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Navegação na Artroplastia Total da Anca: Conceitos Atuais/ Navigation in Total Hip Arthroplasty: Current Concepts

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Navegação na Artroplastia Total da Anca: Conceitos Atuais/ Navigation in Total Hip Arthroplasty: Current Concepts

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Navigation in Total Hip Arthroplasty: Current Concepts

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Abstract

Total Hip Arthroplasty (THA) is one of the most frequent orthopedic procedures. Implant malposition can lead to accelerated wear and a diminished prosthesis' lifespan. The outcome relies on surgical technique among other factors. To overcome this, navigation systems were developed. Computer Assisted Orthopedics Surgery (CAOS) comprises passive navigation systems, semi-active systems and robotic surgery. Navigation systems include image-free, CT-based and fluoroscopy-based navigation. The use of navigation systems in THA is not as well established as in total knee replacement. Recent studies have evaluated the effectiveness of these methods in THA. In this article, the authors aimed to review the recent data regarding the application of navigation systems in THA.

Most authors have found that navigation systems aid the surgeon to improve THA results, compared to conventional methods. Since the outcome depends on factors other than surgical technique, some authors found that there is not a significant improvement in accuracy.

The application of these techniques is still controversial due to its higher cost, radiation exposure and steep learning curve. As the methods improve and its use spreads, these disadvantages tend to fade away.

Introduction

Total Hip Arthroplasty (THA) is most often used as the number one end-stage treatment for osteoarthritis [1, 2] and fractures. Maradit Kremers et al. estimated that the overall prevalence of THA in the USA population in 2010 was 0.83%, with a higher prevalence in women (0.93% versus 0.72% in men) and increasing with age (0.11 in the <50 years old group versus 2.34 in the >50 years old group) [2].

Revision rates of THA are predicted to increase; revision surgery is associated with implant malposition, dislocation and infection, which are often due to ineffective surgical techniques [1]. The most frequent errors in placement occur in the acetabular component. Inappropriate positioning can lead to early dislocation and ultimately decreased lifespan of the prosthesis [3, 4]. Also, incongruent limb length and poor reconstruction of hip offset are common complaints among patients [5], and can also be associated with surgical technique.

Component placement is traditionally assisted by mechanical guides accompanying hip arthroplasty systems. Because they are determined by the data of an averaged bone morphology and do not take into consideration individual anatomic variances, they can lead to extensive variability in prosthesis insertion. For instance, the lifestyle of many Asian patients requires a larger range of motion than that of western ones. Therefore, an accurate placement is preponderant in this population [3]. With the traditional techniques, accounting for changes caused by intra-operative movement of the joint, tracing bony landmarks, limb alignment, and rotational axis of the prosthesis rely upon the surgeon's experience [6, 7]. Also, these devices may increase surgical time and complications, such as bleeding and infection rates [7].

In order to minimize these disadvantages, navigation systems in THA were introduced [6]. These systems allow for a 3D reconstruction of the joint and a dynamic interaction with the images both pre- and post-operatively [1, 3, 8, 9]. Despite increasing placement precision [10], there is still some skepticism regarding its application, because of its increased cost, planning stage, radiation exposure and complexity [5, 6, 8, 11].

The use of navigation systems in THA is not as well studied as in total knee replacement [1]. In this article, the authors aim to review the recent data regarding the application of navigation system in THA.

Computer Assisted Orthopedics Surgery (CAOS)

CAOS gives the operator instantaneous feedback about the performed steps through a virtual guide of the surgical field [12]. It is divided in three categories: active, semi-active and passive. The active system concerns robotic surgery, where autonomous machines execute actions pre-programmed by the surgeon. The semi-active relates to haptic robot arms and the passive ones use navigation systems. For the purpose of this article we will focus on navigation systems.

