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Abnormal spinopelvic mobility as a risk factor for acetabular placement error in total hip arthroplasty using optical computer-assisted surgical navigation system

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Aims

Navigation devices are designed to improve a surgeon's accuracy in positioning the acetabular and femoral components in total hip arthroplasty (THA). The purpose of this study was to both evaluate the accuracy of an optical computer-assisted surgery (CAS) navigation system and determine whether preoperative spinopelvic mobility (categorized as hypermobile, normal, or stiff) increased the risk of acetabular component placement error.

Methods

A total of 356 patients undergoing primary THA were prospectively enrolled from November 2016 to March 2018. Clinically relevant error using the CAS system was defined as a difference of > 5° between CAS and 3D radiological reconstruction measurements for acetabular component inclination and anteversion. Univariate and multiple logistic regression analyses were conducted to determine whether hypermobile (Δsacral slope(SS)$_{\text{stand-sit}}$ > 30°), or stiff ($\Delta SS_{\text{stand-sit}}$ < 10°) spinopelvic mobility contributed to increased error rates.

Results

The paired absolute difference between CAS and postoperative imaging measurements was 2.3° (standard deviation (SD) 2.6°) for inclination and 3.1° (SD 4.2°) for anteversion. Using a target zone of 40° (± 10°) (inclination) and 20° (± 10°) (anteversion), postoperative standing radiographs measured 96% of acetabular components within the target zone for both inclination and anteversion. Multiple logistic regression analysis controlling for BMI and sex revealed that hypermobile spinopelvic mobility significantly increased error rates for anteversion (odds ratio (OR) 2.48, p = 0.009) and inclination (OR 2.44, p = 0.016), whereas stiff spinopelvic mobility increased error rates for anteversion (OR 1.97, p = 0.028). There were no dislocations at a minimum three-year follow-up.

Conclusion

Despite high reliability in acetabular positioning for inclination in a large patient cohort using an optical CAS system, hypermobile and stiff spinopelvic mobility significantly increased the risk of clinically relevant errors. In patients with abnormal spinopelvic mobility, CAS systems should be adjusted for use to avoid acetabular component misalignment and subsequent risk for long-term dislocation.

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Introduction

Total hip arthroplasty (THA) is considered one of the most successful surgeries for end-stage arthritis, resulting in excellent long-term survivorship and significant improvement of pain and overall quality of life.[1,2] Accurate positioning of the acetabular or femoral components is crucial for THA success,

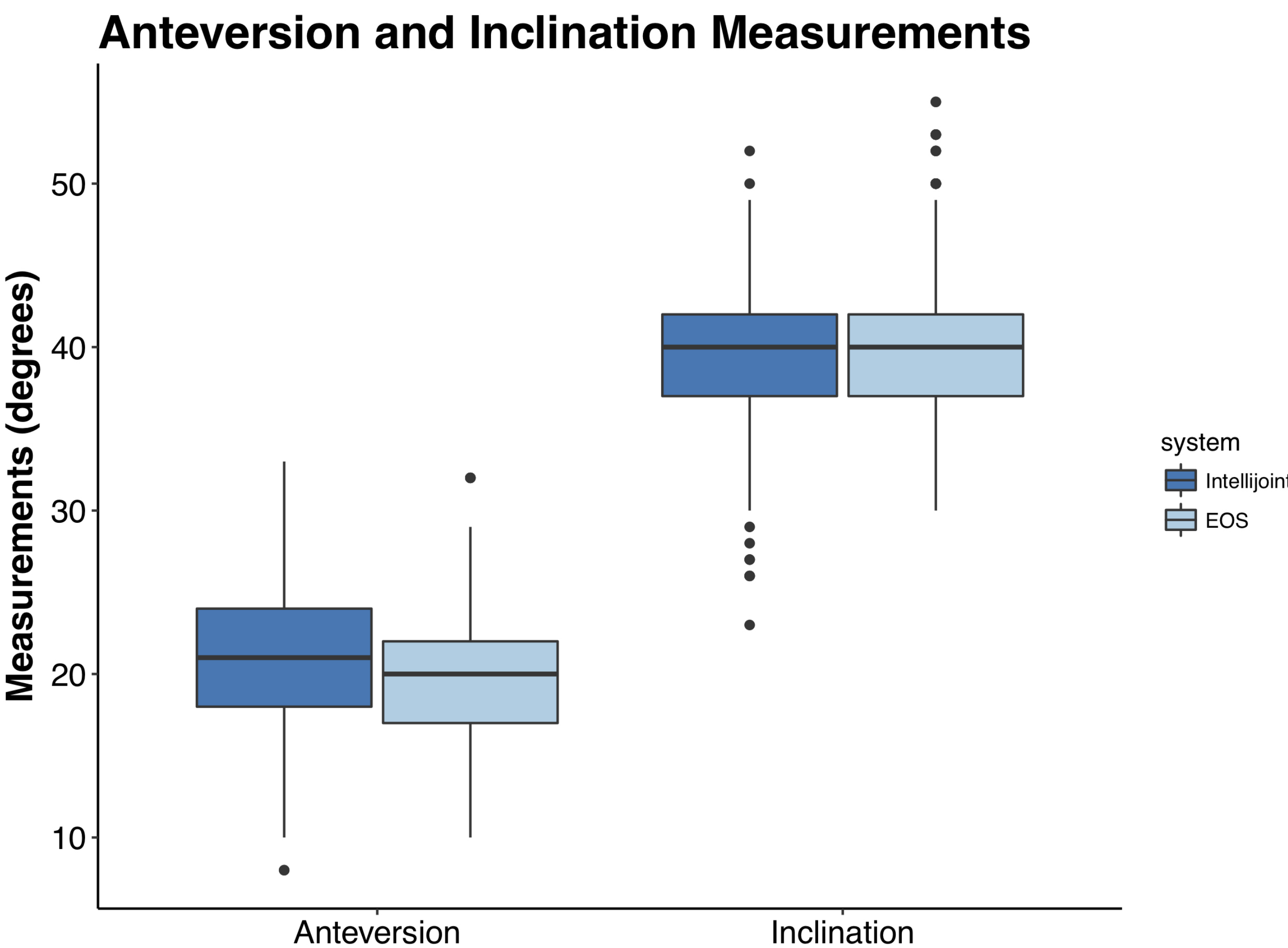

Fig. 1

Degrees for anteversion and inclination measured from both intraoperative computer-assisted surgery navigation system (Intellijiont) and six-week postoperative 3D measurements (SterEOS).

