Update article

Total hip arthroplasty: a still evolving technique☆

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ABSTRACT

It has been advocated that total hip arthroplasty (THA) is probably the most successful surgical intervention performed in Medicine. In the 1960s, Sir John Charnley not only introduced, but also modified and improved the technique of cemented arthroplasties. The concepts on biological fixation established by Pillar and Galante served as the foundation for the development of uncemented implants that are now used worldwide. Currently, THA is a worldwide widespread surgery performed on millions of people. However, keeping abreast of the large number of information available on these procedures, especially on implant fixation, designs, different tribological pairings, and the long-term results can be challenging at times. This article is a brief update on the main aspects of THA.

Atualização em artroplastia total de quadril: uma técnica ainda em desenvolvimento

RESUMO

A artroplastia total do quadril (ATQ) é uma das cirurgias de maior sucesso na história da medicina. Nos anos 1960, *Sir* John Charnley introduziu e aperfeiçoou as artroplastias cimentadas. Pillar e Galante estabeleceram os conceitos da fixação biológica, base para o desenvolvimento das artroplastias não cimentadas. Atualmente, a ATQ é uma cirurgia mundialmente difundida e feita em milhões de pessoas. No entanto, o grande número de

informações disponíveis sobre as artroplastias, especialmente quanto à forma de fixação do implante ao osso, aos diferentes *designs* das hastes e dos acetábulos, aos diferentes pares tribológicos e aos resultados no longo prazo por vezes dificulta a tomada de decisão. Este artigo é uma breve atualização sobre os principais aspectos da ATQ.

Introduction

Hip arthroplasty is considered one of the major advances in the treatment of orthopedic diseases, and one of the most performed surgeries in the world.[1] Due to rapid recovery and return to most activities of daily living, it is considered one of the few medical procedures that benefit the patient as a whole, and the operation with best results in orthopedics.[2]

The basis of this surgery dates back to the end of the 19th century, when Themistocles Gluck demonstrated the tolerance of the human body to foreign bodies. Smith-Petersen, in 1923, *apud* Callaghan et al.,[3] developed studies with prosthesis coated with glass, bakelite and synthetic resins, and Philipe Wiles, in 1938, elaborated the concept of the first THA.

Sir John Charnley was responsible for the great progress of THA,[4] who developed the concept of low friction arthroplasty by the use of femoral heads with 22 mm of diameter, and the association of high molecular weight polyethylene with methyl methacrylate, with this latter material being used under the influence of Leon Wiltsie apud Charnley.[5] There has been a growing search to improve cementation quality. Krause et al.[6] developed the low viscosity cement; Harris et al.[7] described techniques to improve cementation, and Lee et al.[8] emphasized the importance of cement pressurizing.

For a long time, the failures of arthroplasties and large osteolyses were attributed to bone cement, and were called "cement disease". This has motivated several researchers to develop uncemented prostheses.

Bobyn et al.[9] and Galante[10] introduced the concepts of uncemented arthroplasties, had press fit and bone integration as forms of fixation between the bone and the implant. This mode of fixation is known as biological fixation. Several other authors have proposed and introduced prosthetic materials, devices and designs to facilitate biological fixation.

Despite the success of this surgery, the search for its improvement and better results, especially long term results continues, mainly in the development of new surfaces, materials with greater biocompatibility, and less aggressive surgery techniques.

Access routes

THA begins with the selection of the type of approach. The main access routes are the posterior, anterolateral and lateral ones.

The posterior approach, also called Moore's approach, is currently the most widely used. This route was popularized due to the ease of exposure of the acetabulum and femoral canal. In addition, there is no interference with the hip abductor (gluteus medius muscle), and it also shows a lower prevalence of deep vein thrombosis (DVT).[11] There is a greater theoretical potential of dislocation, and more difficulty in measuring lower limbs length. In the literature, the risk of instability is controversial, which can be minimized by reinsertion of the posterior capsule.[12,13]

The classical anterior approach was described by Smith-Petersen[14] and O'Brien.[15] One of its positive issues is that it does not violate tendons and muscles insertions. However, in patients with anatomical changes, it can be more difficult. There is a risk of injury to the lateral cutaneous nerve of the thigh. More recently, the concepts of the previous approach have been adapted to a new form, the anterior right approach. This route would have a lower theoretical risk of dislocation of the arthroplasty. Its more widespread use implies the need for angular (offset) femoral and acetabular drills, the traction table and a long learning curve.[16]

The lateral or Hardinge[17] approach has as a strong argument the ease for implant placement and, theoretically, a lower risk of instability. It was the main approach to the hip for a long time. However, there is the possibility of injury to the insertion of the abductor muscles. In some cases, partial detachment of the gluteus medius muscle is necessary for better exposure. This may cause limping due to deficiency of the abductive musculature, that is transient in most cases.

