.4	33-40	1.47	<0.0001
Vertical offset (mm)	49.9	40-65	4.99	43.8	35-56	4.82	<0.0001
Medullary canal diameter at the lesser trochanter (mm)	20.6	13-30	3.05	19.7	13-27	2.93	0.035
Acetabular angle of sharp (°)	35.3	24-42	3.78	35.7	24-42	2.96	0.401
Acetabular version (°)	17.8	10-33	3.76	19.4	11-33	3.88	0.003

SD=Standard deviation

Table 3: The values obtained in the study

Parameters	Population mean	Male				Female			
		Low value		High value		Low value		High value	
		Right	Left	Right	Left	Right	Left	Right	Left
Femoral head diameter (mm)	42.6	38	40	50	50	36	36	44	46
Neck width (mm)	27.5	19	21	37	35	20	20	31	33
Neck-shaft angle (°)	135.4	128	130	147	144	122	124	144	145
Horizontal offset (mm)	37.6	36	35	44	45	33	33	40	39
Vertical offset (mm)	46.9	41	40	65	61	35	41	56	56
Acetabular angle of sharp (°)	35.5	24	26	42	42	24	28	42	41
Medullary canal diameter at the lesser trochanter (mm)	20.2	15	13	29	30	13	15	27	24
Acetabular version (°)	18.6	11	10	33	29	11	11	33	26

Table 4: Analysis of the various parameters as per the side of the hip joint

Variables	Side	Mean	Range	SD	SEM	*P* (significant values underlined)
Femoral head diameter (mm)	Right	42.5	36-50	2.8	0.197	0.028
	Left	42.6	36-50	2.8	0.205	
Neck width (mm)	Right	26.9	19-37	3.1	0.2219955	<0.0001
	Left	28.1	20-35	3.1	0.2242501	
Neck-shaft angle (°)	Right	134.6	122-147	4.8	0.3422948	<0.0001
	Left	136.2	124-145	4.1	0.2924712	
Acetabular angle of sharp (°)	Right	35.0	24-42	3.9	0.281	<0.0001
	Left	36.0	26-42	3.6	0.259	
Horizontal offset (mm)	Right	37.7	33-44	3.4	0.240	0.154
	Left	37.4	33-45	3.0	0.217	
Vertical offset (mm)	Right	47.4	35-65	6.0	0.425	<0.0001
	Left	46.3	40-61	5.9	0.422	
Medullary canal diameter at the lesser trochanter (mm)	Right	20.6	13-29	3.8	0.272	0.001
	Left	19.7	13-30	3.2	0.230	
Acetabular version (°)	Right	18.0	11-33	4.5	0.321	<0.0001
	Left	19.2	10-29	4.0	0.284	

SD=Standard deviation, SEM=Standard error of mean

In our study, mean value of medullary canal diameter measured at the level of lesser trochanter was 20.6 mm (range 13–30 mm) among males [Table 2]. Among the females, the mean values were 19.7 mm (range 13–27 mm) [Table 2]. When compared with similar Indian study by Rawal *et al.*,[6] the mediolateral canal diameter at the level of lesser trochanter is less among South Indian population.

The mean value of the femoral HD, NW, NSA, HO, VO, and MD_{LT} for male was found to be higher than female and was statistically significant. AV was high in females and was statistically significant. Difference in HO between the male and female was approximately 4 mm. The range of femoral head offset for females of the Indian population is found to be smaller by 37% as compared to males of the same population.[6] The linear fit to the male and female data is approximately 10 mm apart.[6] This could be due to the existing differences in size, shape, and load distribution changes at the hip joint between the male and female.

NW, NSA, AA of sharp, AV, on the left side were higher and were statistically significant. VO, and MD_{LT} on the right side were higher and statistically significant our study results were similar with Saikia *et al.*[13] that the AV differs as per the side of the acetabulum and gender among Indian population [Tables 1 and 4].

Normally, a minimum of three cancellous screws was necessary, while fixing the fracture neck of femur. The diameter of cancellous screw is 6.5 mm. The lowest value of the NW in our study was 19 mm; hence, fixation with three screws will be practically difficult. Cephalomedullary nail study done by Pathrot *et al.* also suggested design modifications for Indian population with lesser NW.[5]

Conclusion

This study concludes that there are significant differences in anthropometric parameters of hip joint among the South Indian population compared with Western population. Due to the large variability of the anthropometry of different populations of the world, ethnic groups having a smaller build, such as Indians, are likely to develop technical errors in total hip arthroplasty THA with most of the commercially available prostheses because of the nonavailability of smaller and proper-sized implants.[6] As per our study, within the Indian population, the anthropometric parameters vary from region to region. Hence, this study may be useful for designing the total hip prosthesis among the Indian population. However, our study group was small with only 200 persons. A large multicentric study in South India is necessary to confirm our results.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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