JB&JS OPEN ACCESS

Reduced Risk of Revision with Computer-Guided Versus Non-Computer-Guided THA

An Analysis of Manufacturer-Specific Data from the National Joint Registry of England, Wales, Northern Ireland and the Isle of Man

Edward T. Davis, FRCS(Tr&Orth), Kerren D. McKinney, MSc, Amir Kamali, PhD, Selena Kuljaca, PhD, and Joseph Pagkalos, FRCS(Tr&Orth)

Investigation performed at The Royal Orthopaedic Hospital NHS Foundation Trust, Birmingham, United Kingdom

Background: Computer-assisted total hip arthroplasty (THA) is known to improve implantation precision, but clinical data demonstrating an improvement in survivorship and patient-reported outcome measures (PROMs) are lacking. Our aim was to compare the risk of revision, PROMs, and patient satisfaction between cohorts who underwent THA with and without the use of computer guidance.

Methods: We used the data set and linked PROM data of the National Joint Registry of England, Wales, Northern Ireland and the Isle of Man. Our sample included THAs performed for osteoarthritis using cementless acetabular components from a single manufacturer (cementless and hybrid THAs). An additional analysis was performed limiting the sample size to cementless-only THAs. The primary end point was revision (any component) for any reason. Kaplan-Meier survivorship analysis and an adjusted Cox proportional-hazards model were used.

Results: There were 41,683 non-computer-guided and 871 (2%) computer-guided cases included in our analysis of the cementless and hybrid group. There were 943 revisions in the non-computer-guided group and 7 in the computer-guided group. The cumulative revision rate at 10 years was 3.88% (95% confidence interval [CI]: 3.59% to 4.18%) for the non-computer-guided group and 1.06% (95% CI: 0.45% to 2.76%) for the computer-guided group. The Cox proportional-hazards model yielded a hazard ratio of 0.45 (95% CI: 0.21 to 0.96; p = 0.038). In the analysis of the cementless-only group, the cumulative revision rate at 10 years was 3.99% (95% CI: 3.62% to 4.38%) and 1.20% (95% CI: 0.52% to 3.12%) for the 2 groups, respectively. The Cox proportional-hazards model yielded a hazard ratio of 0.47 (95% CI: 0.22 to 1.01; p = 0.053). There was no significant difference in the 6-month Oxford Hip Score, the EuroQol-5 Dimension (EQ-5D) and EQ-VAS (Visual Analogue Scale) scores, and patient-reported success rates. Patient satisfaction (single-item satisfaction outcome measure) was higher in the computer-guided group, but this finding was limited by a reduced number of responses.

Conclusions: In our analysis, the use of computer-guided surgery was associated with a lower rate of revision at mean follow-up of 5.6 years. This finding was upheld when the sample was restricted to cementless-only THAs. Causality cannot be inferred in view of the observational nature of the study, and additional studies are recommended to validate these findings.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

Computer-guided surgery has been used in arthroplasty for over 2 decades; the first clinical report, to our knowledge, on the use of an active robot and image-based guidance was published in the early 1990s[1]. Since its introduction, the technology has evolved, and different iterations of computer-guided surgery have been employed,

Disclosure: The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJSOA/A304).

Disclaimer: The data used for this analysis was obtained from the National Joint Registry ("NJR"), part of the Healthcare Quality Improvement Partnership ("HQIP"). HQIP, the NJR and/or its contractor, Northgate Public Services (U.K.) Limited ("NPS") take no responsibility (except as prohibited by law) for the accuracy, currency, reliability and correctness of any data used or referred to in this report, nor for the accuracy, currency, reliability and correctness of links or references to other information sources and disclaim all warranties in relation to such data, links and references to the maximum extent permitted by legislation including any duty of care to third party readers of the data analysis.

including active robotic systems use[2], image-based computer navigation[3], imageless navigation[4,5], and more recently, haptic robotic-arm-assisted hip arthroplasty[6,7]. Proponents of computer-guided surgery cite the improved precision in component placement and, therefore, the reduction in component-positioning outliers[7,8]. Opponents, however, raise the issues of increased capital expenditure, increased operative time, the need for training, and the lack of difference in functional outcome scores or survival in studies[9-12].

Higher-level evidence on computer-guided total hip arthroplasty (THA) remains scarce, with a frequently cited study in THA navigation consisting of 60 patients randomized to computer-navigated or conventional THA using a Watson-Jones approach[9,12,13]. Ten-year follow-up revealed no differences in radiograph-measured wear or patient-reported outcome measures (PROMs)[12]. Large data sets have more recently been used to assess the outcomes of THAs performed with computer navigation. A recent large database study reported a significant reduction in the risk of dislocation and revision of the acetabular component at short-term follow-up[14]. A large percentage of early THA failures are considered avoidable, and suboptimal positioning of the acetabular component was reported as the most common avoidable factor in a large academic-center retrospective study[15].