Types of implants and tribologic pairing

Basically, implants can be divided into two groups: the cemented and non-cemented ones. This division represents the different ways of implant fixation to the bone, with the main difference being the presence or absence of bone cement (polymethylmethacrylate – PMMA).

The cemented implants use the interposition of PMMA between bone and implant. PMMA modulus of elasticity is very close to that of the bone (cement modulus of elasticity ± 2 GPa versus ± 0.5–1 GPa of trabecular bone), and is resistant to compressive forces, but not to strain or shear forces.[18]

The long-term result of cemented arthroplasties depends on the quality of acetabular and femoral cementation. This fixation technique underwent several stages of evolution. In the first-generation cementation, the cement was placed manually, pressurized with the finger, there was no distal femoral cement restrictor for use during hip arthroplasty, and cement mixing was manually performed. The second-generation cementation was made with the use of a pistol for retrograde filling of the femoral canal; the use of a distal femoral cement restrictor was also initiated with the objective of creating a barrier, and favoring PMMA interdigitation through pressurization increase.[19] In the third generation, special

techniques of cement mixing (vacuum mixing or centrifugation) were introduced; however, these mixing techniques are controversial and do not seem to improve PMMA mechanical properties.[20] The introduction of a proximal centralizer, in addition to the changes already adopted, characterized the fourth generation of cementation.[21]

The absence of bubbles or radiolucent lines between the bone and the cement characterizes good cementation.[22] Another parameter is the mantle thickness, considered adequate when it has 2 mm in the femoral canal,[22] and 3 mm in the acetabulum.[23] This routine pattern of cementation differs from the controversial "French paradox", a way of cementation in which the femoral canal is filled with the longest possible stem, PMMA occupying the remaining spaces. The cement mantle is thin and non-uniform.[24]

Some features of cemented femoral stems may interfere with results, and should be closely observed:

1) Design – the cemented stems can be classified as single wedge, double wedge or triple wedge, depending on the implant geometry. Examples are the Charnley, Exeter and C-Stem, respectively.[25] Although the triple wedge stems have less stress in the cement mantle, they are related to a greater posterior rotation[26]; so far this stem model has not shown to be better than the others.[27] Currently, double-wedge stems are the most used.
2) Implant coverage – the best results are obtained with polished (smooth) implants. There are femoral stems with a rough surface, but they are not widely accepted and their long-term results are controversial.[28]
3) Material – they are usually manufactured in cobalt–chromium or stainless steel alloy. The implants produced in titanium have shown poorer results than those obtained with traditional metal alloys.[29]

Uncemented implants aim at obtaining a biological fixation between the implant and the bone. Briefly, there is expectation of bone growth to the porosities of the components and thus their definitive fixation to the bone. The presence of porosities is an indispensable requirement in these implants.

Another requirement for bone growth to occur is the immediate primary stability obtained with component impaction. Even very discrete movements at the bone implant interface may delay or hinder osseointegration and favor the formation of fibrous tissue.[30–32]

Thus, the success of uncemented prostheses depends on an immediate primary fixation (macrolocking) and is ensured by the secondary fixation (microlocking). Macrolocking should occur at the time of insertion, and is obtained by the intimate adjustment of the implant to the bone. Microlocking is the result of bone ingrowth, that is, the formation of bone bridges between the bone and the pores of the component.[31] Ultimately, it is the factor that determines uncemented THA longevity and success.

