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The Impact of Lumbar Spine Disease on Hip-Spine Relationship in Total Hip Arthroplasty: A Mini-Review

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Abstract

Background: Patients with severe lumbar spine diseases run a high risk of dislocation after total hip arthroplasty. Therefore, it is essential to determine the pathological effect of common lumbar diseases on pelvic motions before the surgery.

Aim: This study reviewed the literature on the hip-spine relationship during total hip arthroplasty and explored the degenerative presentations and management of four common lumbar disorders. The review showed that patients with the spinal deformity in ankylosing spondylitis (AS) were characterized by thoracolumbar kyphosis with corresponding hip extension and pelvic retroversion, prone to anterior hip dislocation; patients with lumbar spinal fusion (LSF) were more susceptible to prosthetic impingement and ultimate dislocation, especially in the limited posterior tilt of the pelvis while sitting; those with degenerative disc disease (DDD) had a greater compensatory pelvic posterior angle while standing and greater hip joint flexion while sitting to compensate for the reduced lumbar flexion; those with degenerative lumbar spondylolisthesis (DSPL) demonstrated a pelvic flexibility with a much wider range and relative acetabular anteversion, especially when standing.

Recommendation: According to the literature, spinal osteotomy and total hip arthroplasty are the most common surgical interventions in AS cases. DSPL is classified into the Flexible & Unbalanced type and should be placed more posteriorly, but the literature suggests that patients with lumbar instability should first be placed in a more predictable position. In contrast, LSF and DDD are categorized as the Rigid & Balanced type. For these two types of disorders, the literature suggests that acetabular prostheses require more anterior tilt at the time of implantation.

Conclusion: These findings indicate that for degenerative lumbar disorders, a balance between stable component implantation and minimal wear should be based on the different changes in spinopelvic mobility.

Introduction

Since the hip-spine syndrome was proposed in 1983, much research has explored the hip-spine relationship in recent years[1]. It has been widely documented that tilt-related lumbar spine disease (LSD) is an independent risk factor for dislocation that may lead to an increased risk of revision total hip arthroplasty (THA)[2,3]. In normal spinopelvic motion, the pelvis tilts backwards while in a sitting position and forwards while in a standing position, which directly translates to changes in lumbar spine curvature and biological opening of the acetabulum due to the rigid sacroiliac attachments. In a sitting position, the increased posterior pelvic tilt opens the acetabulum to provide clearance for the flexed and internally

rotated femur, which helps prevent anterior impingement and posterior hip dislocation. In a standing posture, anterior pelvic tilt extends the superior coverage of the acetabulum, which helps prevent posterior impingement and anterior hip dislocations. When LSD occurs, the loss of pelvic mobility increases the hip flexion while in a sitting position or hip extension while in a standing posture, which may lead to pathologic impingement of bones or components. Because of the different postural positions on the operating table, related technical issues, and the presence of a fixed pelvic tilt or pelvic tilt, it is difficult for us, in practice, to address THA patients comorbid with this disease by recommending an appropriately positioned prosthesis. Also, the common lumbar diseases, including degenerative disc disease (DDD), degenerative lumbar spondylolisthesis (DSPL), ankylosing spondylitis (AS) and lumbar spinal fusion (LSF), have different compensatory spinal-hip-femoral mechanisms[3,9,24,25,34-36], which may lead to intraoperative difficulties, even with optimal placement of the prosthesis, such as difficulty in hip placement and possible hip repositioning.

However, many hip surgeons are not aware that the impact of distinct lumbar diseases on the hip-spine relationship is quite different[4,5], which is also one of the reasons for the increased post-THA rate of wear and dislocation[6]. At present, there is no unanimous consensus regarding the relationship between specific lumbar diseases and the pelvis, and no comprehensive evaluation is available in the literature. This paper attempts to review the interactions among the spine, pelvis, and hip in common lumbar diseases and to discuss how these interactions might affect total hip arthroplasty.