The aim of the current study was to assess the effect of computer guidance on the survival of THA and patient satisfaction using the data set and linked PROM data of the National Joint Registry of England, Wales, Northern Ireland and the Isle of Man (NJR).

Our hypothesis was that computer-guided surgery is associated with improved survival and improved PROMs when compared with THAs performed without computer guidance.

Materials and Methods

NJR Data Set

NJR primary THA records from April 3, 2003, to February 8, 2020, were analyzed. The NJR collects data on whether computer-guided surgery was used (yes/no) but not on the type of system used. As a result, our analysis does not include information on the system used for computer guidance. All THAs involving the use of cementless acetabular components by a single manufacturer (Smith & Nephew) were eligible for analysis. THAs with metal-on-metal bearing surfaces were excluded from analysis because of unique failure mechanisms associated with this bearing[16]. Polyethylene-based bearings and ceramic-on-ceramic THAs were included. THAs performed for indications other than osteoarthritis were excluded. The primary end point was revision of any component. Reasons for revisions are selected by the surgeon at the time of surgery from a predetermined list[17]. Multiple reasons can be selected per case. The details of the included cups are available in the full text of the NJR Bespoke Implant Reports on which this manuscript is based[18,19].

Restricted Sample: Cementless-Only THAs

Previous work using the NJR data set has revealed a significant association between stem fixation and prosthetic joint survival[20,21]. In order to eliminate the effect of stem fixation on our analysis, we restricted the sample size to THAs utilizing cementless stems from the same manufacturer (cementless-only THAs). Details of the types of stems included in the analysis are available in the full text of the NJR Bespoke Implant Report[19].

PROMs

PROMs are recorded by NHS Digital for patients undergoing inpatient elective surgery funded by the National Health Service (NHS) in England[22]. Patients are asked to complete preoperative and postoperative questionnaires to assess improvement in health as perceived by the patients themselves. Condition-specific measures and general health measures are used. For patients undergoing THA, the measures used are the Oxford Hip Score (OHS), the EuroQol-5 Dimension (EQ-5D) Index, and the EQ-Visual Analogue Scale (EQ-VAS). The minimal important change (MIC) in the OHS was defined as 11 points, and the minimal detectable change (MDC), 5 points[23].

As different organizations may treat patients of differing complexity or case mix, PROMs are adjusted using statistical models to account for this. Adjusted scores in our analysis correspond to the NHS Digital version 3 case-mix-adjustment model. This includes patient variables from PROMs, Hospital Episode Statistics, and the Index of Multiple Deprivation[24]. Patients were also asked in their postoperative questionnaires how they would describe the results of their operation by answering 2 questions: (1) “Overall, how are your problems now compared with before your operation?” (single-item success measure), and (2) “How would you describe the results of your operation?” (single-item satisfaction measure). The patients provide a response to those 2 questions on a 5-point scale, from poor to excellent.

Statistical Analysis

Survival analysis was performed using a Kaplan-Meier product limit estimator. In addition, a Cox proportional-hazards model was built for the risk of revision between the computer-guided and non-computer-guided groups. The proportional-hazards assumption was tested using scaled Schoenfeld residuals and was met. The hazard ratio reported is a simple average hazard ratio, which is the geometric average of the hazard ratios at all revision times and is not weighted by numbers of individuals at risk. The Cox model was adjusted for sex, American Society of Anesthesiologists (ASA) group, approach, prosthesis head size, year cohort, age group, body mass index (BMI) group, and bearing.

PROM health gains were analyzed using a Mann-Whitney U test (since data were not normally distributed). An analysis of the success and satisfaction measures was performed by plotting each of 5 possible responses for both the computer-guided and non-computer-guided THAs. These responses were not case-mix adjusted. A chi-square test was used to test the significance of any difference in response pattern between the 2 groups.

The statistical analysis was performed independently of the authors of the manuscript as part of a bespoke report request through the National Joint Registry Supplier Feedback framework. An NJR data-sharing request for the bespoke