Macrolocking can be aided by several resources, such as fixation with screws, fins or grooves. Currently, the most used technique is the press-fit, which means the prosthesis is inserted under pressure in an undersized cavity. The uncemented acetabulum is also fixed by press-fit, and screws may or may not be used as auxiliaries in primary fixation.[31,32]

Osseointegration also depends on the porosity characteristics present in the implant cover. Its size, geometry and interconnection are important. Studies have shown that pore size should be between 100 μm and 400 μm. Pores smaller than 50 μm or greater than 500 μm facilitate the growth of fibrous tissue, rather than bone tissue.[30] There are three traditional types of coating: plasma spray, microspheres and fiber mesh.[30] in recent years, surfaces derived from trabecular metal have shown to be promising, but results with longer follow-up are expected. It is estimated that the percentage of porosity at the implant surface is greater in the fiber mesh – between 40% and 50% – and in the trabecular metal – between 75% and 80%.[33]

The interconnection between pores also plays a key role. The greater the interconnection, the greater the bond strength between the bone bridges and the prosthesis. Theoretically, the fiber mesh and trabecular metal coverage allows better interconnection between the pores in comparison with the other types.

Another commonly used type of arthroplasty is the hybrid one. In this case, one of the components is cemented, and the other is not. The prosthesis in which the acetabulum is uncemented and the femoral stem cemented is conventionally called hybrid arthroplasty. When the acetabulum is cemented and the stem is uncemented, it is known as reverse hybrid arthroplasty.

Regarding the weight-bearing surfaces, the most used and studied tribological pairing is the metal-polyethylene one. Ceramic-on-polyethylene, metal-on-metal and ceramic-on-ceramic are also used, with the latter two being called hard-on-hard.

Currently there is a trend for the replacement of ultra-high molecular weight polyethylene for crosslinked polyethylene. The crosslinked polyethylene results from a series of manufacturing interventions that seek to change the bonds between their molecules, producing a harder and more wear-resistant material.[34] The linear wear rate with crosslinked is estimated at 0.04 mm/year compared to 0.22 mm/year of conventional polyethylene.[35]

All the new tribological pairs show less volumetric wear, a fact that in theory can bring benefits to the arthroplasty longevity. There are, however, some peculiarities in these pairs.

The metal-on-metal surface shows extremely low volumetric wear but can release chromium and cobalt ions with potential local and systemic effects. The main local complication is the formation of so-called pseudotumors.[36] Systemic effects include neurological and cardiac damage.[37] There is a carcinogenic potential for systemic release of chromium and cobalt, although the exact repercussion of this exposure is not well known. It is contraindicated for patients with metal allergy and, due to transplacental transfer, also for women of childbearing age.[38]

Ceramic-on-ceramic has the highest resistance to volumetric wear. It is indicated for very young patients, with a high level of activity, and does not have any contraindications for women of childbearing age. Its drawbacks are the risk of fracture of the weight-bearing surface, squeaking during hip movement, and stripe wear. The risk of squeaking is multifactorial, with its main factors being maladjustment, the implant design, the type of material used in the

manufacture, although the triggering factor is not always recognized.[39] The risk of fracture of the ceramic lies between 0.004% and 0.010%, and is usually associated with poor positioning of the components.[40] Stripe wear may occur when the area of contact between the femoral head and the acetabular surface decreases, causing small displacements between the femoral head and the acetabulum; it may occur during the swing phase of gait, or when there is an impact between the neck and the acetabulum. It can cause great volumetric wear. Individuals with tissue hyperlaxity, or with a range of motion that is above expectations, and those who require a wide range of motion of the hip in their activities are prone to impact and consequent stripe wear.[41]

The crosslinked ceramic-on-polyethylene surface has the benefits of not releasing metal ions, it presents no risk of squeaking, and has a very low volumetric wear, although higher than that of hard-on-hard surfaces. There is a minimal risk of ceramic head fracture. It may represent a suitable option for young patients with elements that may complicate the use of other types of tribological pairs.

The appropriate selection of the implant, whether cemented or not, as well as the different tribological pairs, should take the theoretical knowledge about the characteristics of the design, material and long-term results into account, as well as the patient's characteristics and the surgeon's experience.

Complications

The complications associated with THA may vary in specific groups of patients, are influenced by age, gender, bone quality and the presence of comorbidities. Regarding time, they may be intraoperative, acute (between 30 and 90 days of surgery) or chronic.

The number of THAs has increased greatly in recent years, whether in young or old people. Elderly patients are at increased risk of serious clinical complications. Recent studies attributed a mortality rate of 6.9% in patients undergoing THA. This number suffers significant interference from pre-existing diseases and functional reserve.