Navigation systems allow a precise 3D model recreation of a patients' specific anatomy and account for pelvic motion during surgery, allowing the operator to properly plan the procedure. Kreuzer has shown that using this technique, prosthesis' implantation is more accurate and surgical time can be diminished. This could prevent some complications commonly seen, such as: leg-length discrepancy , dislocation and osteolysis [6].
This method uses either optical or magnetic sensors and a charged coupled device camera obtains positional information using infrared lights. Magnetic sensors can be influenced by motors or metallic tools present in the room [3, 7]. In a navigated THA, a tracker is implanted to the pelvis and femur providing data about their shape. The navigation system then guides the placement of the acetabular cup in a planned orientation and the broaching of the femoral canal after femoral neck resection, for proper placement of the femoral component. After hip reduction, the range of motion and impingement of the joint are assessed with the help of navigation system [3]. The anterior superior iliac spines and the pubic tubercles define the anterior pelvic plane. These landmarks serve as reference for the navigation system to determine the acetabular cup orientation [9]. Surgical navigation systems comprise imageless navigation, Computed Tomography (CT) based navigation and fluoroscopy based navigation.

Image free navigation systems rely on epidigitization with a pointer of the anatomical landmarks identified by manual palpation [11]. Its main advantage is the radiation-free obtained data that allows an intraoperative identification of the hip's center of rotation [3].
The accuracy of this technique can be influenced by the surgeon's experience and the amount of soft tissue covering the bony landmarks [3, 8], especially in obese patients [13]. To avoid this, it is recommended that the pointer should be pressed as close as possible to the bone [3]. Also, lateral and supine positions as opposed to the Anterior Pelvic Plane (APP) may improve accuracy in cases where the soft tissue is a significant factor [4]. It is well established that imageless computed navigation is superior to conventional methods [14], but more studies are necessary to evaluate the accuracy of this technique by itself. Spencer et al. found there to be a significant intra- and inter-operator discrepancy in determining the APP on cadavers [15]. Also, it does not allow for preoperative planning [8]. Recent studies have tested the use of ultrasound-assisted navigation, and Hirschmann et al. report this method could eliminate systematic errors in APP orientation found with imageless techniques or no-navigation systems [11].

CT-based navigation is the goldstandard for surgical navigation [3] because it allows for preoperative planning [8]. This system offers a 3D reconstruction based on the 3 anatomical planes providing a dynamic image of the skeleton and implant, which is useful for planning the alignment and positioning of the prosthesis and calculating the range of motion intra-operatively [3, 9]. Since the ideal position for placement was found to be more restrict than that obtained from conventional methods, this technique is proven to present better results [16].
The additional radiation exposure to the patient, increased cost, longer time required for preoperative planning and the steep learning curve are some of the limitations of this technique [3, 8].

Fluoroscopy-based navigation can be used by itself, overcoming the disadvantage of delaying surgery to obtain CT scans; or combined with CT, matching the fluoroscopic image of the patient's bony landmarks obtained during surgery with the preoperative CT data [3, 17]. However, Tannast et al. found that fluoroscopy-based navigation, compared to conventional methods, failed to show an improvement in cup anteversion, due to errors of registration of the mid-pubic point [18]. Associating this technique with pointer based percutaneous palpation improves accuracy of cup placement [3].

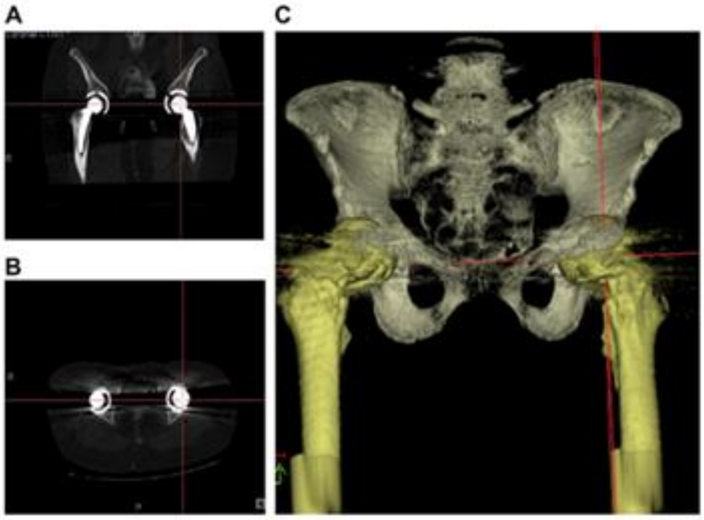

Fig.1 - This figure shows the 3D CT-model analysis for acetabular cup orientation. (A) A frontal view from the post-operative CT scan of the pelvis and proximal femur.(B) A transverse view from the post-operative CT scan of the pelvis and proximal femur. (C)A 3D pelvis–prosthesis model constructed from the CT images. (Courtesy of Lin et al [9])

