Recent Advances In Prevention Of Dislocation After Total Hip Replacement

Essay

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Contents

List of figures

	(and confirmed intraoperatively) was the cause of recurrent dislocation.	
5.10	A vertical and retroverted acetabular component causing intraoperative instability in the right hip of this patient led to the use of a longer femoral neck, resulting in a marked limb-length discrepancy.	82
5.11	Tripolar arthroplasty (A: The larger joint; B: The smaller joint; C: The third joint).	85
5.12	A cup designed with a constrained head that fits onto the femoral component is shown.	87
5.13	(A) Anteroposterior radiograph of a constrained hip is shown. (B) Failure of the constrained liner caused by uncoupling of the implant is shown. (C) The failures occurred at the ring-polyethylene interface.	88
5.14	Acetabular augmentation ring partially fixed to the acetabular component of the dislocating total hip arthroplasty. The ring is fixed to the cup in the position offering the most stability, depending on the anticipated direction of dislocation.	93
5.15	Redislocation. The component is displaced and there is interposition of the augmentation ring in the acetabulum.	94

Introduction

Total hip arthroplasty (THA) is one of the most successful orthopaedic procedures for pain reduction and restoration of functional ambulation for a wide variety of joint pathologies. However, one of the most common complication after THA is instability of the joint and/or recurrent dislocation. The reported rate of dislocation varies widely from 0.5% to 10% after primary THA, and this risk increases to approximately 10% to 25% after revision procedures.[1]

Dislocation after THA can be categorized as early or late on the basis of the timing of the onset. Early dislocation usually occurs in the early post operative period after the arthroplasty and is often successfully treated with nonoperative means. In contrast, late dislocation occurs after five years and generally requires surgical treatment. this classification is useful because it highlights the differences in the etiology of the dislocation in each category, which in turn determine the type of treatment that is selected.[2]

Patients with osteonecrosis, femoral neck fractures, hip dysplasia, neuromuscular disorders, weakened abductor musculature, or dementia have been noted to exhibit higher rates of dislocation. Other patient related risk factors include female sex, advanced age, noncompliance and body habits.[3,4,5,6]

Aspects of the surgical procedure including the posterior surgical approach, implant malpositioning, impingement, small head-neck ratios and decreased surgeon experience have also been correlated with increased instability.[7,8]

Factors under the control of the surgeon include component orientation and restoration of soft-tissue tension.[(9)]

Recently the advances regarding the prosthetic design include increasing the size of the prosthetic femoral head, keeping femoral neck circumference to a minimum, and optimizing the geometry of the acetabular component. Postoperatively, patients should be expected to comply with standard hip precautions. Because the risk of redislocation is much higher than that for first-time dislocation, prevention is critical.[(9)]

Biomechanics of total hip replacement

A basic knowledge of biomechanics of hip and total hip arthroplasty is necessary to properly perform procedures, to successfully manage problems that may arise during and after surgery, and to intelligently select the components.[10]

Assessment of forces around the hip:

Center of rotation of the hip:

To describe the force acting on hip joint, the body weight can be depicted as a load applied to a lever arm extending from the body's center of gravity (in midline anterior to 2^{nd} sacral vertebral body), to the center of the femoral head. The abductor musculature, acting on a lever arm extending from lateral aspect of the greater trochanter to center of femoral head, must exert an equal moment to hold pelvis level when in 1-legged stance, and a greater moment tilt the pelvis to the same side when walking or running(**Fig. 1-1**).[11]

