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Accuracy of anatomical reconstruction after total hip arthroplasty

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Abstract
The hip allows mobility of the entire extremity in 3 planes. Therefore any little derangement in the anatomy of the hip can affect it's functioning and can cripple & severely affect daily living of the person. The most common causes of disability are trauma and degenerative disease, and till date the most successful2 treatment for joints severely damaged has been replacement by artificial parts.
Today replacement arthroplasties are very commonly performed by orthopedic surgeons the world over. In India too this procedure has gained wide acceptance among both surgeons and patients. The primary goal of this procedure is to restore normal anatomy of the hip joint so as to provide painless free mobility with a stable hip, and immediate functional outcomes of this procedure are very satisfactory.
Technically there is little debate that the results of revision procedure are less satisfactory and the primary THR offers the best chances of success. Therefore it would be rational to assess and eliminate the human/iatrogenic factors that would-be influencing and jeopardizing the longevity of the implant since such surgeries in Indian patients are mostly once in a lifetime job. Also since the indications of arthroplasty have expanded and more surgeries are being done, so there is a statistic increase in the percentage of loose implants, which ever the reason.
Although definite evidence and impact of loosing manifests late but the parameters reflecting the causative factors can be detected early in the form of altered anatomy and function. And repetitive cyclical loading of the implant in an unfavorable mechanical environment will over time, ultimately build up to a negative result.

Keywords: Implant, arthroplasty, hip

Introduction

The hip is one of the most important joints for locomotion designed for both mobility & stability. The hip allows mobility of the entire extremity in 3 planes. Therefore any little derangement in the anatomy of the hip can affect it's functioning and can cripple & severely affect daily living of the person.
The most common causes of disability are trauma and degenerative disease, and till date the most successful [2] treatment for joints severely damaged has been replacement by artificial parts.
Today replacement arthroplasties are very commonly performed by orthopedic surgeons the world over. In India too this procedure has gained wide acceptance among both surgeons and patients [1-7]
The primary goal of this procedure is to restore normal anatomy of the hip joint so as to provide painless free mobility with a stable hip, and immediate functional outcomes of this procedure are very satisfactory [1-9]
Technically there is little debate that the results of revision procedure are less satisfactory and the primary THR offers the best chances of success [5-7]
Therefore it would be rational to assess and eliminate the human/iatrogenic factors that would-be influencing and jeopardizing the longevity of the implant since such surgeries in Indian patients are mostly once in a lifetime job.
Also since the indications of arthroplasty have expanded and more surgeries are being done, so there is a statistic increase in the percentage of loose implants, whichever the reason. Although definite evidence and impact of loosing manifests late but the parameters reflecting the causative factors can be detected early in the form of altered anatomy and function.

And repetitive cyclical loading of the implant in an unfavorable mechanical environment will over time, ultimately build up to a negative result.
The present study is to be performed in the Department of Orthopedics, S. P. Medical College, Bikaner. The purpose being to assess the accuracy of placement of implants in terms of normal biomechanics and their correlation with functional results.

Aims and Objective
Early assessment of hip arthroplasty:-
1. By radiographic parameters measuring accuracy of alignment of hip components.
2. By dynamic parameters measuring function of the hip in the form of range of movements and abductor power ability.

The objective would be to predict future wear and loosening liability of the arthroplasty