Recent advances

The use of navigation systems in THA is slowly increasing [1] and new studies are testing the accuracy, effectiveness and relevance of these techniques. Most studies reveal favorable results. A systematic review and meta-analysis from 2017, which ultimately considered seven studies, showed that cup placement was statistically more precise using navigation systems for both anteversion (6/7 studies) and inclination (5/7 studies) [19]. Domb et al. found that the implant was placed in Lewinnek's safe zone in 90.7% of the cases using navigation system versus 69.49% with conventional methods [20]**.** In a study by Nogler et al., THA was performed in 44 cadaveric hips divided in 2 equal groups: with and without navigation. They found the navigated group had a significantly smaller range of deviation from the target angles of inclination [median of 1.3 (0.6–2.2) versus 5.8 (3.0–8.5)] and anteversion [median of 2.4 (1.0–3.2) versus 9.9 (2.2–14)] [21]. Licini et al. reviewed 150 hip replacements after 1-year follow-up and concluded that there was a statistical significant difference in leg-length discrepancy between the 75 navigation THA [0.3 mm (SD=0.3 mm)] and 75 free-handed THA [1.8 mm (SD=0.7 mm)] [22]. Regarding fluoroscopy-assisted navigation, Jennings et al. found this method steered acetabular cup inclination and anteversion to within 10° of a preoperative plan in all cases. When a 5º criteria was used, outliers occurred in 12.8% of the cases for inclination and 23.4% for anteversion, which still was more accurate than conventional THA [23]. In Tannast et al.'s study, 15.3% of cups were placed within the safe zone with a conventional approach, contrasting with 76.9% using fluoroscopy-navigation [18]. Concerning surgical time, some authors believe this technique increases its duration, although Kreuzer et al. found that its application in THA using the direct anterior approach decreased surgical time [6].

However, the functional outcome depends on factors other than cup orientation, such as head–neck ratio, femoral offset, stem orientation and depth of the acetabular component, and muscle tension, as well as the patient's anatomy and comorbidities and the surgeon's experience [19]. Also, in Licini's study, patients did not report a noticeable leg-length difference, even when there was a discrepancy of almost 2 millimeters [22]. A 10-year follow-up study found no difference in acetabular linear wear or survivorship free from aseptic loosening between the navigation-assisted and the control group [24].

Conclusion

Since its early stages, CAOS has been applied in different fields, but especially in orthopedics due to the bone being the most appropriate tissue for these techniques [3]. Despite this, there is still some reluctance in using it, attributable to technical difficulty and the training necessary to overcome the learning curve. As new technologies emerge and the utilization of navigation system spreads, it is expected a decreased difficulty on learning and implementing these type of procedures [12].

Conflict of interest

The authors declare no conflict of interest.

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- Aims and Scope
- Article Processing Charges
- Articles in Press
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If you choose to not deposit your data in the CCDC prior to submission, you must upload your CIF (and RES and HKL/FCF files if necessary), along with a PDF of the checkCIF report (link above) as Supporting Information, at the same as uploading your manuscript. At acceptance, you should then submit your crystal data to an appropriate repository, and update the "Data Availability" statement in your manuscript to indicate how authors can retrieve the data.

The Data Availability section should reference crystallographic data in the following format: "Crystallographic data for the structures reported in this manuscript have been deposited with the Cambridge Crystallographic Data Centre under the CCDC numbers: xxxxxx (Compound name 1), xxxxxx (Compound name 2), and xxxxxx (Compound name 3). Copies of these data can be obtained free of charge from http://www.ccdc.cam.ac.uk/data_request/cif."

Ethical Guidelines

In any studies on human or animal subjects, the following ethical guidelines must be observed. For any experiments on humans, all work must be conducted in accordance with the Declaration of Helsinki (1964). Manuscripts describing experimental work which carries a risk of harm to human subjects must include a statement that the experiment was conducted with the human subjects' understanding and consent, as well as a statement that the responsible Ethical Committee has approved the experiments. In the case of any animal experiments, the authors must provide a full description of any anesthetic or surgical procedure used, as well as evidence that all possible steps were taken to avoid animal suffering at each stage of the experiment.