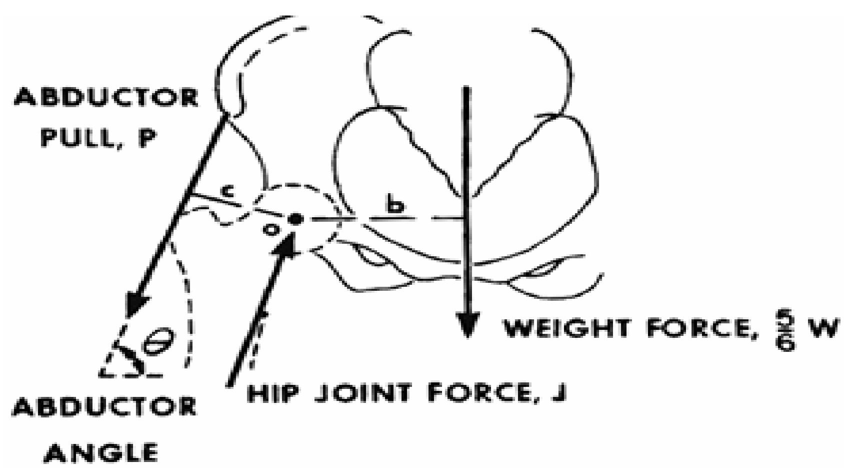

Fig. 1-1: *Forces acting around the hip joint.* [11]

Since the ratio of length of lever arm of the body to that of the abductor musculature is about 2.5:1, the force of the abductor muscles must approximate 2.5 to body weight to maintain the pelvis level when standing on one leg. The estimated load on the femoral head in stance phase of gait is equal to sum of forces created by the abductors and the body weight and is at least 3.5 – 5 times the body weight, load on head during straight leg raising is estimated to be about the same. However, when lifting, running, or jumping, the load may be equivalent to 10 times the body weight therefore excess body weight and increased physical activity add significantly to forces that act to loosen, bend, or break stem of a femoral component.(11)

The forces on the joint act not only on coronal plane, because body's center of gravity is posterior to axis of hip joint, but they also act in sagittal plane to bend the stem posteriorly (**Fig. 1-2**). The forces acting in this direction exert rotatory and posterior bending forces and tend to rotate & bend prosthetic stem.(11)

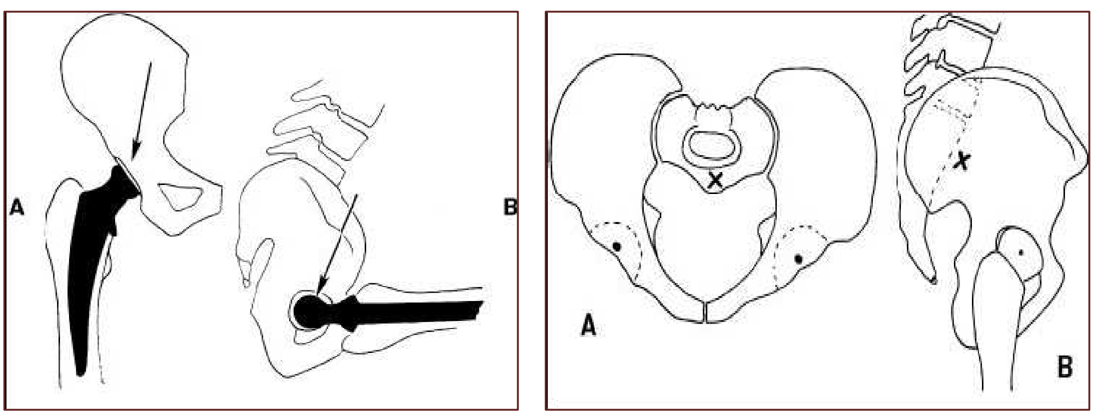

Fig. 1-2*:* *Forces producing torsion of stem. Forces acting on hip in coronal plane (A) tend to deflect stem medially, and forces acting in sagittal plane (B) tend to deflect stem posteriorly. Combined they produce a torsion of the stem.(11)*

Rotational stability of the stem can be increased both proximally and distally. Increasing the width of the proximal portion of the stem to better fill the metaphysis increases the tortional stability of the femoral component, especially when it is implanted without cement. Modifications of the distal portion of the stem may add to rotational stability as well. A rounded, rectangular cross section resists rotation within a cement mantle better than a circular one. Longitudinal cutting flutes and extensive porous coating that scratch the diaphyseal endosteum improve rotational stability in the absence of cement.(11)