TABLE I Patient Demographics and Procedure Details*

	Cementless and Hybrid THAs		Cementless-Only THAs	
	Computer-Guided	Non-Computer-Guided	Computer-Guided	Non-Computer-Guided
Total no. of procedures	871	41,683	761	29,785
Total no. of patients	799	37,956	699	27,018
Demographics				
Age				
Mean *(yr)*	66.8	67.4	65.8	65.5
<50 yr	5.9%	5.2%	6.6%	6.6%
50-59 yr	16.4%	16.9%	18.5%	20.6%
60-69 yr	34.7%	33.0%	35.9%	36.1%
70-79 yr	34.0%	33.2%	32.5%	28.7%
≥80 yr	9.1%	11.9%	6.6%	7.9%
BMI				
Median *(kg/m^2)*	28	29	28	29
% BMI information available	71.8%	67.2%	70.7%	67.5%
Underweight (BMI <18.5 kg/m^2)	0.2%	0.7%	0.2%	0.5%
Normal (18.5 ≤ BMI <25 kg/m^2)	17.0%	17.5%	15.1%	16.7%
Overweight (25 ≤ BMI <30 kg/m^2)	44.0%	39.2%	44.2%	39.0%
Obese I (30 ≤ BMI <35 kg/m^2)	31.0%	27.8%	32.2%	28.4%
Obese II (35 ≤ BMI <40 kg/m^2)	6.6%	11.1%	7.2%	11.5%
Obese III (BMI ≥40 kg/m^2)	1.3%	3.7%	1.1%	3.9%
Sex				
% male	45.6%	42.8%	48.8%	45.9%
ASA grade				
P1 - fit and healthy	16.3%	15.9%	17.5%	17.7%
P2 - mild disease, not incapacitating	78.6%	69.4%	77.8%	69.0%
P3 - incapacitating systemic disease	5.1%	14.4%	4.7%	13.0%
P4/P5	0.0%	0.4%	0.0%	0.3%
Indications				
Osteoarthritis	100.00%	100.00%	100%	100%
Implant usage				
First usage in the NJR	Sep. 9, 2003	Apr. 3, 2003	Apr. 2, 2005	Apr. 3, 2003
Last usage in this data set	Jan. 27, 2020	Feb. 8, 2020	Jan. 27, 2020	Feb. 8, 2020
Max. implantation time *(yr)*	15.7	16.9	14.9	16.8
Mean implantation time *(yr)*	5.6	5.2	5.6	4.9
Centers *(no.)*	26	200	20	179
Surgeons *(no.)*	36	956	27	745

*ASA = American Society of Anesthesiologists, BMI = body mass index, NJR = National Joint Registry, and THA = total hip arthroplasty. The complete NJR Bespoke Implant Reports are available online[18,19].

reports was approved by the Healthcare Quality Improvement Partnership (HQIP). The full reports are available online[18,19].

Source of Funding

The study was funded through a restricted grant by Smith & Nephew. Multiple authors are employees of Smith & Nephew. The funding body had no access to the data or the statistical analysis, which was performed independently of the authors of the manuscript.

Results

Cementless and Hybrid THAs

Computer-guided surgery was used in 871 (2%) of 42,554 cases. There were a total of 943 revisions in the non-computer-guided group and 7 revisions in the computer-guided group. Patient demographics and implant-usage details are shown in Table I. The reasons for revision in both groups are shown in Table II.

Kaplan-Meier survival analysis revealed a significantly lower cumulative revision rate at 10 years in the computer-

TABLE II Reasons for Revision and Components Revised

	Cementless and Hybrid THAs*		Cementless-Only THAs*	
	Computer-Guided	Non-Computer-Guided	Computer-Guided	Non-Computer-Guided
	Revised† (% of All Cases)	Revised† (% of All Cases)	Revised† (% of All Cases)	Revised† (% of All Cases)
Reason for revision				
Unexplained pain	1 (0.11%)	121 (0.29%)	1 (0.13%)	94 (0.32%)
Dislocation/subluxation	1 (0.11%)	203 (0.49%)	1 (0.13%)	121 (0.41%)
Adverse soft-tissue reaction	0	26 (0.06%)	0	18 (0.06%)
Infection	1 (0.11%)	156 (0.37%)	1 (0.13%)	100 (0.34%)
Aseptic loosening: stem	2 (0.23%)	206 (0.49%)	2 (0.26%)	174 (0.58%)
Aseptic loosening: socket	0	79 (0.19%)	0	51 (0.17%)
Periprosthetic fracture: stem	2 (0.23%)	132 (0.32%)	2 (0.26%)	86 (0.29%)
Periprosthetic fracture: socket	0	7 (0.02%)	0	5 (0.02%)
Malalignment: stem	0	31 (0.07%)	0	26 (0.09%)
Malalignment: socket	1 (0.11%)	63 (0.15%)	1 (0.13%)	46 (0.15%)
Wear of acetabular component	0	79 (0.19%)	0	51 (0.17%)
Lysis: stem	0	40 (0.10%)	0	22 (0.07%)
Lysis: socket	0	32 (0.08%)	0	14 (0.05%)
Implant fracture: stem	0	21 (0.05%)	0	10 (0.03%)
Implant fracture: socket	0	15 (0.04%)	0	13 (0.04%)
Implant fracture: head	0	7 (0.02%)	0	5 (0.02%)
Dissociation of liner	0	12 (0.03%)	0	9 (0.03%)
Other/reason not recorded	1 (0.11%)	29 (0.07%)	1 (0.13%)	23 (0.08%)
Total revised	**7 (0.8%)**	**943 (2.26%)**	**7 (0.92%)**	**648 (2.18%)**
	No. (% of Revisions)	No. (% of Revisions)	No. (% of Revisions)	No. (% of Revisions)
Components revised				
Femoral only	2 (28.6%)	271 (28.7%)	2 (28.6%)	212 (32.7%)
Acetabular only	0	176 (18.7%)	0	125 (19.3%)
Both femoral and acetabular	4 (57.1%)	357 (37.9%)	4 (57.1%)	223 (34.4%)
Neither femoral nor acetabular revision recorded‡	1 (14.3%)	139 (14.7%)	1 (14.3%)	88 (13.6%)