Review of Literature
Arthroplasty began in the early twentieth century with surgeons attempting to contour and resurface deformed or ankylosed joint surfaces allowing pain free motion. Materials used ranged from fascia lata to gold foil. These initial attempts met with limited success, setback by patients' complaints of residual pain and stiffness.
In 1925, M.N. Smith-Peterson, M.D., pioneered the concept of "Mould Arthroplasty" using a glass hemisphere to fit over the ball of the hip joint.
By 1938, Dr. Jean Judet and Dr. Robert Judet attempted to use an acrylic material to replace arthritic hip surfaces.
Aufranc, 1950 introduced cobalt chromium alloy implants, which were both very strong & resistant to corrosion.
Frederick R. Thompson & Austin T. Moore separately developed replacements of entire ball of the hip.
Sir John Charnley, in 1958 addressed the eroded arthritic socket by replacing it with a teflon implant. When teflon did not achieve the goal he tried polyethylene. To fix prosthesis components to bone he borrowed polymethyl methacrylate (PMMA) now known as bone cement.
Truly this was the birth of "total hip replacement".
In 1962, he replaced polytetrafluroethylene in acetabular component by high density polyethylene. He also advocated small sized femoral head prosthesis (22 mm).
Murray MP, Gore DR, Brewer BJ, Mollinger LA, Sepic SB (1981) made a 4 year followup of 72 cases with Charnley and Muller replacements and to help determine the duration of benefits in functional performance resulting from total hip arthroplasty (THA), multiple kinesiologic measurements were made before surgery and two and four years after 32 Charnley and 40 Müller THA procedures were done in 58 patients. There were no complications of loosening or infection, nor was there additional disability in other joints of the lower extremities. Measurements of functional performance included range of hip motion, hip abductor and adductor muscle strength, weight distribution between the feet during standing, forces applied to canes or crutches, and multiple components of free-speed and fast-walking performance. The average measurements showed significant improvement in almost all components of function from the time preceding surgery to two years afterward. The two-year level of function was then maintained without significant improvement or decline in function four years post operation [10]

Material & Method
The present study was carried out in the Department of Orthopedics, S.P. Medical College, Bikaner, Rajasthan
No of cases : 27
No of hips : 29
Case selection : Post-operative patients of hip arthroplasties operated before June 2009 were included in the study.
Level of Evidence- Prognostic study, Level II-1(retrospective study) The pre-operative diagnosis and general details of the patients were obtained from records.
Clinical and radiological examination were carried out post operatively and at regular follow up visits The cases were evaluated based on the following parameters-

Radiological analysis
Standard AP radiograph of pelvis (Essentials of Skeletal Radiology, Yochum and Rowe) were taken by X-ray tube centered on the symphysis pubis with the patient lying supine and great toes touching to maintain consistent femoral rotation (15^0 internal rotation).Tube film distance was 102cm, kVp – 75 to 85, film size 14×17 inches with horizontal orientation and no tube tilt.

Measurements
A. Unilateral hip disease
a. Centre of the femoral head or the centre of rotation of hip, in unilateral hip diseases, was identified by using the template of concentric circles of 2mm differences i.e "Moss template Newington modification".

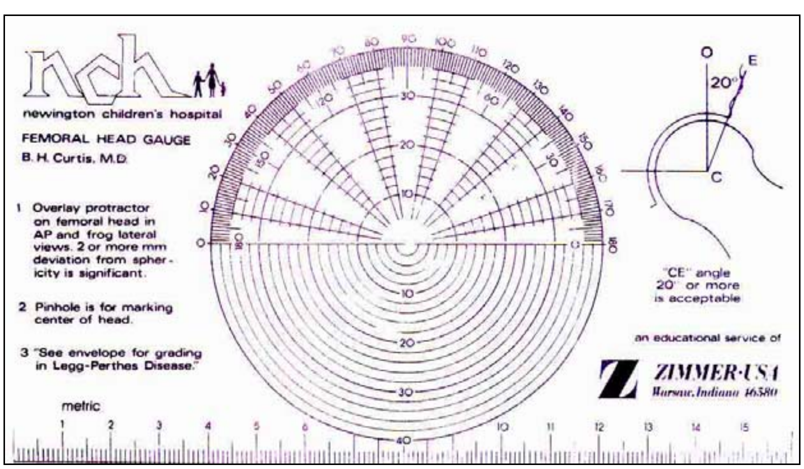


Fig 1

1. Place template over femoral head shadow and adjust position so that circle most nearly approximating the size of the head overlies its cortical margin.
2. Make a dot through pinhole to mark center of head,the small hole in the center of the template facilitates location of the center of the femoral head.
3. A horizontal line is drawn on centers of both femoral heads, which was parallel to the interischial line.
4. A perpendicular, passing through the center of the involved head, is then erected to this horizontal line.