as malpositioning can lead to multiple early and late complications including dislocation, aseptic loosening, accelerated wear, and hip impingement.[3,4] However, appropriate placement of the acetabular component to a target zone using freehand conventional techniques remains difficult irrespective of surgeon experience.[5]

The use of computer-assisted surgery (CAS) navigation systems has improved the accuracy and reliability of patient-specific component positioning by providing intraoperative feedback.[6-9] These systems have high accuracy and positive predictive values for determining cup inclination and anteversion inside a target zone.[6] Consequently, CAS systems can significantly reduce the number of acetabular components placed outside target cup positions.[7-10] Despite this improvement, numerous patient-specific and CAS-dependent factors are still reported to increase acetabular component placement error when using CAS navigation systems.[7,11-13]

Although studies have investigated BMI and soft-tissue thickness as patient-specific factors contributing to increased error in CAS systems,[11-13] studies have not investigated whether abnormal spinopelvic mobility can also contribute to increased error. Specifically, spinopelvic hypermobility, as defined by a change in sacral slope (SS) greater than 30° or 35° between sitting and standing, can influence acetabular component target and placement during THA.[14-16] Likewise, spinopelvic hypermobility has been correlated with worse outcomes following THA.[17]

This study had two specific aims. We aimed to first evaluate the accuracy of an optical intraoperative CAS navigation system in a large patient cohort with both standing and sitting radiographs. Then we aimed to determine whether abnormal spinopelvic mobility was associated with higher rates of clinically relevant error using the CAS navigation system. Given that spinopelvic mobility can potentially alter the registration of CAS navigation systems, we hypothesized abnormal spinopelvic mobility would significantly increase the risk of clinically relevant error in component acetabular placement during THA.

Table I. Summary of computer-assisted surgery Intellijoint and radiological 3D SterEOS measurements.

Measurement	CAS intraop, °	Six wks postop, °	Paired differences, °
Inclination			
Mean (SD)	39.3 (4.3)	40.2 (4.7)	2.3 (2.6)
Range	23 to 52	30 to 55	0 to 14
Anteversion			
Mean (SD)	20.7 (4.7)	19.7 (4.1)	3.1 (4.2)
Range	8 to 33	10 to 32	0 to 18

CAS, computer-assisted surgery; SD, standard deviation.

Methods

Patients. A total of 356 consecutive patients undergoing unilateral cementless primary THA were prospectively enrolled into this institutional review board-approved study from November 2016 to March 2018 to assess the intraoperative accuracy and reliability of an optical CAS navigation system (Intellijoint HIP; Intellijoint Surgical, Canada). Patients with pre-existing implants, post-traumatic arthritis, contralateral hip arthroplasty, septic arthritis, or previous hip fracture were excluded for enrolment. All patients had standing and relaxed sitting biplanar radiographs (EOS Imaging System; EOS Imaging, France) preoperatively and six weeks postoperatively.[18]

Surgical technique. Surgical technique using Intellijoint HIP has been previously described.[19] Two threaded pins are inserted percutaneously into the iliac rim and an optical 3D camera is placed on the pelvic platform. The patient is positioned in the lateral decubitus position on a hip table with a post positioned at the level of the pubis anteriorly and gluteal crease posteriorly, centred over the greater trochanter. Inclination is registered according to the horizontal (floor) and the anteversion reference plane is made according to the surgeon-positioned alignment rod, which is placed parallel to the functional pelvic plane. The resulting acetabular component orientation is calculated using Murray's radiological orientation.[20]

Measurements. Postoperative acetabular alignment angles (inclination and anteversion) were measured from EOS imaging using independently validated 3D sterEOS software protocols (EOS Imaging System; EOS Imaging). Anatomical references were used to define acetabular and femoral component position to avoid angular differences that can occur with pelvic tilt or femoral rotation (changes in functional implant alignment). The anterior pelvic plane (APP), which is defined by the two anterior superior iliac spines and the pubic symphysis, was used as an anatomical reference for acetabular anteversion. All measurements were converted and transformed to fit Murray's radiological definition in order to match outputs from the CAS system.[21] Sacral slope was measured using the preoperative radiographs in both the standing and sitting position. SS was defined as the angle between a line parallel to the sacral endplate and the horizontal on a lateral radiograph.[15,22] Data were evaluated by two blinded adult reconstruction fellowship-trained observers.