*THA = total hip arthroplasty. †Multiple reasons may be listed for 1 revision procedure. ‡Includes isolated head and/or liner exchange. The complete NJR Bespoke Implant Reports are available online[18,19].

guided group (1.06% [95% confidence interval (CI): 0.45% to 2.76%]) compared with the non-computer-guided group (3.88% [95% CI: 3.59% to 4.18%]) (Fig. 1-A). A Cox model that was adjusted for sex, ASA group, approach, prosthesis head size, year cohort, age group, BMI group, and bearing revealed a hazard ratio of 0.45 (95% CI: 0.21 to 0.96). This was significant (p = 0.038).

Cementless-Only THAs

Computer-guided surgery was used in 761 (2.5%) of 30,546 cases. There were a total of 648 revisions in the non-computer-guided group and 7 revisions in the computer-guided group.

The cumulative incidence of revision at 10 years was 1.20% (95% CI: 0.52% to 3.12%) in the computer-guided group and 3.99% (95% CI: 3.62% to 4.38%) in the non-guided group (Fig. 1-B). The adjusted Cox model revealed a hazard ratio of 0.47 (95% CI: 0.22 to 1.01). This did not reach significance (p = 0.053).

PROMs and Single-Item Responses

The analysis of PROMs revealed clinically notable improvements in the postoperative scores of all measures recorded in both the hybrid and cementless group and the cementless-only group (Table III). Both the computer-guided and non-guided groups exceeded the MIC of 11 points in the OHS. The mean difference in the 6-month OHS between groups did not reach the MDC of 5 points. The comparison of the adjusted health gain between the computer-guided and non-guided groups did not reveal a significant difference in the OHS, the EQ-5D, or the EQ-VAS (Table III). Patient-reported success rates at the 6-month postoperative point (single question) did not differ between the 2 groups (chi-square test, p = 0.123 in

