REVIEW ARTICLE

Complex primary total hip arthroplasty

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Summary Although total hip arthroplasty is now a classic procedure that is well controlled by orthopedic surgeons, some cases remain complex. Difficulties may be due to co-morbidities: obesity, skin problems, muscular problems, a history of neurological disease or associated morphological bone deformities. Obese patients must be informed of their specific risks and a surgical approach must be used that obtains maximum exposure. Healing of incisions is not a particular problem, but adhesions must be assessed. Neurological diseases may require tenotomy and the use of implants that limit instability. Specific techniques or implants are necessary to respect hip biomechanics (offset, neck-shaft angle) in case of a large lever arm or coxa vara. In case of arthrodesis, before THA can be performed, the risk of infection must be specifically evaluated if the etiology is infection, and the strength of the gluteal muscles must be determined. Congenital hip dysplasia presents three problems: the position and coverage of the cup, placement of a specific or custom made femoral stem, with an osteotomy if necessary, and finally lowering the femoral head into the cup by freeing the soft tissues or a shortening osteotomy. Acetabular dysplasia should not be underestimated in the presence of significant bone defect (BD), and reconstruction with a bone graft can be proposed. Sequelae from acetabular fractures presents a problem of associated BD. Internal fixation hardware is rarely an obstacle but the surgical approach should take this into account. Treatment of acetabular protrusio should restore a normal center of rotation, and prevent recurrent progressive protrusion. The use of bone grafts and reinforcement rings are indispenisible. Femoral deformities may be congenital or secondary to trauma or osteotomy. They must be evaluated to restore hip biomechanics that are as close to normal as possible. Fixation of implants should restore anteverision, length and the lever arm. Most problems that can make THA a difficult procedure may be anticipated with proper understanding of the case and thorough preoperative planning.

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Introduction

Total hip arthroplasty is a frequent procedure for orthopedic surgeons specialized in the lower extremities. There are more than 100,000 hip replacements per year and although
this procedure is well defined in most cases, certain principles must be followed to obtain the expected functional results and for long term implant survival.

Soft tissue trauma must be limited during THA, thus improving neurological and functional recovery while reducing the risk of infection (fewer hematomas, less tissue damage) and neurological complications. Biomechanics of the hip necessary to restore the center of rotation must be respected, including restoring the lever arm and correct positioning of implants to limit impingement and wear from different components, which is a cause of long term implant failure.

Like all surgical procedures, THA also involves managing risks. Thus a difficult THA procedure is a THA that increases functional, infectious, and neurological risks or that involves technical difficulties, and the former may be linked to the latter.

This is why THA requires planning: which surgical approach should be used for the soft tissues? Which implant? How should the implant be positioned in relation to the patient’s anatomy? This approach to planning, which was inspired by aviation procedures and which takes the form of a checklist in the operating room, should limit the risk of unforeseen problems during surgery as well as of long- and short-term complications.

Difficulties associated with soft tissue anomalies

This element must be taken into account even if it cannot be seen on imaging.

Limiting soft tissue trauma does not only mean making a small incision, but it also means making it large enough to avoid having to stretch the skin, preserving the muscles and exposing the bones so that replacement components can be correctly positioned.

These requirements mean that a surgical approach that can be extended should be chosen.

Weight

In obese patients the risk of the following complications are significantly increased: postoperative mortality, infection, thromboembolic complications and dislocation [1,2].

THA in these patients is difficult from the outset during the preoperative consultation because the patient must be informed of these increased risks.

Installation of the patient is also difficult and the depth of the soft tissues sometimes requires the use of a specific retractor. However, the surgical approach does not seem to influence the risks even if so called mini-invasive techniques are used [3].

Despite the lower cortical index in obese subjects, the risk of fracture is not higher [4].

On the other hand the procedure will be longer [5] with more bleeding [6] in these patients.

A classic surgical approach is recommended, while paying careful attention to hemostasis. The risk of instability should be evaluated during the preoperative assessment, and specific hardware should be available if necessary, or techniques to stretch out the gluteal muscles to decrease this risk.

Cutaneous complications

There are relatively few problems with the hip if there has been previous surgery: internal fixation, osteotomy...