It was an integral part of Charnley's concept of THA to shorten the lever arm of the body weight by deepening the acetabulum (centralization of the femoral head) and to lengthen the lever arm of the abductor mechanism by reattaching the osteotomized greater trochanter laterally (**Fig.1-3**). Thus the moment produced by the body weight is decreased and the counterbalancing force that the abductors must exert is decreased.(10,12)

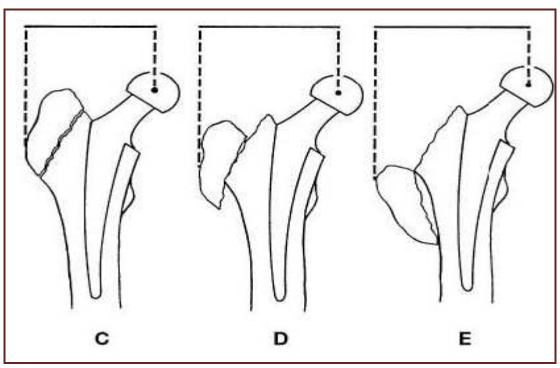

Fig. 1-3: *Lengthening the lever arm of the abductor mechanism.*

C: Osteotomized trochanter has been replaced anatomically, D and E: More lateral and distal reattachment of trochanter helps lengthen lever arm and tightens abductor musculature.(12)

The analytical models indicate that the largest joint forces and moments occur when the hip center is located superior, lateral, and posterior to the original location, while joint forces are minimized when the joint center is moved medially, inferiorly, and anteriorly. Therefore neck angle of the femoral stem and neck length have an impact not only on the abductor muscle force and resultant hip force, but also on the bending moments in the proximal femur. A varus hip or an increased neck length increases bending moments in the proximal femur by increasing the moment arm of the forces transmitted along the shaft of the femur. Prostheses must be designed to resist these bending moments. Decreasing the neck length or increasing the head neck angle (valgus) will decrease the bending moments in the stem, but these alterations compromise the abductor function and increase the joint reaction force. If changes in the neck angle, neck length, and joint center position decrease the abduction moment arm relative to the body weight, and no compensation in function occurs, then an increase in the resultant force would be expected.(10,12)

Clinical studies have associated inferior outcomes with superior movement of the joint center, and have associated decreases in abductor strength and loss of passive hip flexion motion with superior movements of the joint center, unless the superior movements are compensated for with increased neck length. Higher femoral loosening rates are also associated with joint centers placed in a superior and lateral position, as opposed to those placed in an anatomic position, whereas higher volumetric polyethylene wear is associated with decreased femoral offsets and decreased abductor moment arms. The analytical models predict a higher contact force for these anatomic changes (superior and lateral joint center position, decreased femoral offset, and abductor moment arms), which is consistent with the clinical reports of increased wear and loosening rates.[13]

It is important to understand the benefit derived from centralizing the head and lengthening the abductor lever arm; however, neither technique is currently emphasized. The principle of centralization has given way to preserve as much subchondral bone in the pelvis as possible and to deepen the acetabulum only as much as necessary to obtain bony coverage for the cup. Because most total hip procedures are now done without osteotomy of the trochanter, the abductor lever arm is altered only relative to the offset of the head to the stem. These compromises in the original biomechanical principles of THA have evolved to obtain beneficial trade-offs of a biological nature namely, to preserve pelvic bone, especially subchondral bone, and to avoid problems related to reattachment of the greater trochanter.[14]