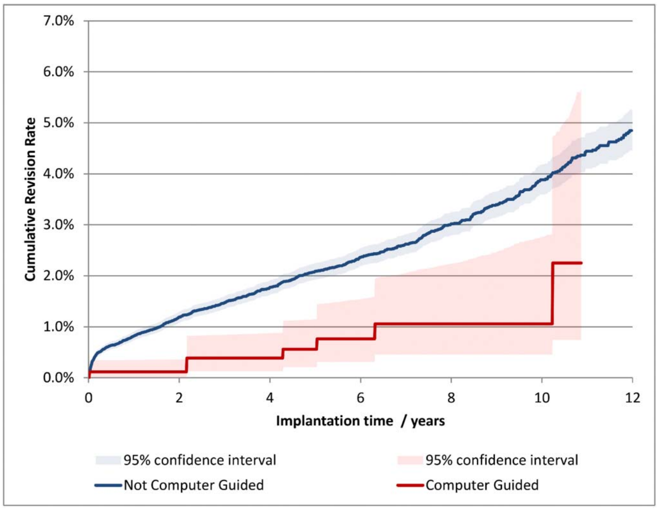

Fig. 1-A

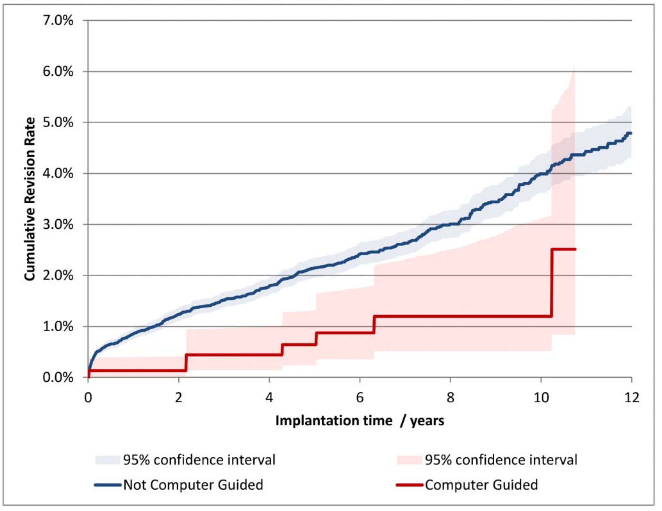

Fig. 1-B

Fig. 1-A Kaplan-Meier survival curve of cementless and hybrid total hip arthroplasties. The complete NJR Bespoke Implant Report is available online[18].
Fig. 1-B Kaplan-Meier survival curve of cementless-only total hip arthroplasties. The complete NJR Bespoke Implant Report is available online[19].

the full analysis and p = 0.173 in the cementless-only analysis). However, the satisfaction rate was significantly higher in the computer-guided group (chi-square test, p = 0.003 and p = 0.039, respectively).

Discussion

Our study revealed a lower rate of revision in THAs performed with computer guidance; this reached significance in our analysis of the group with cementless and hybrid THAs. In the analysis of our cementless-only THA group, the effect was of similar magnitude but did not reach significance in this smaller sample size. Our PROM analysis was limited by the low number of responses in the computer-guided groups. No significant difference was seen between the groups in the comparison of adjusted health gain, leading us to reject our hypothesis on PROMs. Patients who underwent computer-guided surgery had better satisfaction scores for the question "How would you describe the results of your operation?"

The strength of our study is the use of a national joint registry with long and comparable follow-up for both the computer-guided group (mean, 5.6 years; maximum, 15.7 years) and non-computer guided group (mean, 5.2 years; maximum, 16.9 years). To our knowledge, this is the first study using the NJR data set to investigate the effect of computer-guided THA on implant survivorship. Furthermore, our sample included computer-guided cases performed by a total of 36 surgeons (and 27 when the analysis was restricted to the cementless THA group), which makes our results more generalizable than those of some clinical trials. The results of the cementless-only group analysis confirmed that the effect seen was not associated with stem-fixation discrepancies between the groups. Finally, the use of a fully adjusted Cox proportional-hazards model, controlling for a range of confounding variables, yielded a hazard ratio that confirmed the significantly reduced risk of revision for the computer-guided group.

The finding of a reduced risk of revision surgery is in agreement with a recent study by Bohl et al., who used the 100% Medicare Part A claims data set for their analysis[14]. The authors identified a significantly lower risk of aseptic acetabular component revision in navigated cases (1.03% versus 1.55%; adjusted hazard ratio, 0.75 [95% CI: 0.64 to 0.88]). The hazard ratio in our study was lower and the confidence interval was wider (hazard ratio for cementless and hybrid, 0.45 [95% CI: 0.21 to 0.96]), possibly reflecting the smaller sample size. The proportion of patients who underwent computer-guided surgery in our study (2%) was similar to that in the study by Bohl et al. (1.81%). Our study included patients of all ages, while the study by Bohl et al. was limited to patients ≥65 years of age who are covered by Medicare[14]. We believe that the inclusion of all age groups makes the results more generalizable, as it includes higher-demand younger patient groups.

In another large database study (Nationwide Readmission Database), Gausden et al. reported that computer-guided navigation was associated with reduced complication and readmission rates at 90 days using an adjusted model[25]. The authors did not identify a significant difference in readmissions that involved revision surgery at 90 days post-surgery (odds ratio, 0.84 [95% CI: 0.67 to 1.05]; p = 0.13). The longer follow-up durations in our study (mean, 5.6 and 5.2 years) might explain our ability to capture a difference in revision rates.

Our findings are not in agreement with some commonly cited clinical trials. Parratte et al. reported on 10-year follow-up of a randomized controlled trial comparing 30 computer-guided THAs and 30 THAs implanted with conventional instrumentation[12]. The authors reported no difference between the groups in the Short Form (SF)-12, the Harris hip score, and the Hip injury and Osteoarthritis Outcome Score or the revision rate at 10 years. We believe that the small sample size of