Statistical analysis. A primary outcome was the absolute difference between intraoperatively acquired data for acetabular inclination and anteversion compared to postoperative radiological measurements. Linear regression analyses were conducted for both anteversion and inclination (Pearson product-moment correlation coefficients) as well as a paired *t*-test to test for significant differences between intraoperative and postoperative measurements. In accordance with the analysis conducted by Snyder et al[6] of another CAS system, we also calculated the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for acetabular component placement within a specific target range. Although the Lewinneck safe zone has been traditionally defined as an inclination of 40° (± 10°) and an anteversion of 15° (± 10°), other target zones have been demonstrated to be more effective in reducing dislocations.[16,23,24] In this study, surgeons based their intraoperative target on the hip-spine classification.[25] The distribution of intraoperative cup targets for the surgeons was 40° (± 10°) for inclination and 20° (± 10°) for anteversion in this study. Thus, using the postoperative radiological measurements as the standard reference for acetabular alignment, we defined a "true positive" result as an acetabular component placed in 40° (± 10°) for inclination and in 20° (± 10°) for anteversion for both the intraoperative CAS and postoperative radiological measurements. Adjustments were made with the Bayesian model for PPV and NPV given the prevalence of cups outside the safe zone in the study was lower than that of other studies and published data. A 10% prevalence was similarly used.[6]

Differences in SS were calculated between standing and sitting radiographs, and patients were categorized as either having hypermobile ($\Delta SS_{stand\text{-}sit} > 30°$), normal ($10° \leq \Delta SS_{stand\text{-}sit} \leq 30°$), or stiff ($\Delta SS_{stand\text{-}sit} < 10°$) spinopelvic mobility. Clinically relevant errors between intraoperative and postoperative inclination and anteversion measurements were defined as absolute differences greater than 5°.[26,27] Chi-squared test analyses were performed to determine the interaction between patient-specific factors, including obesity, sex, and spinopelvic mobility, with rates of clinically relevant acetabular component placement error in anteversion, inclination, anteversion or inclination, and anteversion and inclination. Obesity was defined as a BMI > 30 kg/m^2. Multiple logistic regression analysis was performed to determine the odds of acetabular component placement error based on patient-specific factors. A power analysis using an α of 0.05 demonstrated that 698 patients were required for an 80% power to show a significant increase in the clinically relevant error rate by 10% based on preliminary analysis of the data with a 21% error rate in anteversion in

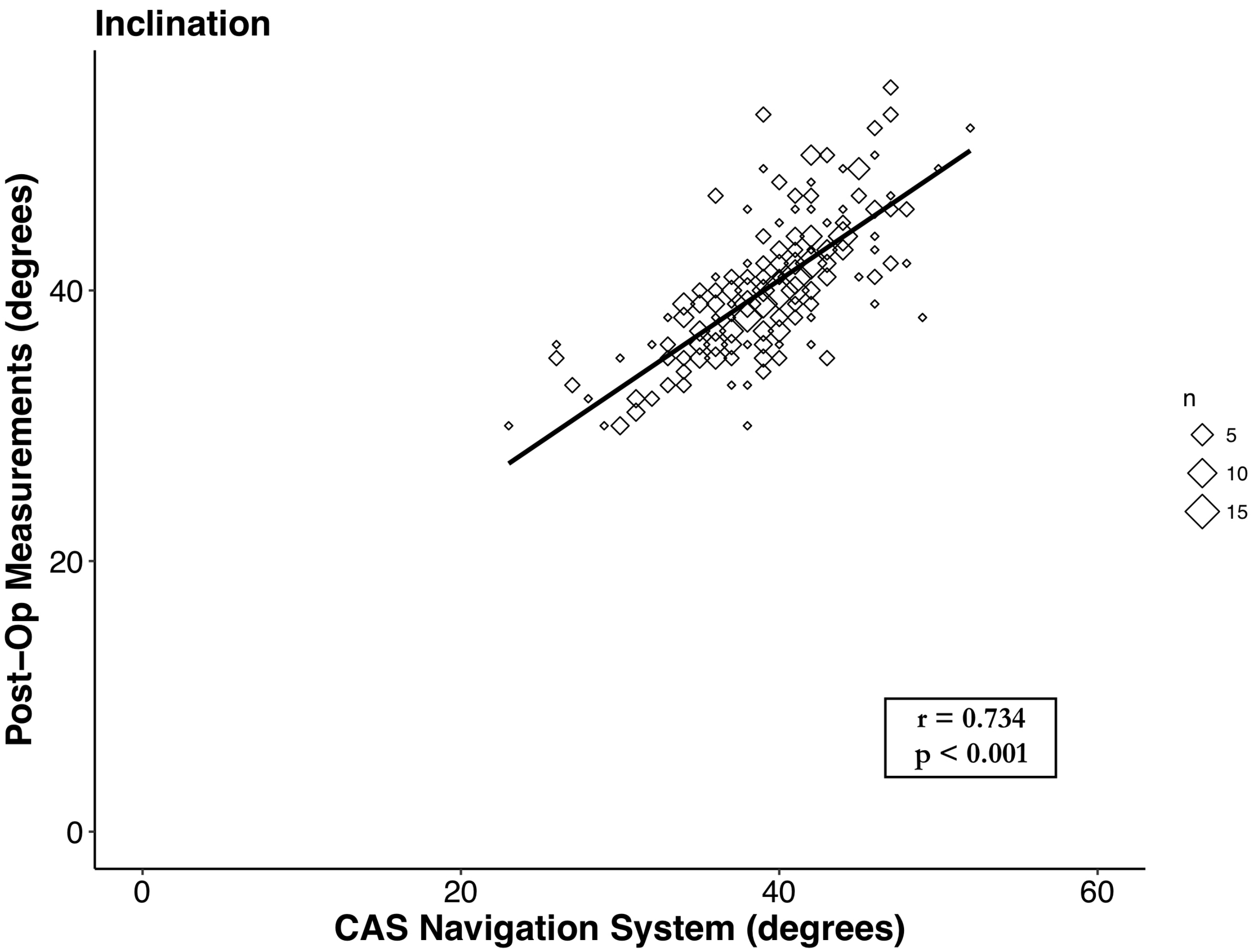

Fig. 2

Linear regression of inclination measurements between intraoperative computer-assisted surgery (CAS) navigation system (Intellijoint) and postoperative radiographs (EOS) with line of best fit. Analysis revealed a strong, significant correlation between the measurements ($r = 0.734$; $p < 0.001$).

patients with normal spinopelvic mobility. In the analysis, BMI was categorized as obese and non-obese, whereas spinopelvic mobility was categorized into hypermobile, normal, and stiff. A p-value under 0.05 was deemed statistically significant. All analysis were conducted with R software (R Foundation for Statistical Computing, Austria).

