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Original article

Dynamic evaluation of THA components by Prosthesis Impingement Software (PIS)

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Abstract. *Background and aim of the work:* Implant dislocation in total hip arthroplasties (THA) is a common concern amongst the orthopedic surgeons and represents the most frequent complication after primary implant. Several causes could be responsible for the dislocation, including the malpositioning of the components. Conventional imaging techniques frequently fail to detect the mechanical source of dislocation mainly because they could not reproduce a dynamic evaluation of the components. The purpose of this study was to elaborate a diagnostic tool capable to virtually assess if the range of movement (ROM) of a THA is free from anterior and/or superior mechanical impingement. The ultimate aim is to give the surgeon the possibility to weigh the mechanical contribution in a THA dislocation. *Methods:* A group of patients who underwent THA revision for acute dislocation was compared to a group of non-dislocating THA. CT scans and a virtual model of each patient was obtained. A software called "Prosthesis Impingement Simulator (PIS)" was developed for simulating the (ROM) of the prosthetic hip. The ROM free of mechanical impingement was compared between the two groups. *Results:* The PIS test could detect the dislocations with a sensitivity of 71,4%, and a specificity of 85,7%. The Fisher's exact test showed a p-value of 0,02. *Conclusion:* The PIS seems to be an effective tool for the determination of hip prosthetic impingement, as the main aid of the software is the exclusion of mechanical causes in the event of a dislocation.

Key words: total hip arthroplasty, THA, dislocation, software, revision surgery, range of motion, impingement

Introduction

The number of primary total hip arthroplasties (THA) over the last decades has constantly increased (1). Dislocation is the most common complication after primary THA and has an estimated incidence between 0.3% to 10% (2).

Approximately 50% of the dislocations occur within the first 3 months after surgery, and more than 75% occur within the first year (3). Within the first 2 years postoperatively, dislocation is the most common cause for revision surgery (4).

Prosthetic dislocation is defined as the complete loss of articulation contact between the artificial joint components. In the THA there is an ideal biomechanical system that must be recreated, and a stable implant is obtained through optimal cup inclination and anteversion, stem antetorsion, reconstruction of the rotational center of the hip, offset, and leg length (5).

It is of utter importance to distinguish whether the THA dislocation is due to a sufficient traumatic event or it is secondary to implant instability. The latter is suggestive of inadequate tissue tension or component malpositioning (5).

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Table 2. Contingency table of the administered impingement test.

	Case	Control	Total
PIS test +	5	2	7
PIS test -	2	12	14
	7	14	21

In table 2 the contingency table for the PIS test is shown. The test sensitivity was 71,4%, the test specificity was 85,7%. The positive predictive value was 71,4%, and the negative predictive value was 85,7%. The Fisher's exact test showed a p-value of 0,02.

Discussion

Our results analysis shows that PIS could identify the THAs at risk for dislocation with a sensitivity of 71,4% and a specificity of 85,7%. It is possible to state that it is a satisfactory performance with statistical significance because the main aid of the software is the exclusion of mechanical causes in the event of a dislocation. If the software couldn't find any impingement, we should consider that other reasons except for malpositioning could be involved. This is a crucial aspect for the planning of the subsequent treatment. Along with that, the discharge of a malpositioning case could also positively affect the possibile related medico-legal issues.

The optimal components location has been debated for decades, and the historical concept of the "safe zones" proposed by Lewinnek has been questioned by many authors (10). The problem is intricate and it has a double face. From one side the optimal positioning is influenced by the hip anatomy, the spino-pelvic angles and the dynamic changes that occur during motion; on the other hand, it was demonstrated that the prosthetic definitive orientation by sight alone could widely deviate from the surgeon's intra-operative estimation. (11). If we consider all these variables, it becomes clear how hard it is to perform a conclusive analysis on prosthetic stability only on the basis of the x-rays or even a CT scan, for they provide static images and could not give a thorough evaluation of the ROM. From this perspective a dynamic analysis as the one given by the PIS appears to be a precious tool for the surgeon.