All above parameters were taken on both normal and operated side and on operated side the new centre of the femoral head is marked and compared with the normal side

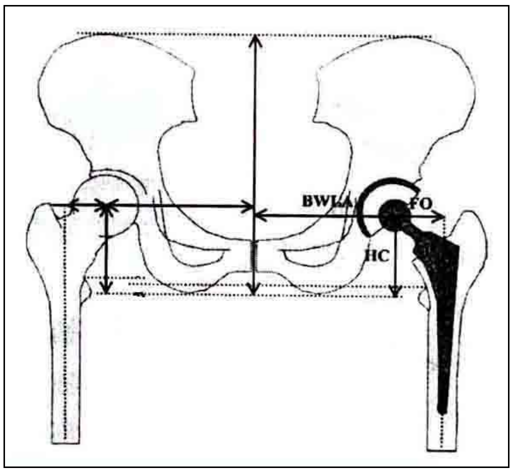


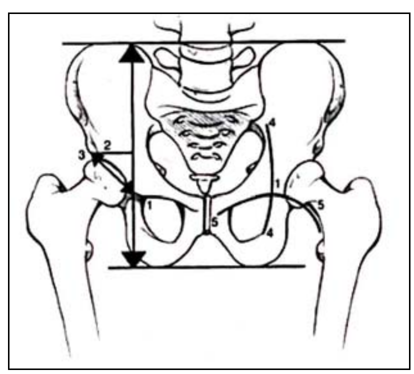
Fig 2: FO = femoral offset, BWLA = Body weight Lever Arm, HC =Head Centre

b. Abductor Lever Arm (ALA) [9] is the perpendicular distance from the tip of the trochanter to the centre of rotation of femoral head. Tip of trochanter is an important and easily measurable landmark. Also, since abductors, which play a crucial role in the biomechanics of the hip joint are attached here and by any means if there is a change in the distance between the tip of the trochanter and femoral head centre there will be definite change in the biomechanics of the hip joint and that will affect function. This Abductor Lever Arm was measured on both side by using of the “Moss Template”.
c. In addition the distance from the centre of the rotation of the femoral head to a vertical line through the symphysis pubis was recorded as the body weight lever arm.
d. The Lever Arm ratio is the ratio of abductor lever arm to the body weight lever arm and the affected side is compared with the normal side.
e. Vertical shifting of head was noted from the AP pelvis radiograph on the operated side. Vertical shift shows the shifting of the femoral head on the perpendicular line that passes through the centre of the femoral head drawn with the help of the “Moss Template”. This vertical shifting of head is a representative of the abductor lever arm, ie. proximal shift means the shortening and distal shift means the lengthening of the abductor lever arm.

Medialisation of the centre of rotation of the hip decreases the momentum arm for body weight, and lengthens the lever arm for the abductor muscles and increases the femoral offset. These changes in the hip biomechanics have a double benefit, a reduction in the required abductor forces and lower joint reaction forces. Accumulated clinical evidences suggest that such favourable alteration in biomechanics can improve clinical outcomes and reduce wear. Higher femoral offset has been associated with greater hip abduction motion and abductor muscle strength. In two independent studies higher femoral offset has been associated with a significant reduction in polyethylene wear. On this basis, improving the biomechanics is an important goal of THR.

B. Bilateral hip disease [9] In Bilateral hip diseases, a method has been developed by Ranawat *et al* (JBJS 1980) to locate the correct anatomical position of the acetabulum & centre of head, and to enable any variation in the position of the acetabular component following hip arthroplasty. Standard radiographs of pelvis are taken in AP view. Parallel horizontal lines are drawn at the level of the iliac crest and the ischial tuberosities, and were connected by a perpendicular passing through a point(A) located 5mm lateral to the intersection of Kohler’s & Shenton’s line. The length of the perpendicular between the parallel lines is equal to the height of the pelvis, and 1/5 of this equals the height of the acetabulum. A second point (B) is located on the perpendicular, superior to point A at distance equal to 1/5 of the perpendicular line. From point B, a perpendicular is directed laterally to point C so that distance BC equals the distance AB. Joining points A & C completes an isosceles triangle indicating the correct position of the acetabulum of the hip to be reconstructed. In a normal hip the superior border of the triangle will pass through the superior aspect of subchondral bone of the acetabulum and the hypotenuse of the triangle is equal to the diameter of the mouth of the acetabulum.