Results

In total, 354 hips were used in this study with two patients excluded due to failure to collect intraoperative values. The mean BMI was 28 kg/m^2 (18 to 51). Of the hips included, 178 were from female patients and 176 were from male patients. Preoperative standing radiographs were unavailable for 16 patients, leading to a total of 338 patients for analysis regarding spinopelvic mobility (169 male and 169 female). No hips in this study resulted in dislocations at a minimum three-year follow-up.

The mean inclination and anteversion for intraoperative and postoperative measurements are depicted in Figure 1. The absolute paired difference between intraoperative and 3D sterEOS imaging postoperative measurements was 2.3° (standard deviation (SD) 2.6°) for inclination and 3.1° (SD 4.2°) for anteversion (Table I). Linear correlation analysis revealed there was a significant, strong correlation ($r = 0.734$) for inclination between intraoperative CAS and postoperative radiological measurements (Figure 2). There was also a significant, but weaker, correlation between intraoperative and postoperative measurements for anteversion ($r = 0.335$) (Figure 3). Anteversion and inclination were significantly different between the intraoperative and postoperative measurements, and the means were different by 1.0° and 0.9°, respectively ($p < 0.001$, paired *t*-test).

Figures 4 and 5 depict the anteversion and inclination of each hip and their placement relative to a target range

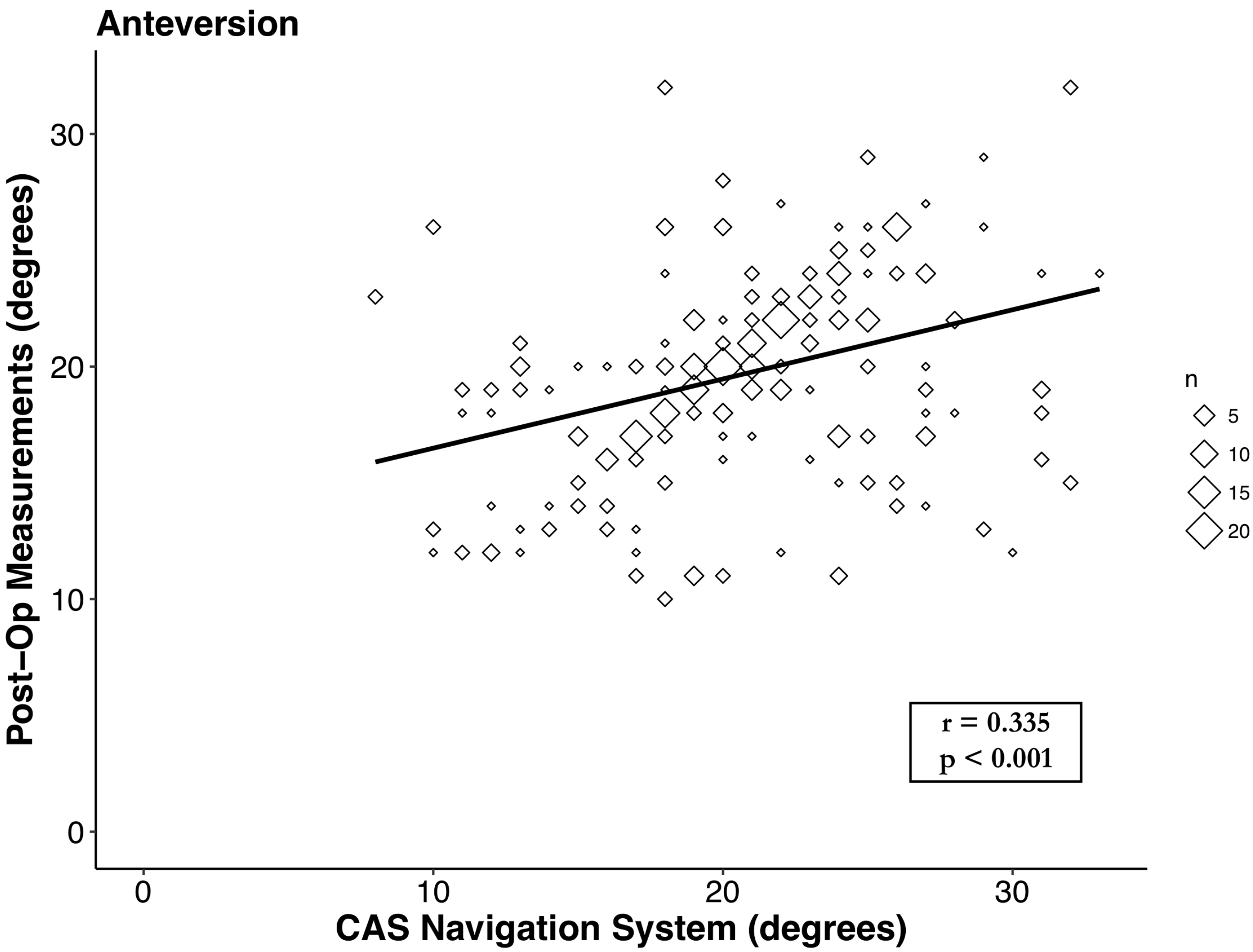

Fig. 3

Linear regression of anteversion measurements between intraoperative computer-assisted surgery (CAS) navigation system (Intellijoint) and postoperative radiographs (EOS) with line of best fit. Analysis revealed a weak, significant correlation between the measurements ($r = 0.335$; $p < 0.001$).

of 40° ± 10° for inclination and 20° ± 10° for anteversion. For the intraoperative CAS measurements, 330 hips (93%) were placed within this target range whereas for the postoperative measurements, radiographs revealed that 341 hips (96%) were placed within the target range. Accordingly, the sensitivity of the intraoperative CAS was 0.94 and specificity was 0.23 for placement within the target range. Using the radiological measurements as the reference for correct placement, and an assumed prevalence of 90% of hips correctly within the range, the PPV was calculated as 0.92 and NPV as 0.29. Further analysis using the traditional Lewinnek safe zone of 40° ± 10° for inclination and 15° ± 10° as the target range,[23] revealed a sensitivity, specificity, PPV, and NPV of 0.86, 0.45, 0.93, and 0.27, respectively.