Risk Classifications

The spinopelvic motion is classified into four patterns based on sagittal spinal balance or imbalance and flexibility or rigidity[4], which is similar to the classification of Stefl et al.'s study[40]. Table 1 shows the classification of the four diseases and related pelvic-acetabular changes. Patients with no prior spinal conditions were classified into the flexible and balanced group (F&B), where the acetabular cup can be placed within the traditional safe zone due to unrestricted spinopelvic mobility. The second pattern is the rigid and balanced group (R&B), which can occur after significant degenerative changes or prior long lumbosacral fusion. Stefl et al. defined such patients as "stuck standing" who have ΔSS≤10°and SS >30°when in both sitting and standing positions. For these patients, it is better to place the cup in a more anteverted position to make up for a lack of compensation capabilities when positions change, thus avoiding anterior impingement and posterior dislocation. Patients in the flexible and unbalanced group (F&U) have an increased posterior pelvic tilt while standing due to postlaminectomy kyphosis and neuromuscular kyphosis or DSPL[39], possibly leading to posterior impingement and anterior dislocation during hip extension. This pathological change is known as kyphotic (SS<5°with undefined mobility) in Stefl et al.'s classification. It's worth noting that they consider another flexible type of hypermobility, which is not caused by kyphosis of the spine, as a variant of normal with greater mobility (ΔSS>30°). Rigid and unbalanced (R&U) patients show ankylosis or long lumbosacral fusion with an unbalanced spine in sitting and standing positions, without compensatory mechanisms due to rigidity. Stefl et al. defined such patients as "stuck sitting" who have ΔSS≤10° and SS <30° when in both sitting and standing positions. These patients have a pelvis that is always "stuck" in the posteriorly tilted position of sitting, leading to potentially posterior impingement and anterior dislocation while standing due to hyperextension of the femur for balance.

However, based on the preexisting increased acetabular anteversion, fewer changes will occur in the seated movement arc, although there may still be significant impingement for the original imbalance. In the last two types of patients, the first treatment option is to transform the spinal deformity surgically into the rigid and balanced category, which has a more predictable outcome in terms of the dislocation rates. The second alternative is to perform THA with the acetabular component in a highly similar position to that of a balanced patient. However, the patient is still at risk of a hip revision without a balanced spine. Stefl et al. believed that even though most spino-pelvic imbalances could be compensated by adjusting the anteversion and inclination of the cup, there still exists a higher risk of impingement and subsequent dislocation in patients with pathological spinal imbalance.

Table 1: Classification of the Four Diseases and Related Pelvic-Acetabular Changes

	Classification	Pre-operative			Intra-operative		
		Pelvic Rotation	Inclination	Anteversion	Pelvic Rotation	Inclination	Anteversion
AS	R&U	Increase	Increase or not	-	<20°	45°	20°
LSF	R&B	Decrease	-	Less	-	-	More
DDD	R&B	Increase	Increase	Increase	Less	Less	More
DSPL	F&U	Increase	-	-	(Acetabular component -More retroverted)		

Abbreviations: AS, ankylosing spondylitis; LSF, lumbar spinal fusion; DDD, degenerative disc disease; DSPL, degenerative lumbar spondylolisthesis; R, rigid; U, Unbalanced; B, Balanced; F, Flexible

Ankylosing Spondylitis

Generally, patients with ankylosing spondylitis (AS) are also afflicted with hip degeneration, which requires a homogenized treatment cohort to investigate the relationship between the spine and the pelvic[4]. It has been documented that normal individuals have an acetabular anteversion of approximately 20°and that patients with thoracolumbar kyphosis secondary to AS have a mean anteversion of 31.4°[7,8].

The spinal deformity in AS is characterized by thoracolumbar kyphosis with corresponding knee flexion, hip extension, and pelvic retroversion[9]. As a result of these abnormal changes, the rigid spinopelvic junctions tilt upright[10]. When in the standing position, the pelvis in AS patients usually tilts extremely backwards due to the malformation of the sagittal plane of the spine, in which thoracic kyphosis increases and lumbar lordosis decreases[11-13]. Some studies have found that after primary THA, AS patients are at a high risk for anterior hip dislocations[9, 14].