Deep vein thrombosis (DVT) is another important and relatively frequent complication. The percentage of hospitalization during the first 90 days can reach 0.7% of patients and cases of pulmonary embolism can add up to 0.3%. When prophylaxis was not used, the prevalence of this event was close to 50% in cases of THA. At the 6th Conference of the American College of Thoracic Surgery, it was established that all patients undergoing THA should be considered at high risk for DVT.[42] Currently, guidelines have been developed to standardize the use of drugs to prevent DVT after arthroplasty, such as low molecular weight heparins, oral anticoagulants, aspirin, as well as mechanical prophylaxis (stockings and intermittent calf compression devices). Despite efforts, the ideal method of thromboprophylaxis remains controversial. The only consensus seems to be the beneficial effect of early mobilization, that is, the shortest possible return to ambulation.

THA dislocation is one of the most feared complications, and one of the main causes of surgical revision. Its incidence is estimated between 1% and 3%, and most episodes take place in the first three months of surgery.[43] The main risk factors are poor component positioning, obesity, previous surgeries, and insufficient abdominal muscles.[44] Some risk factors are more controversial, such as the posterior access route. The initial treatment is bloodless reduction, which is successful in most cases. When it becomes recurring, the option, in most cases, is surgical treatment.

The incidence of major neurological lesions ranges from 0.8% to 3.5%, the sciatic nerve lesion is the most common, followed by that of the femoral nerve. The frequency of this type of lesion is usually influenced by the type of access route.[45] Neurological lesions with less repercussion, such as the lateral cutaneous nerve of the thigh, can occur in up to 15%, especially in the direct anterior approach.

Vascular lesions are extremely rare in THA, and are more frequent when structural bone grafting, reinforcing rings, or other devices are required in complex cases, such as hip dysplasias and acetabular protrusions.[45] There is a potential risk of vascular injury during the placement of the screws for acetabular fixation, minimized by the knowledge of the safety zones, that is, the posteroinferior and posterosuperior quadrants, described by Wasielewski et al.[46]

Another complication is that of fractures, with the femur being the most affected segment, especially when the implant of choice is uncemented. There are situations in which the chance of intraoperative fracture is greater, such as in elderly patients with rheumatoid arthritis, in extremely rigid hips when more vigorous joint dislocation maneuvers are used. On the acetabular side, fractures are much rarer and related to an undersized milling for the acetabular component that will be implanted.

Infection occurs in approximately 1% of cases of THA. As it is a devastating complication, the identification of risk factors is fundamental for its prevention. International consensus was made to define diagnostic criteria and therapeutic measures. Most of the time, the treatment is surgical. When the infection is rapidly identified in the immediate postoperative period, and is treated with debridement and replacement of the prosthesis interchangeable components, the chance of cure is high. In late-onset infections, THA should be reviewed in a single stage or in two stages. Irrespective of the option chosen, germ identification, thorough local cleaning, and prolonged antibiotic treatment are essential.[47]

Discussion

In arthroplasties, as with any surgery, the initial step is the careful selection of the patient, the knowledge of the patient's expectations regarding treatment, the close guiding for arthroplasty care, and an accurate preoperative planning.

The selection of the patient should be marked by pain and loss of quality of life, that is, when optional measures of nonsurgical treatment have already been exhausted. After this step, a careful evaluation of comorbidities and other factors that affect immediate or late outcomes should be conducted.

Surgical planning is an indispensable factor for success. It begins with the patient's broad knowledge (orthopedic diseases – hip dysplasias, acetabular protrusion – previous surgeries, lower limb dysmetria, pre-existing neurological lesions, primary or secondary hip arthrosis etiology). After

that, the implant itself is chosen based on imaging tests, basically hip radiography.

One of the goals of surgery is to reproduce the patient's anatomy. The properly performed hip radiography is fundamental and invaluable for this. It helps identifying specific bone morphology characteristics, such as the cervico-diaphyseal angle and the femoral offset, femoral canal diameter, and acetabular cavity size, as well as other aspects such as bone quality, coverage and acetabular depth.

It is well known that the number of complications decreases with the surgeon's experience and the institution where the surgery was performed. Briefly, the greater the number of procedures performed by the surgeon per annum, the less chance of complications and greater likelihood of success.

One of the concerns that should always be present is THA long-term results. The most reliable and increasingly cited references is the national arthroplasty registry. With the data obtained in them, a much broader and at the same time much more in-depth view of the causes of failure and success of certain implants has been possible.