This diagram of the pelvis shows the method of calculating the anatomic position of the acetabulum described by Ranawat. Parallel horizontal lines are drawn at the levels of the ischial tuberosities and the iliac crests. These lines are connected by a perpendicular line that passes through a point (point 1) located 5 mm medial to the intersection between Shentons line (line 5) and Kohlers’ lines (4). A second point (point 2) is located on the perpendicular line superior to point 1 at a distance equal to one fifth of the pelvic height measured between the two horizontal lines. From point 2, another perpendicular line is drawan laterally to point 3 which equals the distance from 1 to 2. The isosceles triangle between 1, 2, 3 locates the acetabulum of a normal hip, with the line from 2 to 3 passing through the subchrondral bone of the acetabulum.



a. Kohler Line (Ilioischial line) is drawn from the medial border of the ilium to the medial border of the ischium. This line is a good reference for the horizontal migration of head of the femur and therefore the degree of protrusion.
b. Shenton’s Line is drawn along the inferomedial border of the femoral neck and it usually extends as a continuous

line on to the inferior border of the iliopubic ramus.

c. Tear drop corresponds to the true floor of the acetabulum. It lies in the inferomedial portion of the acetabulum just above the obturator formen. A normal tear drop is 'U' shaped. Medial border of the tear drop is continuous with the ilioischial line (Kohler`s line) and the lateral wall is continuous superiorly with the floor of the acetabulum.

Functional Assessment

A. Range of motion in flexion, abduction, adduction, internal rotation and external rotation were measured by using a goniometer on both normal and operated sides and compared.

Flexion, extension, abduction, adduction and rotations are the different movements of the hip joint. The average ranges of movements in a normal individual are as follows:

Flexion - with the knee extended cannot be done more than 90° due to the tension of the hamstring muscles which prevents full flexion; but with the bent knee the hip joint can be flexed upto 120° or more till the front of the thigh comes in contact with the front of the abdomen.

Extension - is permitted to about 15°; Abduction - to about 45°- 55^0; Adduction - to about 40°, which means the limb can be made to cross the middle third of the other thigh. Internal rotation - is possible to about 40° and external rotation - to about 45°.

During testing the movements it is ensured that the pelvis does not move, and the pelvis is steadied or fixed by holding the iliac crest of the affected side.

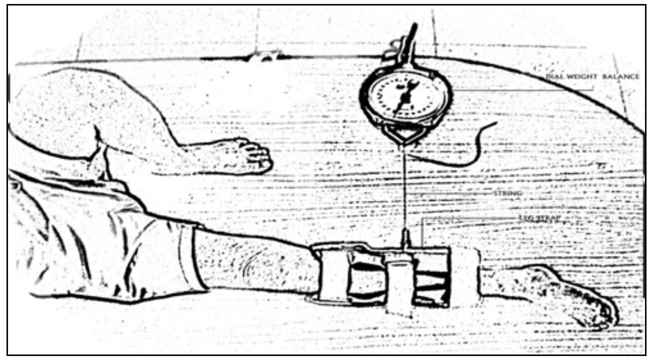
- **a. Flexion:** The patient lie supine, the pelvis is grasped and the patient is asked to flex the hip as far as possible. The amount of flexion possible without causing any movement of the pelvis is noted. The angle between the horizontal and the long axis of thigh is the angle of flexion.
- **b. Abduction:** The patient lies supine on the table. The pelvis is steadied by holding the iliac crest of the affected side. Keeping the pelvis at right angle to the limbs the patient is asked to abduct the limb. The angle between the midline of the body (line passes through the xiphisternum, umbilicus and pubic symphysis) and the long axis of the limb is the angle of abduction.
- **c. Adduction:** The pelvis is first steadied in supine position and the patient is asked to lift the affected limb and then cross it over its fellow. It is noted whether the limb crosses the sound thigh at its upper third or middle third or lower third and the angle formed between the midline of the body (line passes through the xiphisternum,umbilicus and pubic symphysis) and the long axis of the limb is the angle of adduction.
- **d. Rotation:** The patient lies supine on the table.The hip and knee are flexedto 90 degrees and the limb is rotated externally and internally and the angle is measured by comparing the position of the leg and the midline

B. Limb length discrepancy was noted if present. Length of the whole limb is measured from the anterior superior iliac spine to medial malleolus in squared pelvis as per standard technique.

C. To test the abductor muscle function [24] the muscle strength & fatigability were calculated.

a. Strength [29] refers to the muscles ability to generate force against physical resistance.