TABLE III Comparison of Patient-Reported Outcome Measures*

Patient-Reported Outcome Measure	Cementless and Hybrid THAs			Cementless-Only THAs		
	Computer-Guided	Non-Computer-Guided	P Value†	Computer-Guided	Non-Computer-Guided	P Value†
Oxford Hip Score (0 to 48)						
Paired records *(no.)*	355	10,454		316	7,681	
Preop. score	19.4 (18.6-20.2)	18.2 (18.1-18.4)		19.7 (18.8-20.6)	18.6 (18.4-18.7)	
6-mo score	41.3 (40.5-42.2)	39.9 (39.7-40.1)		41.5 (40.5-42.4)	40.3 (40.1-40.5)	
6-mo score, adjusted	40.5 (39.7-41.2)	39.7 (39.6-39.9)		40.4 (39.6-41.2)	39.8 (39.7-40.0)	
Health gain	21.9 (20.9-22.9)	21.7 (21.5-21.9)		21.8 (20.7-22.8)	21.8 (21.5-22.0)	
Health gain, adjusted	22.4 (21.7-23.2)	21.7 (21.5-21.8)	0.11	22.4 (21.6-23.2)	21.8 (21.7-22.0)	0.27
Score improved	97.2%	97.2%		97.2%	97.3%	
EQ-5D Index (−0.59 to 1.00)						
Paired records *(no.)*	329	9,643		297	7,119	
Preop. score	0.396 (0.362-0.430)	0.363 (0.357-0.369)		0.405 (0.368-0.441)	0.373 (0.366-0.380)	
6-mo score	0.829 (0.804-0.854)	0.802 (0.797-0.807)		0.830 (0.803-0.858)	0.808 (0.803-0.814)	
6-mo score, adjusted	0.814 (0.791-0.836)	0.798 (0.793-0.802)		0.811 (0.787-0.835)	0.799 (0.794-0.804)	
Health gain	0.433 (0.398-0.467)	0.439 (0.432-0.446)		0.426 (0.389-0.462)	0.435 (0.427-0.443)	
Health gain, adjusted	0.459 (0.437-0.481)	0.443 (0.438-0.447)	0.3	0.456 (0.433-0.480)	0.444 (0.439-0.450)	0.41
Score improved	92.1%	89.7%		91.6%	89.7%	
EQ-VAS (0 to 100)						
Paired records *(no.)*	317	9,212		286	6,817	
Preop. score	68.3 (66.0-70.6)	65.4 (64.9-65.8)		68.8 (66.3-71.2)	65.6 (65.1-66.1)	
6-mo score	79.7 (77.9-81.4)	77.9 (77.5-78.2)		79.5 (77.6-81.4)	78.6 (78.2-79.0)	
6-mo score, adjusted	78.0 (76.5-79.6)	77.6 (77.2-77.9)		77.7 (76.0-79.3)	77.9 (77.5-78.3)	
Health gain	11.3 (9.0-13.6)	12.5 (12.1-13.0)		10.8 (8.4-13.1)	13.0 (12.5-13.6)	
Health gain, adjusted	13.0 (11.5-14.6)	12.5 (12.2-12.9)	0.92	12.6 (11.0-14.3)	12.9 (12.5-13.3)	0.42
Score improved	67.2%	67.5%		66.1%	68.4%	

*Values are given as the mean and 95% CI, except as indicated. Adjusted scores correspond to the NHS Digital version 3 case-mix-adjustment model. This includes patient variables from PROMs, Hospital Episode Statistics, and the Index of Multiple Deprivation data. THA = total hip arthroplasty. †Mann-Whitney U test. The complete NJR Bespoke Implant Reports are available online[18,19].

their study makes it difficult to identify a difference in survival. Most clinical trials on computer-guided surgery and robotic-assisted THA in the literature have sample sizes of <200 cases[10,13]. In order to identify a difference in prosthetic joint survival with clinical trials, the sample size would have to be large. National database and registry studies are more likely to have the power to identify smaller differences in survivorship as the sample analyzed is much larger.

Our study failed to identify a significant difference in PROMs between the groups analyzed. The sample of patients with recorded PROMs in our study was smaller than the survivorship cohort, with 317 patients (286 in the cementless-only analysis) submitting pre- and postoperative EQ-VAS scores. This raises the possibility of the cohort being insufficiently powered to identify a difference in PROMs. Computer-guided surgery and robotic-arm haptic-system guidance have been shown to improve the precision of implantation of the acetabular component within a safe zone[8] and restoration of the native center of rotation and combined offset[7]. Whether this translates to improved PROMs, and to what extent, remains a topic for ongoing research[26]. In addition to the PROMs recorded, NHS Digital records a single-item satisfaction measure using wording and response scales consistent with the International Society of Arthroplasty Registries PROMs Working Group recommendations[27]. In our study, the response to the single-item satisfaction question was significantly higher in the computer-guided group.