The most common causes of hip arthroplasty revision are the same in the records and publications. Sometimes the outcomes varied, depending on the specific population studied, but in general the reasons and causes for revision are the same: aseptic release, dislocation, infection, and periprosthetic fractures.[48,49]

A worldwide trend toward the use of uncemented implants has been observed. The National Register of England, Wales and Northern Ireland, published in 2014, reported that in 2003, cemented implants were used in 60.5% of the THA compared to 33.2% in the year 2013; the uncemented implants showed an increase from 16.8% to 42.5% in the same period.[48] This is probably due to the greater reproducibility of the results with uncemented implants and the difficulty in the execution of a perfect cementation.

Several national registries have observed that cemented THA showed better results in older patients.[49,50] However, reference centers throughout the world demonstrated up to 99% survival in uncemented femoral stems after 12 and up to 26 years of follow-up.[51,52]

Studies on the position of the acetabular component point to a better positioning of the cemented acetabula when compared to the uncemented acetabula, since these would tend to deviate from their original position during impaction. This fact should be taken into consideration and all care should be observed during surgery to avoid this problem. It is always good to remember that improper positioning of the acetabulum can bring several risks, such as instability, increased polyethylene wear and early aseptic loosening.

The incidence of intraoperative femoral fractures has increased with the use of uncemented stems. Thigh pain is also more common on uncemented stems. However, knowledge of the implant, its habitual use, and the experience of the surgeon minimize these risks.

The greatest questioning regarding cemented implants relates to reproducibility. To achieve the excellent results published by centers using cemented implants, the cementing technique should be perfectly performed. For this, the use of pulsatile lavage irrigation, proper pressurization, and a uniform cement mantle are considered prerequisites.

When THAs are performed for treating degenerative osteoarthritis, the national registries present similar data. The overall revision rate for all ages over a 10-year period ranges from 5 to 6%. When we divide it by the type of implant, the British report a rate of 3.2% for totally cemented, 7.68% for uncemented, and 3.95% for hybrid arthroplasties, while the Australian report rates of 6%, 5.4% and 4.8% respectively. If we separate the operations by gender and age, young women are at greater risk of revision in ten years. A reversal occurs if the arthroplasty is performed around age 65, when the incidence of revision at that age is slightly higher in men.[48,49]

Regarding the tribological pairs, if we put aside costs and some laboratory tests, there is no real evidence for or against any of these surfaces, except for the metal-on-metal combination, which presented inferior outcomes in virtually all publications. In their 2014 report, the Australians recorded a very similar 10-year revision rate for the combination of ceramic head with ceramic or polyethylene acetabulum: 4.7% and 4.5%, respectively. The lowest revision rate would be for the combination of metal and crosslinked polyethylene, not too far from the others, with 4.3% over the same period.[49] In the British report, a hybrid assembly with the combination of crosslinked ceramic–polyethylene showed the best outcome with 2.19% of failures in 10 years.[48] This way, the best tribological pair to be used remains open; we believe that the ceramic head associated with crosslinked polyethylene may be the best choice at this time, considering the risks and benefits.

The material with which the femoral stems are produced, as well as the size of the heads, also influences the results. The exclusive use of titanium seems to present a lower failure rate when compared to components made from titanium and cobalt-chromium. The heads of 32 mm in diameter show a lower revision rate when compared to those of 28 mm. However, there is no difference between those of 32 mm compared to larger heads. It has been suggested that this data may be related to the higher incidence of dislocation found with heads 28 mm or smaller.

Patient reports regarding their satisfaction with results, or PROMs (patient-reported outcome) have become increasingly important.[53] In a 2012 Swedish report, patient satisfaction after one year of total hip arthroplasty in 2010–2011 ranged from 82.8 to 93.4%. Depression and anxiety were indicated as important predictors of post-surgical pain, pain relief, and overall satisfaction with the procedure.[53] There is no doubt that in the near future patient's reports will play a key role in the progress of hip arthroplasty and should be in the center of attention by the surgical team.

The benefits brought by THA to patients are unquestionable; however, many details should be observed, known, and mastered. Firstly, remember that THA, although being one of the most performed and systematized surgeries, it should not, under no circumstances, be trivialized. Surgeons who perform it must be highly trained, have specialized teams, and work in equipped hospitals. Only this way will there be, in fact, minimization of risks and more predictable results.

Conflicts of interest

The authors declare no conflicts of interest.

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