Although ideally an existing surgical approach should be used, the incision can be made elsewhere at no major risk. The surgical approach may also be a problem in irradiated hips, with a risk of healing difficulties. There is also a risk of stiffness due to deep fibrosis. In the presence of extensive skin retraction, plastic surgery may be necessary.

Neurological diseases

Neurological diseases can be separated into two families, those that reduce muscle tone (polio, myelomeningocele...) and those that increase it (spastic hemiplegia, Parkinson’s...).

When these diseases have been present since childhood, they result in dysplasia and even dislocation of the hip, due to the increase in stresses that tend to dislocate the femoral head out of the acetabulum.

Whatever the type, a neurological disease increases the risk of dislocation, due to lack of or excess muscle tone. An implant that limits the risk of dislocation is usually indicated.

This justifies a preoperative neurological assessment including an electromyogram (EMG) to ensure that there is a minimum of muscle tone, and possible management of spasticity with appropriate techniques. Spasticity and muscle retraction can be treated by tenotomies during surgery, especially of the adductor muscles [7].

Difficulties due to biomechanical anomalies of the operated hip (significant offset, coxa vara, length of the lower extremities)

The length of the lower extremities and offset are known to be important elements in patient satisfaction [8,9] and implant survival [10], and if these biomechanics are not respected, stresses on contact area are increased [10].

Thus THA must be planned by evaluating length and offset and the components that are best adapted to each case must be chosen. Certain authors suggest using navigation to closely evaluate and restore offset [11].

When traditional hip replacement systems (standard or lateral offset) are not appropriate, a trochanterotomy or special components can be proposed:

- implants with modular stems to restore offset [12], but these are associated with problems of corrosion and breakage due to the modular design and are also more expensive [9];
- hip resurfacing to respect offset and leg length as much as possible [13,14] but this requires significant technical skill: it also involves a metal on metal bearing surface which could pose problems.
Finally the cause of any case of oblique pelvis must be determined, and balance should not be restored by adjusting the length of the operated limb.

**Significant lateral offset**

When there is significant lateral offset with a normal femoral neck-shaft angle, a certain number of solutions are possible to preserve offset or muscular strength.

From a strictly anatomical point of view it is possible to propose a modular neck, a customized stem with appropriate neck or resurfacing.

If a traditional implant is used there are two possibilities to restore gluteal muscle moment arms:

- preserving the lever arm by lateralization of the acetabular cup, with a graft of the acetabular wall (Fig. 1);
- processing with standard implants by trochanterotomy followed by lowering and lateralization of gluteal muscle insertions to preserve satisfactory moment arms.

**Coxa vara**

A varus femoral neck is not compatible with the biomechanics of THA. There are two solutions:

- respecting the patient’s anatomy with either monoblock hip replacements with a varus neck (Fig. 2), with a modular neck, a customized neck or once again resurfacing;
- respecting the biomechanics of the prosthesis: with a stem with a neck-shaft angle of 130°, there is a risk of leg lengthening and/or reducing the lever arm of the gluteus muscles, with a risk of instability. With this option a trochanterotomy to stretch the muscles should be considered.

**Ankylosis and arthrodeses**

Arthrodeses may have been performed due to joint deterioration from trauma, infection, Legg-Calve-Perthes disease or epiphysiodesis. Ankylosis can be due to heterotopic ossifications.

The results of conversion of hip arthrodeses to THA are good, with a rate of complications that are comparable to those of revision THA [15–17].

If arthrodesis is due to infection, it is important to identify the source and obtain normalization of biological signs of infection before deciding upon surgery. During the procedure, five samples must be taken and the patient must receive antibiotic therapy for the causal germ if it is known or empirical antibiotics if not. Antibiotics may be stopped or continued depending on intraoperative sample results. Nevertheless an old infection is not a contraindication to THA [18].
When the arthrodesis was performed, it should be taken into account, because if the patient was younger than 15, growth will have considerably modified the morphology of the proximal femur, especially the development of the greater trochanter, which affects access to the gluteus maximus. It is essential to estimate gait quality after arthroplasty, which requires a thorough preoperative evaluation [19]. EMG must be performed to assess the muscles as well as magnetic resonance imaging (MRI). Significant weakness of the gluteal muscles can be a contraindication to THA. Muscular weakness should be evaluated in all cases. It creates a risk of instability, which can be prevented by the use of a dual mobility cup.