Our study has several limitations. The type of computer-guidance system used during the study period was not recorded by the registry and therefore not included in our analysis. We did not have access to component-orientation data, and thus, we cannot comment on orientation differences between groups. The observational nature of registry data raises the possibility of unaccounted-for confounders, despite the statistical modeling. The number of surgeons in the computer-guided group was small and may represent a group of surgeons with characteristics different from the surgeons in the non-guided group, such as being concentrated in academic centers or receiving additional manufacturer support. In addition, the non-guided group was more likely to represent more varied (and hence representative) surgical expertise and skill. The small number of revisions in the computer-guided group (7) limited our ability to further analyze reasons for revision. Satisfaction rates (single-item satisfaction measure) were higher in the computer-guided group. As with all PROMs in our analysis, patients were not blinded to the technology used, and this should be considered when interpreting the results. When surgeons use both computer-guided and non-guided surgery, selection bias applies. In addition, the threshold to revise THAs may be different when computer guidance was used at the time of the primary procedure. We have analyzed THAs using components by a single manufacturer, and therefore the results might not be generalizable to all THAs in the registry. We believe that by restricting the analysis to components from a single manufacturer, the effect of component design features was less likely to affect our results. The independent nature of the reports on which our manuscript is based meant that the methodology was decided a priori, and subsequent analyses were not possible. We believe that further analysis of the complete NJR data set and other registries is justified to validate our findings.

Conclusions

The use of computer-guided surgery was associated with a reduced rate of revision in this manufacturer-specific analysis of registry data at a mean follow-up of 5.6 years. The response to the single-item satisfaction measure was higher in the computer-guided group, although the patients were not blinded. Causality cannot be inferred, as our study was observational in nature and cannot account for unmeasured confounders. If confirmed, the reduced risk of revision is valuable information for future health economics studies investigating the cost-effectiveness of the technology. We recommend further clinical trials and database/registry studies to investigate the effects of computer-guided surgery on prosthetic joint survival. Areas of interest for future research include patients at high risk for dislocation, such as patients identified through spinopelvic assessment. Computer-guided surgery should also be evaluated against new and increasingly popular technologies, such as dual-mobility bearings or large-head THA components. ■

Edward T. Davis, FRCS(Tr&Orth)[1,2]
Kerren D. McKinney, MSc[3]
Amir Kamali, PhD[3]
Selena Kuljaca, PhD[3]
Joseph Pagkalos, FRCS(Tr&Orth)[1]

[1]The Royal Orthopaedic Hospital NHS Foundation Trust, Birmingham, United Kingdom

[2]Institute of Inflammation and Ageing, University of Birmingham, Birmingham, United Kingdom

[3]Smith & Nephew plc, Watford, United Kingdom

Email for corresponding author: pagkalos@doctors.org.uk

References

1. Paul HA, Bargar WL, Mittlestadt B, Musits B, Taylor RH, Kazanzides P, Zuhars J, Williamson B, Hanson W. Development of a surgical robot for cementless total hip arthroplasty. Clin Orthop Relat Res. 1992 Dec;(285):57-66.

2. Bargar WL, Parise CA, Hankins A, Marlen NA, Campanelli V, Netravali NA. Fourteen year follow-up of randomized clinical trials of active robotic-assisted total hip arthroplasty. J Arthroplasty. 2018 Mar;33(3):810-4. Epub 2017 Oct 6.

3. Kalteis T, Handel M, Bäthis H, Perlick L, Tingart M, Grifka J. Imageless navigation for insertion of the acetabular component in total hip arthroplasty: is it as accurate as CT-based navigation? J Bone Joint Surg Br. 2006 Feb;88(2):163-7.

4. Pagkalos J, Chaudary MI, Davis ET. Navigating the reaming of the acetabular cavity in total hip arthroplasty: does it improve implantation accuracy? J Arthroplasty. 2014 Sep;29(9):1749-52. Epub 2014 Apr 5.

5. Davis ET, Schubert M, Wegner M, Haimerl M. A new method of registration in navigated hip arthroplasty without the need to register the anterior pelvic plane. J Arthroplasty. 2015 Jan;30(1):55-60. Epub 2014 Sep 6.

6. Nodzo SR, Chang CC, Carroll KM, Barlow BT, Banks SA, Padgett DE, Mayman DJ, Jerabek SA. Intraoperative placement of total hip arthroplasty components with robotic-arm assisted technology correlates with postoperative implant position: a CT-based study. Bone Joint J. 2018 Oct;100-B(10):1303-9.

7. Kayani B, Konan S, Thakrar RR, Huq SS, Haddad FS. Assuring the long-term total joint arthroplasty: a triad of variables. Bone Joint J. 2019 Jan;101-B(1_Supple_A):11-8.

8. Domb BG, Redmond JM, Louis SS, Alden KJ, Daley RJ, LaReau JM, Petrakos AE, Gui C, Suarez-Ahedo C. Accuracy of component positioning in 1980 total hip arthroplasties: a comparative analysis by surgical technique and mode of guidance. J Arthroplasty. 2015 Dec;30(12):2208-18. Epub 2015 Jul 2.