Interestingly, the acetabular anteversion changes at a ratio of 1 to 1 for each tilting degree, either for sacral or for pelvic[15]. In 2000, a study showed that 9 of the 58 AS patients undergoing THA had the acetabular component revised. The study attributed the postoperative dislocation and revision to the excessive backward extension of the hip joint in the standing position[9]. Then, in 2007, Tang et al. showed, in a 3D computer model, that AS patients were accompanied with hip hyperextension and fixed pelvic retroversion, without any positional changes, in which the authors elaborated the adjustment of the decreased abduction and anteversion angles on the basis of the posterior pelvic tilt to prevent the anterior dislocation after the operation[10].

Two possible treatments have been proposed to address the concomitant pathological sites. As recommended by Zheng et al., one option is to correct the spinal deformity surgically before THA[14]; another alternative is to reverse the sequence of spinal deformity correction and hip arthroplasty, which allows for a more precise calculation of the residual fixed deformity[16].

Lumbar Spinal Fusion

With the advent of an aging society, an increasing number of patients will suffer from hip and spinal disorders, simultaneously undergoing THA and lumbar spinal fusion (LSF)[17]. Previous studies have shown that LSF is associated with spine stiffness and serves as an important risk factor for dislocation following THA, especially when it involves lumbar and lumbosacral spinal fusion[18-20]. On the one hand, LSF decreases the variation in pelvic tilt from standing and sitting, which creates less acetabular anteversion. As a result, the pelvis/hip joint is less able to protect itself from prosthetic impingement and ultimate dislocation[3]. On the other hand, under decompensation of the spine due to reduced lumbar motion, the femur must bend more to reach a sitting position, which leads to a higher risk of prosthetic impingement[21]. Therefore, for a stiff spine, the literature suggests that the acetabular prosthesis requires more anterior tilt when it is implanted to compensate for the limited "posterior tilt" of the pelvis when in a sitting position[22]. However, controversies remain about the lumbar-pelvic-femoral alignment in the safe zone. Regarding the impact of the timing of lumbar fusion on the efficacy of total hip arthroplasty, available literature shows that compared with lumbar fusion before THA, postoperative LSF has a lower risk of dislocation and revision, which suggests that LSF should be performed after THA to minimize the risk of dislocation and revision[23].

Degenerative Disc Disease

Similar to spinal fusion, patients with degenerative disc disease (DDD) have a decreased lumbar spine/hip flexion ratio and greater hip joint flexion when in a sitting position, to compensate for the reduced lumbar flexion. Multilevel DDD may also reduce the motion of the lumbar spine and decrease the variation in pelvic tilt between standing and sitting[24,25]. Worth noting, when in a standing posture, patients with DDD have a greater forward torso and a greater compensatory pelvic posterior angle than those without DDD, leading to a greater opening of the acetabular cup. A recent study demonstrates that patients with severe DDD show increased posterior pelvic tilt during gait, resulting in increased cup anteversion and inclination[26]. However, an excessive anteversion of the prosthesis may cause a rear impingement in the standing position[27]. Therefore, for severe DDD patients, especially those with sagittal imbalance, excessive forward tilt should be avoided when performing THA[28,29]. Another study[30] shows that large-diameter femoral heads may increase the range of motion up to the impingement when compared with small diameter femoral heads in the vast majority of the tests performed, increasing stability and impingement-free range of motion. However, it has been documented that patients with severe DDD have increased hip joint external rotation and decreased flexion during gait[26], which contradicts the findings of increased hip flexion in patients with DDD while sitting. The potential explanation may lie in the stiffness of the spine and pelvis and the decreased gait step length[27].