Morphology should be evaluated on standard X rays, including assessment of the lever arm of the contralateral hip, and the possibility of restoring it to the stiff hip, of lower limb length discrepancies. A CT scan is needed to evaluate bone loss (BD) in the acetabulum as well as any deformities of the proximal femur.

The surgical approach is lateral so that osteotomies can be performed. If it is difficult to identify the different muscular planes (lateral vastus, gluteus medius), a trochanterotomy can be performed, which may be difficult when the greater trochanter is hypoplastic. An X ray should be performed if there is any doubt. Osteotomy of the femoral neck in situ to remove a round bone fragment allows dislocation from the socket without forcing the bone ends.

The acetabulum is identified with three points making it easy to find: the oval foramen below, the anterior-inferior iliac spine in front, and the ischiatic notch below. The intersection of these three points corresponds to the center of the acetabulum; reaming begins here. Cup orientation can be difficult and the position of the pelvis in relation to the table should be carefully noted. The use of a dual mobility cup should be discussed to prevent dislocations when muscles are weak (Fig. 3).

The proximal femur may be deformed, requiring trochanterotomy to expose and identify the medullary canal, if necessary with the help of manual reamers. In case of significant deformity a cemented prosthesis makes it easier to obtain the desired orientation and satisfactory hip biomechanics.

When stiffness is due to heterotopic ossifications, which are excised during arthroplasty, postoperative preventive treatment is necessary to prevent recurrence: either indomethacin or radiation therapy [20].

Bone morphology anomalies

Congenital hip dislocation

Classification

There are three anatomical types of congenital hip dislocation according to the position of the femoral head in relation to the true acetabulum:

- anterior, with a neoacetabulum located above and in front of the true acetabulum which it overlaps/contacts (low dislocation with contact);
- intermediary, with a neoacetabulum located above and separate from the middle part of the roof of the true acetabulum (high dislocation with contact);
- posterior without a neoacetabulum (high dislocation without contact). The femoral head is superoposterior.

The Crowe classification [21] (four types I – IV), which is the most frequently used classification, assesses only the importance of proximal migration of the femoral head.

Dysplasia is often bilateral and may be symmetric but is often asymmetric. Leg length discrepancies are very frequent.

Indications and consequences

Total arthroplasties are especially indicated for painful arthritis of the neoacetabulum (contact dislocations). In the high forms without contact, pain may develop due to contact between the femoral head and the iliac ala, which may be seen on CT Scan. Symptoms in the spine and knee contribute to the indication.

Spinal alignment may be restored with arthroplasty if the spine is flexible, if the hip is stable and if leg length discrepancies are resolved. Stability is not always obtained even if reconstruction is satisfactory [22].
Main techniques

**Acetabulum.** The goal is to insert the cup into the true acetabulum (arthroplasty with lowering) for anatomical reasons because that is where there is a cavity, while the iliac crest is flat, and for mechanical reasons because the center of hip rotation must be medialized and the lever arm of the gluteal muscles restored to correct pelvic imbalance.

Small diameter cups must be used with or without cement. It is often necessary to reconstruct the acetabulum, especially in high dysplasias. Several techniques have been proposed:

- classic shelf augmentation;
- cotyloplasty [23], with medial advancement of the cup and a controlled fracture of the medial wall. The internal layer of the periosteum must be left intact, a morselized central autograft must be performed, and reinforced if necessary with a metal cage. Great care must be taken not to weaken the central region, which would increase the risk of secondary migration;
- osteotomy of the iliac crest with distal sliding of the detached fragment.

In certain cases the cup can be placed in a high position. The procedure is simpler, but functional results seem to be less good, and complication and loosening rates are higher. This is especially indicated in bilateral dislocations, and when no more than 50% of the cup is covered by the true acetabulum [24]. In this case the neacetabulum, which is arthritic due to contact dislocation must be reamed until the apex of the cup is covered by the iliac bone. An additional shelf augmentation is necessary.