Ideally the strength of muscle is calculated by using a Cybex II[1,] dynamometer which measures the strength in terms of torque (Nm), but in our clinical setting due to unavailability of dynamometer, a simple method was adopted. The "spring dial weight balance", although that was not as accurate but was the only available option which serves the purpose of broadly categorising function.



The spring dial weight balance gives reading in terms of kg, and we took three readings for every patient and average of these were calculated. We standardized the technique by measuring the strength in normal individuals, and on measuring an average of 3 readings in our patients, it was observed that, the technique was simple to measure, was reproducible and gave constant readings.

In our study the participants were asked to lie down supine on a wide table on which maximum abduction of a limb could be possible. A leg strap was applied on the leg(just above the ankle) of the limb to be tested, and a string was tied with the spring end of the dial weight balance, while the other end of the spring dial weight balance was fixed at the edge of the table. After that the patient was made to flex his nontest limb at hip and knee to remove obstruction and asked to abduct the test limb with full strength keeping the heel touching the table to eliminate the gravity. Maximum amount of weight pulled and sustained for 30 seconds was noted for 3 successive readings and an average of these was calculated. The same procedure was repeated on the affected side. The normal side abductor strength were taken as control.

b. Fatigability refers to the failure to maintain required or expected force from a muscle following repeated activity.

The participants were asked to lie down on a padded table in a side lying position with the test leg up and were asked to raise the test leg up to 45° and hold it for as much time as possible comfortably.

The maximum time for which the position is retained was noted to measure fatigability. In cases with bilateral hip disease, the controls were calculated by taking average strength of ten normal patients in the similar age group for every patient.

The ratio of strength and fatigability of the reconstructed side to that of non-operated side were calculated. For cases with bilateral hip arthroplasties, the abductor function was compared with the control group.

D. Limp

Limp [9] is defined as any visual evidence of lateral imbalance of pelvic movement during gait. Visual limp assessment was done under natural conditions at the time when patients were not aware of specific observation taking place.

Patients were grouped as;

Walking with crutches <	With double crutches
	With single crutch
Walking without crutches <	With limp
	without limp

E. Delayed Trendelenburg sign

The delayed Trendelenburg test [9] was administered and evaluated for each patient according to the procedure described by Hardcastle and Nade. While standing, the patients were asked to raise their non-test knee to achieve a balanced static position of unilateral stance with the non-test hip flexed to between 0" and 30°. After balance is achieved in this position, the patient is then asked to lift the non-test hip (raise the nonstance side of the pelvis) as high as possible, while the examiner carefully observes the patient's ability to maintain this posture for 30 seconds. The test was scored as "negative" if the pelvis on the non-stance side was elevated as high as hip abduction on stance side allows, and this posture was maintained for a full 30 seconds. The test was "positive" if this wasn`t done. Furthermore, if the pelvis was lifted on command but could not be maintained in that position for 30 seconds, it was also scored as "positive."

Statistical Analysis: Pearson correlation coefficient were used for statistical analysis, and simple linear correlation established between abductor lever arm, abductor lever arm ratio, loss of strength, loss of holding time.

Discussion

Total hip replacement surgery requires a lot of preoperative planning ranging from case selection, general evaluation regarding medical problems, and local evaluation of hip joint. The latter involves detailed assessment of function of the hip, including handicap assessment and radiological evaluation for degree of articular damage, bone quality and dimensions [1]

In the Indian context, these considerations have an important place, since the average Indian patient finds it difficult to manage budget for this kind of surgery and which is beyond the range of poor patients. This can be contemplated from the fact that average per capita income in India is Rs1936.75($ 43) per month (2004-05) and percentage of population below poverty line (ie. people with income of Rs229/- i.e. $5 per month) was 28.6% in the year 2003, which amounts for around 308.59 millions of people and the numbers have been increasing.

This makes it all the more important to g*et al*l parameters correct in the first sitting so as to increase the longevity of the implant since the patient may not be in a position to afford a revision in his life time (An average revision THR in the US costs about $ 54000).

Secondly the infrastructure and patient factors may not be equivalent and at par as in the developed countries, so all the more reason to try to avoid the situation of a need for revision surgery, which is considered a difficult and critical procedure everywhere.