On univariate analysis, there was a significant interaction between spinopelvic mobility and clinically relevant errors (> 5°) using the CAS navigation system (Table II). This interaction was evident in anteversion ($p < 0.001$), inclination ($p = 0.042$), and inclination or anteversion ($p = 0.005$). Notably, 40.0% (18/45) of patients who had hypermobile spinopelvic mobility had clinically relevant errors in anteversion compared to 21.3% (48/225) of patients who had normal spinopelvic mobility and 33.8% (23/68) patients who had stiff spinopelvic mobility. For inclination, 31.1% (14/45) of patients who had hypermobile spinopelvic mobility had clinically relevant errors compared to 15.6% (35/225) of patents who had normal spinopelvic mobility. Furthermore, 51.1% (23/45) patients who had hypermobile spinopelvic mobility had clinically relevant errors for either inclination or anteversion compared to 27.6% (62/225) patients who had normal spinopelvic mobility. Obesity and sex did not have a significant interaction with clinically relevant errors for either inclination or anteversion.

Controlling for BMI and sex through multiple logistic regression, hypermobile spinopelvic mobility significantly increased the odds of having an error > 5° in anteversion

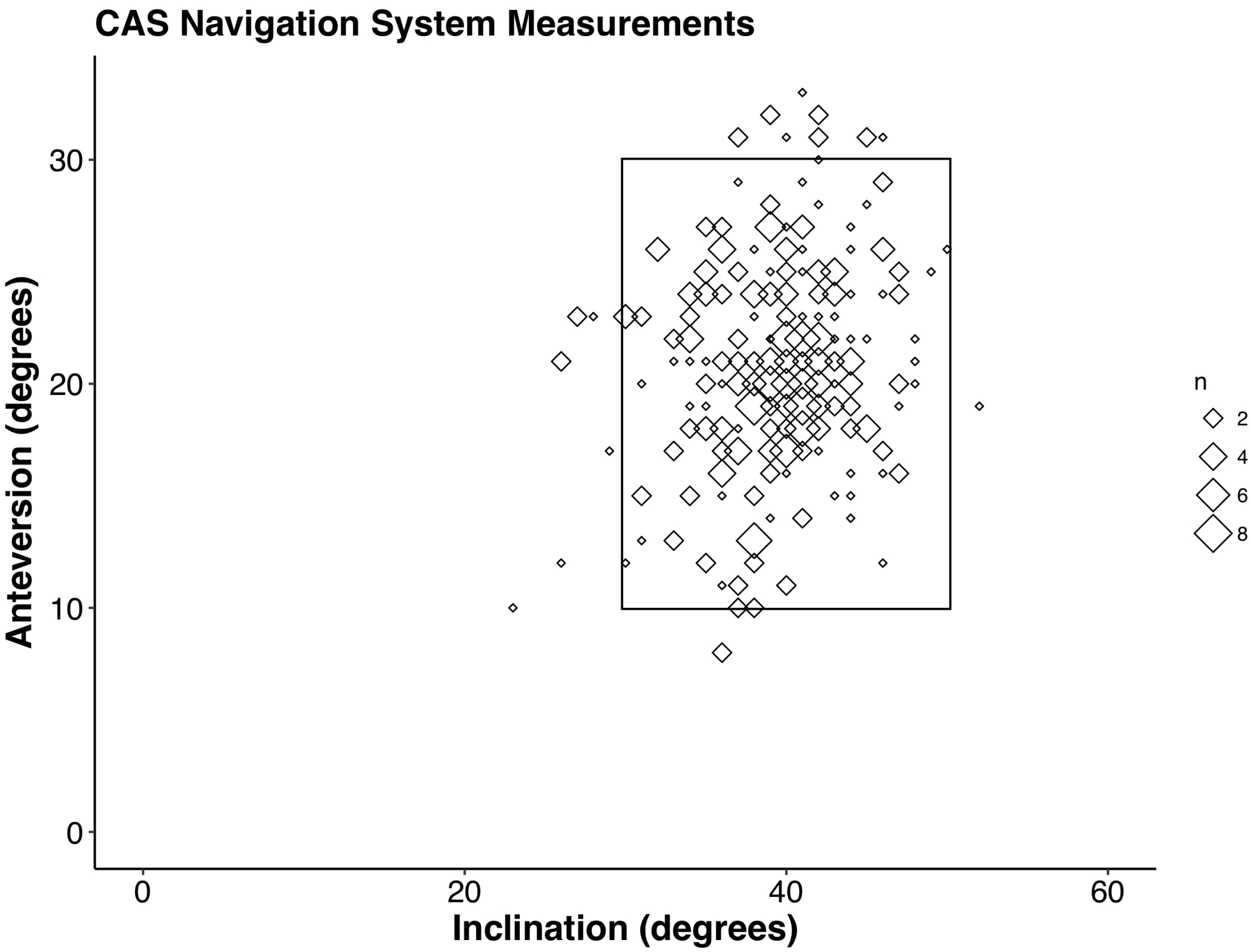

Fig. 4

Intraoperative computer-assisted surgery (CAS) measurements for inclination and anteversion of every hip relative to the target zone of 40° ± 10° for inclination and 20° ± 10° for anteversion. For CAS measurements, 330 (93%) hips were within the zone for both inclination and anteversion. When broken down by inclination and anteversion, 345 (97%) hips were within the target for inclination and 339 (96%) for anteversion.