Degenerative Lumbar Spondylolisthesis

Several studies have reported sagittal alignment in patients with degenerative spondylolisthesis (DSPL)[31-33]. To our knowledge of current studies[34-36], patients with degenerative spine disease have a significant reduction in

Table 2: Pathological alterations of the Four Diseases and Surgical Recommendations

Lumbar Spine Disease	Pathological alterations	Advice
Ankylosing Spondylitis	Posterior pelvic tilt	Cup's acetabular anteversion should be raised within the Lewinnek safety zone.
Lumbar Spinal fusion	Posterior pelvic tilt	Cup's acetabular anteversion should be raised within the Lewinnek safety zone.
Degenerative Disc Disease	Posterior pelvic tilt	Cup's acetabular anteversion should be raised within the Lewinnek safety zone.
Degenerative Lumbar Spondylolisthesis	Anterior pelvic tilt	Cup's acetabular anteversion should be reduced within the Lewinnek safety zone.

lumbar lordosis and sacral slope and a significant increase in the pelvic tilt. As mentioned above, lumbosacral pelvic junction alignment is very important in understanding the overall alignment of the spine. In the normal population, the correlations between pelvic incidences, sacral slope, and lumbar lordosis in the sagittal alignment of the spine have been well documented[37]. These spinopelvic parameters play a predominant role in explaining the pathology of DSPL.

For a routine clinical condition like DSPL, fusion surgery is often indicated for sagittal spinopelvic alignment. The prevalence of degenerative spondylolisthesis associated with osteoarthritis of the hip joint in Japanese patients is as high as 31-36%[38]. Barrey et al. analyzed the spinopelvic alignment of the pelvic-spine complex in three degenerative lumbar diseases and concluded that patients with DSPL may have variations of sagittal alignment, such as greater pelvic incidence, less global lumbar lordosis, and increased pelvic tilt[31,37]. Compared with lumbar fusion and other fixed spinopelvic alignments, DSPL patients demonstrate flexible mobility of the pelvis with a much wider range through which adaptation can occur[39]. In the current study, the authors found that patients with degenerative spondylolisthesis had significantly increased risks of postoperative prosthetic hip dislocation, revision THA, peri-prosthetic fracture, and prosthetic joint infection. In the study comparing four degenerative lumbar spine conditions, the average complication risk ratios for spondylolisthesis were the highest at day 90 after primary THA[6,39].

For DSPL Patients with lumbar instability, the rigid and balanced orientation should be ascertained by fusion surgery in a balanced position, which puts the acetabulum in a more predictable position before THA. The other possible option is to proceed with THA, in which the placement of the acetabular component of patients with DSPL should be more retroverted to help correct the relative acetabular anteversion, especially when in a standing posture.

Recommendations of Acetabular Cup

Ankylosing spondylitis is in the R & U type. Before THA, the spinal deformity needs to be corrected surgically. The risk of impingement in THA patients can only be resolved if the posterior pelvic tilt is corrected[14]. Therefore, the anterior tilt of the acetabular prosthesis within the safety zone may alternatively be raised to accommodate a posteriorly tilted pelvis[16]. DSPL belongs to the F & U type and also has a large anterior tilt of the acetabulum. Conversely, the acetabular anteversion of the acetabular prosthesis should be reduced within the safety zone, for DSPL patients have an anterior pelvis due to pathological anteversion of the spine. Considering pelvic flexibility, for DSPL patients with lumbar instability, a rigid balance orientation should be achieved by fusion surgery before THA to put the acetabulum in a more predictable position[37-39]. LSF and DDD belong to the R & B type, which reduces PT changes and the anterior angle of the acetabulum. Therefore, for these two types of diseases, the literature suggests that the acetabular prosthesis requests more anterior tilt during implantation[22,28,29]. For LSF patients, according to controlled case analysis, performing LSF surgery after THA can reduce the risk of posterior dislocation and revision[23] (Table 2).

Conclusion

LSD is a substantial factor for the assessment of spinopelvic mobility. To obtain a satisfactory THA with a low rate of dislocation and wear, the surgeon should pay more attention to the relationship between lumbar disease and sagittal spinal balance, and then formulate treatment plans according to the patients' risk classifications.

Conflict of Interest

No conflicts of interests to declare.

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