Two THAs out of seven were identified as non-impinging on the software results if they had clinically dislocated, this could be explained by the software impossibility to take into account the soft tissues, as they reasonably have a significant role in the ROM limitation. Woerner et al. state that frequently only bony and prosthetic impingement are taken into account when analyzing dislocations, but the soft tissues could also be relevant (12). In their study they measured the maximum intra-operative ROM with a navigation computed system, then all the patients underwent a 3D-CT post-operatively; with the aid of a collision-detection algorithm, the ideal ROM free from bony and/or prosthetic impingement was calculated. They found out that the intra-operative ROM was significantly reduced if compared to the one calculated with the software, concluding that soft tissues impingement had a role in the ROM reduction. Regarding flexion, extension, abduction and adduction the ROM was found to be reduced by over 20°, whereas in external rotation by over 10°. On the contrary, the soft tissue impingement was found to have little less impact on internal rotation at 90° of flexion. The soft tissues play also a crucial function in determining the tension of the implant, which is in the end the only constraint that keeps the prosthetic ball and socket coupled.

Our study has some limitations, starting from the small case series analyzed. We also didn't analyze other specific movements that could produce dislocations except the reported ones. The analysis may be limited as we considered a common normal ROM as the specific target of the analysis and we decided to focus only on the posterior dislocation for its higher incidence (13). In this context, Ghaffari et al. (14) studied the relations between prosthesis components and patients' dislocation-prone activities by developing a 3D model simulation. They found that specific activities produce peculiar hip motions which bring the components more or less near to their ROM limits and thus closer to dislocate. It seems that the sit-to-stand and standing while bending at the waist are the most prone to dislocation activities. A possible interesting implementation of the PIS could be the inclusion in the simulation of the real critical patients' movements.

We have also to mention the struggle to standardize the patients' position in the CT scan, thus influencing the relative position of the components in the virtual model. In order to solve it, a prospective study should be designed with an associated CT torsional study of the femur.

Conclusion

The PIS seems to be an effective tool for the determination of hip prosthetic impingement. Its leading convenience could be the exclusion of mechanical causes for recurrent dislocations, due to the malpositioning of the components. Some criticism still exists for the extension of its versatility, especially for the account of the soft tissues. Future implementations will concentrate on the accuracy of the movements simulations and the standardization of the imaging protocols.

Conflicts of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

References

1. Australian Orthopedic Association National joint replacement registry. Annual report 2017.
2. Parvizi J, Picinic E, Sharkey P. Revision total hip arthroplasty for instability: surgical techniques and principles. J Bone Joint Surg [Am] 2008;90-A:1134–1142.
3. Bolland BJ, Whitehouse SL, Timperley AJ. Indications for early hip revision surgery in the UK–a re-analysis of NJR data. Hip Int. 2012;22:145–152.
4. Bozic KJ, Ong K, Lau E, et al. Risk of complication and revision total hip arthroplasty among medicare patients with different bearing surfaces. Clin Orthop Relat Res. 2010;468:2357–2362.
5. Dargel J, Oppermann J, Brüggemann GP, Eysel P. Dislocation following total hip replacement. Dtsch Arztebl Int. 2014 Dec; 111(51-52): 884–890.
6. Masonis JL, Bourne RB. Surgical approach, abductor function, and total hip arthroplasty dislocation. Clin Orthop Relat Res 2002; 405: 46–53.
7. Lewinnek GE, Lewis JL, Tarr R, Compere CL, Zimmerman JR. Dislocations after total hip-replacement arthroplasties. J Bone Joint Surg Am. 1978;60:217–220.
8. Amlie E, Hovik O, Reikeras O. Dislocation after total hip arthroplasty with 28 and 32-mm femoral head. J Orthop Traumatol. 2010;11:111–115.
9. Howie DW, Holubowycz OT, Middleton R. Large femoral heads decrease the incidence of dislocation after total hip arthroplasty: a randomized controlled trial. J Bone Joint Surg Am. 2012;94:1095–1102.
10. Lawrence D. Dorr, John J. Callaghan. Death of the Lewinnek “Safe Zone”. Journal of Arthroplasty. 2019 Editorial volume 34, issue 1, p1-2,
11. Wines AP, McNicol D. Computed tomography measurement of the accuracy of component version in total hip arthroplasty. J Arthroplasty 2006; 21: 696–701.
12. Woerner M, Weber M, Sendtner E, et al. Soft tissue restricts impingement-free mobility in total hip arthroplasty. Int Orthop. 2017 Feb;41(2):277-282.
13. Fessy MH, Putman S, Viste A, et al. What are the risk factors for dislocation in primary total hip arthroplasty? A multicenter case-control study of 128 unstable and 438 stable hips. Orthop Traumatol Surg Res. 2017 Sep;103(5):663-668.
14. Ghaffari M, Nickmanesh R, Tamannaee N, Farahmand F. The impingement-dislocation risk of total hip replacement: effects of cup orientation and patient maneuvers. Conf Proc IEEE Eng Med Biol Soc. 2012;2012:6801-4.

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