(odds ratio (OR) 2.48; 95% confidence interval (CI) 1.24 to 4.87; p = 0.009), inclination (OR 2.44; 95% CI 1.15 to 4.99, p = 0.016), in either anteversion or inclination (OR 2.76; 95% CI 1.43 to 5.35, p = 0.002), and in both anteversion and inclination (OR 2.42, 95% CI 0.99 to 5.58, p = 0.044). Stiff spinopelvic mobility significantly increased the odds of having an error > 5° in anteversion only (OR 1.97, 95% CI 1.07 to 3.59, p = 0.028). BMI and sex, however, did not significantly increase the odds of acquiring an error > 5° (Table III).

Discussion

The mean paired absolute difference between intraoperative and postoperative measurements was 2.3° (SD 2.6°) for inclination and 3.1° (SD 4.2°) for anteversion. Our results are consistent with those found in previous studies using radiological analysis for the validation of other CAS systems, as well as a cadaver study using the same CAS system.[21] Studies with other systems also had mean differences from 1.8° to 9.0° for anteversion and 2.0° to 6.5° for inclination with postoperative measurements with similar SDs. However, these studies had fewer than 100 patients in evaluating the accuracy of intraoperative CAS systems.[11,26,28-30] In this study, we used a large patient cohort and compared CAS measurements against 3D radiological measurements. Consistent with previous work, the small deviation between intraoperative and postoperative values in our study validates the use of this optical CAS navigation system.

Furthermore, there was a strong correlation for inclination ($r = 0.734$; p < 0.001) and a lower correlation for anteversion ($r = 0.335$; p < 0.001). Likewise, Hohmann et al[7] reported that in 32 subjects who underwent imageless navigation THA with postoperative CT scans, there was a strong correlation ($r = 0.68$; p < 0.01) for cup inclination in intraoperative and postoperative measurements.

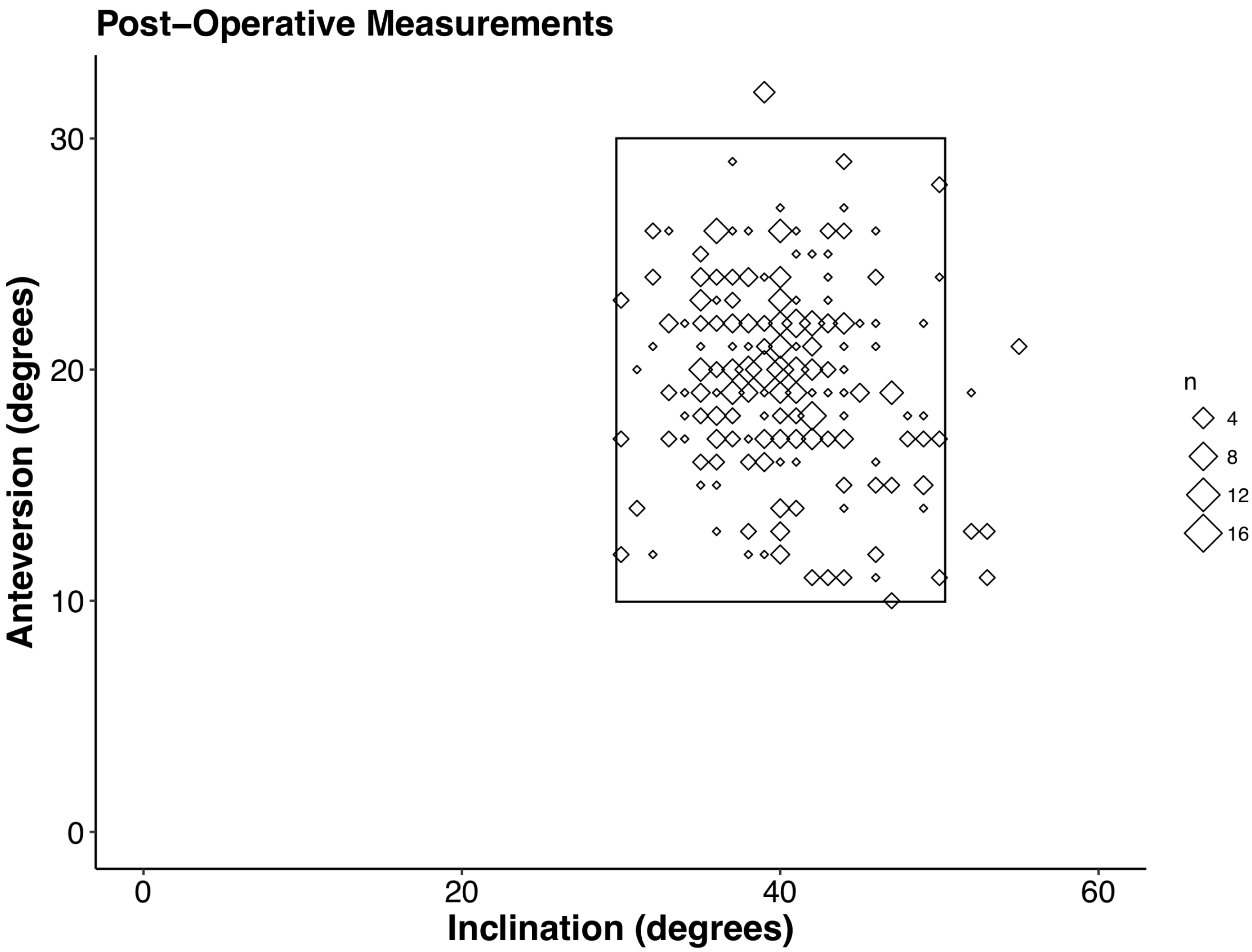

Fig. 5

Postoperative radiological measurements for inclination and anteversion of every hip relative to the target zone of 40° ± 10° for inclination and 20° ± 10° for anteversion. For the postoperative radiological measurements, 341 (96%) hips were placed within the zone for both inclination and anteversion. When broken down by inclination and anteversion, 345 hips (97%) were within target for inclination and 350 (99%) for anteversion.