Increasing numbers of primary total hip arthropalsties have been done over the past 3 decades and because the operation is being performed in younger and more active patients, the number of revision procedure has increased dramatically. In 2002, 17.5% of all hip arthroplasties performed in the United States were revision procedures and in many patients the failure of total hip arthropalsty could be traced to one or more technical problems that occurred at the time of the primary procedure.

Summary

The present study was conducted in the department of Orthopedics, S.P. Medical College, Bikaner.

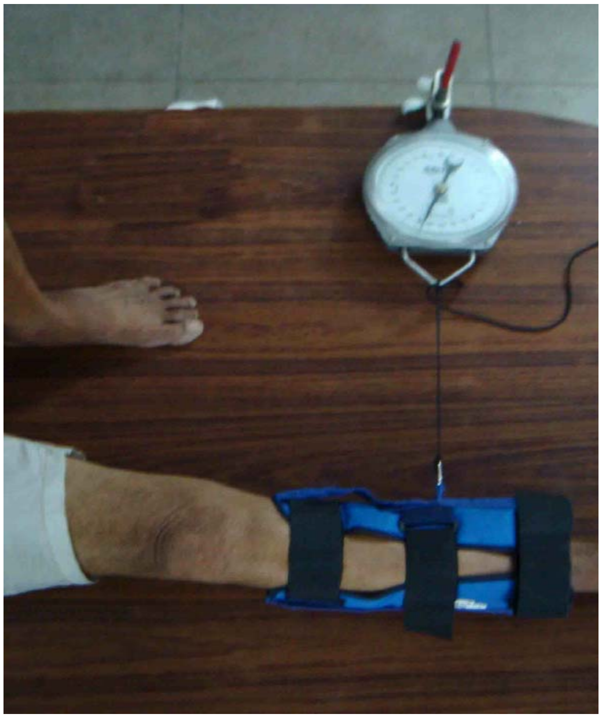
27 patients with THA were studied retrospectively.

- 64.1% of patients were in the age group of 30-70 yrs.
- Average follow up period was 10.22 weeks.
- No limb length discrepancy was found in any of the case.
- All the patients had a negative delayed Trendelenburg sign.
- None of the patients had limp on walking.
- Average percentage loss of flexion was 16.37%, loss of abduction was 23.61%, loss of adduction was 35.01%, loss of internal rotation was 37.43% and average loss of external rotation was 33.04%.
- Average loss of limb holding time in abduction against gravity was 24.51%.
- Average loss of abductor strength was 12.13%.
- Average loss of strength in increased or unchanged abductor lever arm ratio group was 1.1%.
- Average loss of strength in decreased abductor lever arm ratio group was 14.7%.
- Average percent loss of movements of hip had a significant negative correlation (p=0.05) with change in abductor lever arm ratio.
- Vertical head centre shifting had negative correlation with the percent loss of range of movement.
- Vertical head centre shifting had significant negative correlation with the loss of muscle strength (p=0.005, r= 0.41324).
- Change in abductor lever arm had significant negative correlation with percentage loss of abductor muscle strength (p=0.001, r =0.739).
- Change in abductor lever arm had a negative correlation with percentage loss of holding time (p=0.05, 0.047).
- Lever arm ratio had a negative correlation with percent loss of abductor muscle strength (p= 0.001, r =0. 61774).
- Lever arm ratio had a negative correlation with percent loss of limb holding time in abduction against gravity (p=0.05, r=0.396)

Conclusion

1. In operated THA cases, there is a strong correlation between inaccurate biomechanics and abductor function.
2. There is a significant correlation between biomechanics and post-operative hip joint mobility.
3. A functional score system (eg. Harris hip score) does not detect even moderate amount of altered biomechanics, which appears to be compensated by the body mechanics in the early post-operative period.
4. Disadvantageous biomechanics are expected to have negative influence on future life of the arthroplasty, among other factors.
5. There is no system available to predict peroperatively the desired accurate location of the bony landmarks especially the trochanter tip, but biomechanically advantageous overcorrection in the form of inferomedial location of acetabulum and increased neck length can be deliberately executed to decrease the energy consumption by the hip abductor mechanism and thereby decreasing the wear and tear, and thus increasing the life of the implant.

All this would ultimately decrease the incidence of need for revision arthroplasty, which is a expensive and complicated proposition even in the developed world.



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