**Femur.** Femoral deformities include coxa valga, excess anteversion, and often small sized femurs (posterior dislocations). When the femoral deformity is slight, specific so-called straight stems may be used. In case of a deformity or a preexisting osteotomy, an osteotomy may be necessary, a corrective osteotomy or a customized prosthesis (Fig. 4).

**Femoral lowering and shortening.** Lowering the femoral head into the cup may be very difficult. Specific techniques should be planned and the surgeon must be ready to respond to anatomical realities at any moment during the procedure.

The main risk is pulling the sciatic nerve until sciatic palsy, which is why the knee must be flexed throughout surgery so the nerve can be released.

Trochanterotomy provides excellent exposure and releases the deep gluteal muscles which favors lowering of the femur and of the greater trochanter at the end of surgery. Fixation of the greater trochanter must be perfect to prevent non-union.

One must always begin with a total capsulectomy. If this does not lower the femur, two techniques are possible:

- proximal femoral shortening osteotomy, knowing that repeated osteotomy cuts of the proximal femur make it difficult to insert the stem into the femoral shaft which is often very narrow. A trochanterotomy is necessary to lower the greater trochanter afterwards in relation to the osteotomy to prevent it from being too proximal and too near the pelvis;
- sub-trochanteric shortening osteotomy and sometimes derotation, which is especially indicated in high dislocations [25]. A trochanterotomy is not necessary and bone capital of the proximal femur is preserved, facilitating lowering, and reducing the risk of sciatic paralysis, but increasing the risk of non-union of the osteotomy [25].

**Dysplasia**

The risk of acetabular dysplasia is to underestimate it and treat the cavity in a traditional way. If the bearing surface of the cup is insufficient, it may loosen and revision
surgery may be necessary. During the procedure BD must be evaluated, which is basically superior and anterior.

In case of minimal BD, a reinforcement ring that presses on the bone may be used to obtain satisfactory cup orientation without a graft if the entire ring is on healthy bone. Divergence of up to 30° between the cup and the ring can be tolerated. The ring transfers strength to the bone, while cup orientation should optimize the biomechanics of the bearing couple.

In other cases, acetabular reconstruction by bone graft is necessary. The graft is usually an autograft harvested from the femoral head. When the size of the femoral head is insufficient, a bone bank graft is necessary (Fig. 5).

In case of superior BD, shelf augmentation with screw fixation should be enough. The acetabular reaming need to be located into the true acetabulum, then BD is evaluated, shelf augmentation is performed and attached with two screws. Once shelf augmentation is complete, the spherical shape of the acetabulum must be reconstructed with increasingly wide reaming [24].

In case of significant BD, which is usually anterior and superior, the acetabulum must be reconstructed with a bone graft that restores an anterior wall and sufficient superior coverage: the definitive cup may be attached to a reinforcement ring, which is pressing upon the reconstructed acetabulum.

**Traumatic sequelae**

In case of post-traumatic arthritis, two elements can be a problem: first BD due to trauma and bone wear, which is usually found in the columns and the floor of the acetabulum, and on the other hand the presence of fixation screws.

BD is treated by bone grafts harvested from the femoral head (and if necessary an allograft from a bone bank) and stabilized with a metal cage with screw fixation.

Internal fixation screws do not usually disturb the preparation and stabilization of an acetabular component. Nevertheless it is probably safer to plan on removing them in case of a problem, which means that the surgical approach used for initial internal fixation should be used again (Fig. 6).

When there are obvious significant difficulties a two-step strategy can be proposed: removal of internal fixation, then placement of the prosthesis.

The rate of complications and revisions with these procedures are higher and mechanical failures are linked to a failure to restore satisfactory hip biomechanics.

**Acetabular protrusio**

Acetabular protrusio may be due to a dysmorphic syndrome or secondary to trauma, Paget’s disease, rheumatoid arthritis. .

The goal is to recover a satisfactory mechanical center of rotation and to prevent recurrent protrusion while maintaining or restoring equal length to the lower limbs.