However, there was a non-significant correlation for cup anteversion, which was later attributed to systematic error associated with anatomical landmark acquisition. Despite this reduced correlation for anteversion, we still demonstrate a high accuracy rate in placing the acetabular component in a defined target zone. Furthermore, this study compared anteversion measurements against the use of 3D sterEOS, which has been shown to measure anteversion with less accuracy when compared to CT measurements.[31,32] Thus, the error comparing anteversion from this CAS system to the 3D radiological measurements may be due to either the CAS system, the 3D radiological measurements, or a combination of both. Comparison of the CAS system against CT scans would provide the most accurate analysis in future studies.

We assessed the accuracy of the navigation system for its sensitivity, specificity, PPV, and NPV in placing the acetabular component in a specified target range. Using a range of 40° ± 10° for inclination and in 20° ± 10° for anteversion based on the surgeon's targets, we found the sensitivity in placing the cup was 0.94, indicating that 94% of hips within the target acetabular positioning will be correctly placed by the CAS system. We also calculated a PPV of 92%, indicating that 92% of hips intraoperatively placed within this target range will be correctly positioned according to postoperative radiographs. These values are similar to that of Snyder et al's[6] study, which found a PPV of 94% and a specificity of 90% for a different CAS system using a target zone of 45° ± 10° for inclination and in 20° ± 10° for anteversion. Of note, they defined specificity as correctly placing a hip within the target zone, which is how we defined the sensitivity of the CAS system used in this study. Our NPV was calculated as 0.29, indicating that the CAS system was not as effective in reliably placing a hip outside the target zone. Given that the target zone in both this study and Snyder

Table II. Univariate analysis.

Variables	N	Anteversion			Inclination			Anteversion or inclination			Anteversion and inclination		
		Normal (n = 249)	Outlier (n = 89)	p-value	Normal (n = 278)	Outlier (n = 60)	p-value	Normal (n = 227)	Outlier (n = 101)	p-value	Normal (n = 300)	Outlier (n = 38)	p-value
Spinopelvic mobility, n (%)*													
Hypermobile	45	27 (11)	18 (20)	< 0.001†	31 (10)	14 (21)	0.042†	22 (10)	23 (21)	0.005†	36 (12)	9 (24)	0.117†
Normal	225	177 (71)	48 (54)		190 (72)	35 (56)		163 (72)	62 (59)		204 (68)	21 (55)	
Stiff	68	45 (18)	23 (26)		57 (18)	11 (23)		42 (19)	26 (23)		60 (20)	8 (21)	
BMI, n (%)													
Obese	100	71 (29)	29 (33)	0.470‡	84 (30)	16 (27)	0.585‡	65 (29)	35 (32)	0.584‡	90 (30)	10 (26)	0.639‡
Normal	238	178 (71)	60 (67)		194 (70)	44 (73)		162 (71)	76 (68)		210 (70)	28 (74)	
Sex, n (%)													
Female	169	122 (49)	47 (53)	0.537‡	137 (49)	32 (53)	0.569‡	110 (48)	59 (58)	0.418‡	149 (50)	20 (53)	0.731‡
Male	169	127 (51)	42 (47)		141 (51)	28 (47)		117 (52)	52 (42)		151 (50)	18 (47)	

*Hypermobile = ΔSS (Sacral Slope) > 30°; Normal = 10° ≤ ΔSS ≤ 30; Stiff = ΔSS<10.
†Fisher's exact test.
‡Chi-squared test.

Table III. Multiple logistic regression of patient-specific factors against clinically relevant error.

Measurement	Odds ratio	95% CI	p-value
Anteversion			
Hypermobile*	2.477	1.244 to 4.866	0.009
Stiff†	1.970	1.068 to 3.587	0.028
BMI, kg/m^2	0.805	0.487 to 1.325	0.376
Sex	1.018	0.978 to 1.059	0.395
Inclination			
Hypermobile*	2.438	1.154 to 4.991	0.016
Stiff†	1.069	0.488 to 2.196	0.861
BMI	0.873	0.491 to 1.543	0.800
Sex	0.994	0.946 to 1.041	0.639
Anteversion or inclination			
Hypermobile*	2.761	1.433 to 5.347	0.002
Stiff†	1.699	0.948 to 3.019	0.072
BMI	0.795	0.497 to 1.269	0.502
Sex	1.013	0.975 to 1.052	0.338
Anteversion and inclination			
Hypermobile*	2.420	0.985 to 5.578	0.044
Stiff†	1.319	0.523 to 3.053	0.533
BMI	0.891	0.444 to 1.775	0.944
Sex	0.998	0.939 to 1.054	0.742

*Hypermobile = ΔSS (sacral slope) > 30°
†Stiff = ΔSS (sacral slope) < 10°
CI, confidence interval.

et al's[6] study is not the traditional Lewinnek safe zone,[33] we also assessed the accuracy of the navigation system using a target zone of 40° ± 10° for inclination and in 15° ± 10° for anteversion, finding a similar sensitivity of 0.86 and PPV of 0.93. These results suggest this CAS system is a highly reliable tool in placing the acetabular hip within the defined target zones. This can provide advantages to the surgeon by potentially increasing accuracy of cup placement, decreasing operating time in position targeting, and mitigate learning curves for trainees.[34] Furthermore, these potential benefits are of interest for future investigations for this CAS system.

