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RESEARCH TOPIC CLI20

Toward Personalised Implant Positioning in Total Hip Arthroplasty: The Role of Spinopelvic Dynamics in Optimising Outcomes

Research area
Surgical area

Clinical Unit name
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Abstract
For over half a century, total hip arthroplasty (THA) has established itself as an effective and reliable treatment for end-stage hip osteoarthritis (OA). Once reserved for the elderly, THA is now increasingly offered to younger, more physically demanding patients. The expansion of eligible patients, along with advances in implant design and surgical techniques have allowed surgeons to achieve excellent outcomes and improved patient satisfaction. Yet despite this success, the revision burden remains substantial and projected to grow in the coming years. Recent registry estimates confirm component malpositioning as one of the leading causes of early and late revision surgery. Suboptimal implant positioning results in impingement, dislocation, and early loosening, and sets the stage for wear and osteolysis over time.

Novikov et al. demonstrated that over half of early revision THAs are potentially avoidable, with suboptimal acetabular positioning accounting for the majority of instability. The relationship between the hip, pelvis, and spine has been of great interest in this perspective. The hip, pelvis, and spine form a kinetic chain that works synergistically, and atypical pelvic kinematics can lead to aberrant "functional" implant orientation.
Spinopelvic parameters vary significantly between patients (reflecting differences in pelvic morphology, spinal balance, and lumbar lordosis) and shift dynamically with posture from standing to sitting, while evolving over time with ageing and degenerative disc disease. Patients can present with stiff or hypermobile spinopelvic units and with balanced or unbalanced spines, each configuration carrying distinct implications for functional cup and stem orientation. Yet, current implant positioning strategies largely ignore this individual variability.

For decades, the Lewinnek safe zone (i.e., a fixed target of 40° ± 10° inclination and 15° ± 10° anteversion) guided acetabular cup positioning. However, Abdel et al. demonstrated that the vast majority of dislocated THAs fall paradoxically within this zone, exposing its fundamental

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limitation as a static target. The field has therefore shifted towards functional, individualised approaches that consider the synergistic interaction between spine, pelvis (i.e. cup), and femur (i.e. stem). In their work, Grammatopoulos et al. showed that integrating the patient's specific spinopelvic dynamics significantly recudes dislocation risk. Specifically, they demonstrated that a single standing lateral spinopelvic view can be a valuable screening and planning tool for functional cup orientation. Moreover, by incorporating the pelvic-femoral angle (PFA) into the Combined Sagittal Index (CSI = pelvic-femoral angle + cup anteinclination), they acknowledged that optimal stability requires both pelvis (i.e. cup) and femur (i.e. stem) to be considered.

A patient-tailored approach to implant positioning has the potential to close this gap, making THA safer and more durable. Tung et al. demonstrated that simulating activities of daily living beyond standard standing and sitting reveals substantially higher impingement rates than conventional planning anticipates, confirming that no fixed, population-averaged target can adequately protect all patients, and that implant positioning must be tailored to each individual's mobility and lifestyle demands.

This clinical PhD will investigate which spinopelvic parameters most influence short (impingement, dislocation) and long-term (wear, osteolysis, loosening) THA outcomes and which patient phenotypes most benefit from personalised implant positioning. A standardised, evidence-based protocol for patient-specific cup and stem targeting, integrating population-level mobility data and individual posture, will be developed and translated into the operating room through machine learning (ML) and patient-specific instrumentation (PSI) in collaboration with the Humanitas 3D Innovation Lab.

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