The location of the center of rotation of the hip from superior to inferior also affects the forces generated about the implant. In a mathematical model, Johnston, Brand, and Crowninshield (1979) found that the joint reaction force was lower when the hip center was placed in the anatomical location compared to a superior and lateral or posterior position. Isolated superior displacement without lateralization produces relatively a small increase in stresses in the periacetabular bone. This has clinical importance in the treatment of congenital dysplasia and in revision surgery when superior bone stock is deficient. Placement of the acetabular component in a slightly cephalad position allows improved coverage or contact with viable bone. Nonetheless, clinical studies have documented a higher incidence of progressive radiolucencies and migration of components in patients with protrusion dysplasia, and revision situations when the hip center was placed in a non anatomical position.(14)

The ideal femoral reconstruction reproduces the normal center of rotation of the femoral head These location is determined by three factors; (1) vertical height (vertical offset), (2) medial offset (horizontal offset or, simply, offset), and (3) version of the femoral neck (anterior offset) (**Fig. 1-4**).(15)

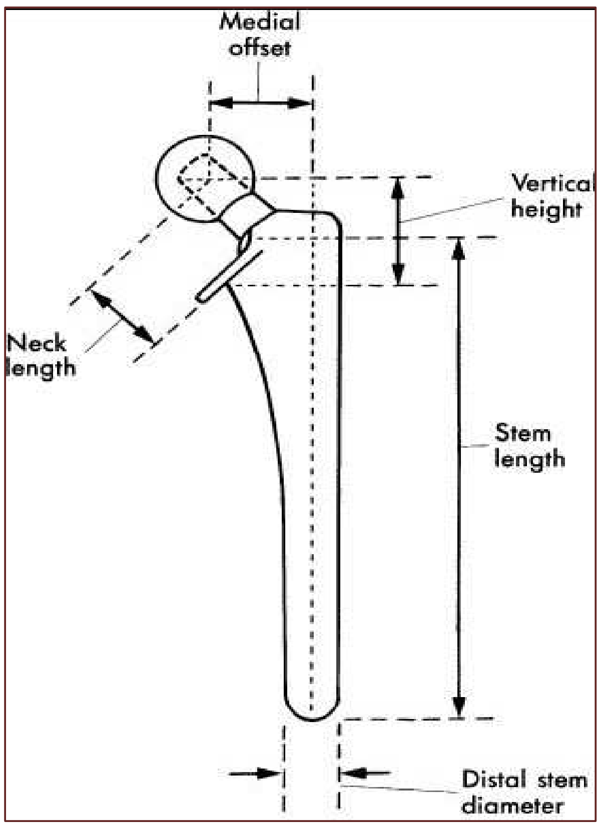

Fig. 1-4*: Vertical height and offset & neck length.*

Vertical height and offset both increase as the neck is lengthened, and proper reconstruction of both features is the goal when selecting the length of the femoral neck.(15)

Vertical height and offset both increase as the neck is lengthened, and proper reconstruction of both features is the goal when selecting the length of the femoral neck. In most modern systems, neck length is adjusted by using modular heads with variable internal recesses that fit onto a Morse taper on the neck of the stem. Neck length typically ranges from 25 to 50 mm, and adjustment of 8 to 12 mm for a given stem size routinely is available.(15)

The vertical offset of the femoral head is usually measured as the distance of the head from a fixed point, such as the lesser trochanter, Restoring this distance is essential to correct leg length Using a stem with variable neck lengths provides a simple means of adjusting this distance.(16)

Medial offset is the distance from the center of the femoral head to a line through the axis of the distal part of the stem. Inadequate restoration of this offset shortens the moment arm of the abductor musculature and results in increased joint reaction force, limp, and bony impingement, which may result in dislocation. Conversely, an excessive increase in offset results in increased stresses within the stem and cement mantle that may lead to stem fracture or loosening. Offset is primarily a function of stem design.(15)

Femoral components must be produced with a fixed neck-shaft angle, typically about 135 degrees. However there exists a wide variation of neck orientation in cadaver studies of normal hips. Varus hips have a center of rotation with a small vertical height and relatively larger offset, whereas the opposite is true of valgus hips. The height of the greater trochanter is not an accurate indicator of the correct position for the