A clinically relevant error was defined as an error greater than 5° based on studies assessing the accuracy and precision of CAS navigation systems.[7,23,27] Despite the relatively high accuracy of this CAS system, for 338 patients included in the analysis for spinopelvic mobility, 89 (26%) patients had a clinically relevant error for anteversion, 60 (18%) patients for inclination, 101 (30%) patients for either anteversion or inclination, and 38 (11.2%) patients for both anteversion and inclination. In a study of 30 THAs, Hohman et al[7] found a similar pattern where more cases had an error greater than 5° in anteversion (63%) compared to inclination (23%), and the error was attributed to a higher BMI (> 30 kg/m^2) in their patient cohort and difficulty palpating the pubic symphysis. Similar studies suggest truncal obesity may play a critical role in correct acetabular placement.[7,12,13,27,29,35] Anatomical landmarks, specifically the anterior superior iliac spine (ASIS) and pubic tubercle, function as inputs for other CAS navigation systems, and anatomical variations, such as the thickness of soft-tissue overlying these regions, may contribute to these differences.[11,12,35] We found no significant correlation between BMI and absolute differences in intra- and postoperative measurements. The CAS system evaluated in this study does not reference the anterior pelvic plane with the ASIS and pubis. Instead, inclination is registered according to the horizontal (floor) and the anteversion reference plane is registered according to the alignment rod, which is placed parallel to the anterior pelvic plane longitudinal axis. Therefore, BMI and soft-tissue thickness is less likely to affect its accuracy and, as our results show, BMI and sex did not have a significant interaction.

Critically, our results suggest that abnormal spinopelvic mobility increased the risk of error even after controlling for BMI and sex. In recent literature, spinopelvic hypermobility has been correlated with worse outcomes following THA. Grammatopoulos et al[17] showed that patients who had spinopelvic hypermobility had poorer patient-reported outcome measures (PROMs), such as Oxford Hip Score, which was statistically significant. In their study, spinopelvic hypermobility was also more present in patients who underwent revision secondary to dislocation even despite acceptable cup orientation. Kanawade et al[14] found that the hypermobile group was associated with a larger change in ante-inclination of the acetabular component due to higher spinopelvic motion, potentially leading to a more vertical cup in the seated position and increased risk of anterior dislocation. No dislocations were reported at a minimum three-year follow-up in the study cohort. Although we report no dislocations to date in our study, the results of the THAs in the patient cohort with high spinopelvic mobility are of continued interest.

A greater error in cup placement within the hypermobile spinopelvic mobility group may be a contributing factor to the poorer outcomes and greater dislocation rates reported in literature among patients with spinopelvic hypermobility. One potential explanation for the increased error observed in these patients is that they have more pelvic tilt variation in the surgical position, making it difficult to reliably estimate the APP when registering the coronal plane using the alignment rod. This suggests that CAS systems with similar registration methods may benefit from patient-specific adjustments in individuals with hypermobile and stiff spinopelvic mobility during positioning to account for this variability. Furthermore, another possible explanation for the increased error is that patients with hypermobile spinopelvic mobility can undergo large changes in spinopelvic mobility after THA, due to resolution of flexion contractures and hip stiffness, which may change the standing pelvic position postoperatively. This may leading to a possible discrepancy between intraoperative and postoperative cup measurements.[36,37] This was recently reported in a study where 67% of patients who had hypermobile spinopelvic mobility preoperatively no longer had hypermobile spinopelvic mobility after THA at six weeks' follow-up as “hip driven” spinopelvic hypermobility resolved.[38] However, all postoperative measurements were taken according to the APP,[39] making this a less likely explanation in this study.

There were several limitations. First, it was underpowered to determine whether spinopelvic mobility increased the risk of a clinical error, although the results still demonstrated a significant difference. Second, patient-specific sensitivity and specificity analysis were not conducted based on individual intraoperative targets but rather intraoperative target distributions. Studies investigating system performance based on specific targets are warranted. Third, spinal alignment in the coronal plane for spinal pathologies such as scoliosis and fixed pelvic obliquity were not included in this study. Fourth, the exact cause for the low accuracy of the optical system for cup anteversion angle restoration against postoperative measurements is still an investigation of interest. In particular, postoperative imaging was conducted in the standing position whereas intraoperative registration was conducted in the lateral decubitus position, which may have contributed to increased variability in accuracy. Finally, the findings in this study may be unique to this CAS system, as anatomical landmarks were not used for registration as in other systems. Comparative studies are still necessary to determine this CAS system’s ability to improve cup orientation placement against other systems, as well as its impact on long-term clinical outcomes. Nonetheless, we highlight that the large patient cohort findings reported here still emphasize the importance of considering spinopelvic mobility when using similar CAS systems, as abnormal spinopelvic mobility can increase error in acetabular component placement.

In conclusion, the use of this computer-assisted navigation system demonstrated high accuracy and reliability in acetabular component position and orientation for inclination, but less so for anteversion, when compared to 3D sterEOS imaging. The CAS system provides an additional intraoperative tool for surgeons to facilitate THA and enable real-time intraoperative values. Despite high reliability for inclination, we demonstrated that abnormal spinopelvic mobility is a potential risk factor leading to clinically relevant errors. As such, we suggest patient-based modifications and precautions are taken when patients with an abnormal spinopelvic mobility undergo primary THA using CAS navigation systems. Furthermore, future studies are necessary to evaluate long-term clinical outcomes and cost-effectiveness of this CAS navigation system for THA compared to conventional THA, as well as the use of CAS navigation systems for patients with abnormal spinopelvic mobility.

Take home message

- Despite using a highly reliable computer-assisted surgical navigation system for acetabular component placement, abnormal spinopelvic mobility was a potential risk factor for clinically relevant placement error.
- This suggests that patient-based modifications and precautions should be taken when patients with an abnormal spinopelvic mobility undergo primary total hip arthroplasty using certain computer-assisted surgical navigations systems.

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