Three principles should be followed:

- initial resection of the femoral neck to facilitate dislocation and extraction of the femoral head;
- peripheral acetabular reaming only to avoid perforating the acetabular floor;
- bone graft of the acetabular floor to restore a normal center of rotation by lateralization using an acetabular reinforcement ring to prevent secondary cup migration [26] (Fig. 7).

**Femoral deformities**

**Morphological deformities**

There are two types of morphological deformities of the proximal femur: congenital due to dysplasia or secondary
to traumatic injuries, treated or not by internal fixation or even an osteotomy.

The following mechanical problems must be managed:

- stabilize/attach the component;
- control anteversion;
- restore the lever arm of the hip;
- respect the length of the lower limb.

To assess these cases:

- imaging of the femur must be obtained on the three planes (besides AP and profile views X rays, a CT scan should be performed to visualize the deformity on the three planes, as well as the intramedullary cavity, which can be measured);
- long leg standing AP X ray is also needed.

This assessment will help choose the best method of fixation and stabilization:

- custom prosthesis [27];
- short stem prosthesis;
- revision implant after a complex osteotomy;
- undersized cemented prosthesis;
- resurfacing prosthesis;
- a modular implant for certain authors [27,28].

Technically the difficulty is sometimes removal of existing hardware, but it is usually opening the medullary cavity in the correct direction for positioning of the implant. This may require a trochanterotomy [29] for preparation of the femoral shaft and optimal positioning of the implant. In these very complex cases a two-stage strategy can be proposed: first a femoral osteotomy to correct the deformity, then placement of the prosthesis [27].

When there is significant deformity, especially if there is a history of infection, resurfacing can be proposed (Fig. 8).

The results of these THA in femoral deformities are comparable to those of primary THA [30,31]. The results with cemented [32] or uncemented [31] stems are equally satisfactory: the choice is based on the surgeon’s preferences and the situation.

**Bone dystrophies**

Bone dystrophies (Paget’s disease, osteoporosis, osteopetrosis, radiated bone… ) associate structural and morphological...
bone anomalies. These dystrophies may be associated with a risk of hemorrhage, in particular in Paget’s disease requiring preoperative medical management to control the risk. Poor quality bone makes it difficult to adapt the intramedullary cavity (neck shaft) to the implant, with a risk of using an undersized implant: a cemented implant adapts better to the patient’s anatomy than an uncemented implant, because the latter requires invasive preparation of the bone. This is also true for osteoporosis, with a difference in the Young modulus between the rigid component and the fragile underlying bone that is too great. The risk is fractures and displacement of stresses that could worsen local osteoporosis.

Failed internal fixation of the proximal femur may require revision THA

Unsuccessful internal fixation of per- and subtrochanteric fractures is often due to mechanical failure. Revision THA is often technically difficult. Implants with more extensive distal fixation — usually cemented — are needed for reinsertion of bony tuberosities onto the proximal femur. One should take advantage of the fracture to perform the equivalent of a trochanterotomy, which preserves the gluteal muscles and provides the best retention of these muscles.

There is some risk of instability, because of repeated surgery. When the acetabulum is intact and the patient is over 80, the use of an hemi-arthroplasty can be proposed. If the acetabulum is not intact the following should be proposed:

- a dual mobility cup in patients over the age of 70;
- in younger patients: THA with a bearing couple adapted to age, and sometimes a dual mobility cup if patient assessment or preoperative tests suggest instability.

Although different authors emphasize the technical difficulties of these arthroplasties, the satisfactory results [33,34] and the few postoperative complications [34] make it a reliable solution.

Femoral neck fractures treated by internal fixation complicated by non-union or femoral head necrosis are not technically difficult and can be revised by THA with good results [35].

Conclusion

Most of the problems that make THA difficult can be anticipated by thoroughly understanding the case and good preoperative preparation including detailed planning: from analysis of the patient and his/her morphology to analysis of the risks. This preparation will limit intraoperative problems, which directly influence postoperative risks and the overall result of THA. All of this should then be completed by informing the patient about the procedure and the risks.

There is one major issue that has not yet been spoken of: the influence of the surgeon with two classic potential limitations: skill in a certain type of surgery and sometimes a certain “lack of shape”. These factors, are concerns, which must not be ignored and play a role in the managing certain difficult patients.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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