9. Potter BK. From bench to bedside: robotics and navigation in orthopaedics-rise of the machines or just rising costs? Clin Orthop Relat Res. 2019 Apr;477(4):692-4.

10. Chen AF, Kazarian GS, Jessop GW, Makhdom A. Robotic technology in orthopaedic surgery. J Bone Joint Surg Am. 2018 Nov 21;100(22):1984-92.

11. Najarian BC, Kilgore JE, Markel DC. Evaluation of component positioning in primary total hip arthroplasty using an imageless navigation device compared with traditional methods. J Arthroplasty. 2009 Jan;24(1):15-21. Epub 2008 Apr 3.

12. Parratte S, Ollivier M, Lunebourg A, Flecher X, Argenson JNA. No benefit after THA performed with computer-assisted cup placement: 10-year results of a randomized controlled study. Clin Orthop Relat Res. 2016 Oct;474(10):2085-93.

13. Xu K, Li YM, Zhang HF, Wang CG, Xu YQ, Li ZJ. Computer navigation in total hip arthroplasty: a meta-analysis of randomized controlled trials. Int J Surg. 2014;12(5):528-33. Epub 2014 Feb 27.

14. Bohl DD, Nolte MT, Ong K, Lau E, Calkins TE, Della Valle CJ. Computer-assisted navigation is associated with reductions in the rates of dislocation and acetabular component revision following primary total hip arthroplasty. J Bone Joint Surg Am. 2019 Feb 6;101(3):250-6.

15. Novikov D, Mercuri JJ, Schwarzkopf R, Long WJ, Bosco JA Iii, Vigdorchik JM. Can some early revision total hip arthroplasties be avoided? Bone Joint J. 2019 Jun;101-B(6_Supple_B):97-103.

16. Bolland BJRF, Culliford DJ, Langton DJ, Millington JPS, Arden NK, Latham JM. High failure rates with a large-diameter hybrid metal-on-metal total hip replacement: clinical, radiological and retrieval analysis. J Bone Joint Surg Br. 2011 May;93(5):608-15.

17. National Joint Registry. H2 hip revision data collection form MDS v7.0. Accessed 2021 Feb 27. https://www.njrcentre.org.uk/NJRCentre/Portals/0/MDSv7.0_03_2020/MDSv7_0%20H2%20V4_0.pdf

18. Bespoke Implant Report - Smith & Nephew cementless acetabular component THAs. https://www.smith-nephew.com/Documents/Education%20and%20Evidence/Literature/2021/Comparison_Report_HP_Computer%20Guidance%20All%20SN%20cementless%20cups%20V6_18-05-20.pdf

19. Bespoke Implant Report - Smith & Nephew fully cementless THAs. https://www.smith-nephew.com/Documents/Education%20and%20Evidence/Literature/2021/Comparison_Report_HP_Computer%20guidance%20in%20selected%20SN%20hips%20V5_18-05-20.pdf

20. Davis ET, Pagkalos J, Kopjar B. Effect of bearing surface on survival of cementless and hybrid total hip arthroplasty: study of data in the National Joint Registry for England, Wales, Northern Ireland and the Isle of Man. JB JS Open Access. 2020 May 15;5(2):e0075.

21. Kandala NB, Connock M, Pulikottil-Jacob R, Sutcliffe P, Crowther MJ, Grove A, Mistry H, Clarke A. Setting benchmark revision rates for total hip replacement: analysis of registry evidence. BMJ. 2015 Mar 9;350:h756.

22. PROMs Analytical Team. NHS Digital. Finalised Patient Reported Outcome Measures (PROMs) in England for hip & knee replacements, April 2018 – March 2019. 2020 Feb 13. Accessed 2020 May 30. https://digital.nhs.uk/data-and-information/publications/statistical/patient-reported-outcome-measures-proms/finalised-hip–knee-replacements-april-2018—march-2019

23. Beard DJ, Harris K, Dawson J, Doll H, Murray DW, Carr AJ, Price AJ. Meaningful changes for the Oxford hip and knee scores after joint replacement surgery. J Clin Epidemiol. 2015 Jan;68(1):73-9. Epub 2014 Oct 31.

24. Secondary Care Analysis (PROMs). NHS Digital. Patient Reported Outcome Measures (PROMs) in England. A guide to PROMs methodology. 2017. Accessed 2021 Apr 29. https://digital.nhs.uk/binaries/content/assets/legacy/pdf/g/t/proms_guide_v12.pdf

25. Gausden EB, Popper JE, Sculco PK, Rush B. Computerized navigation for total hip arthroplasty is associated with lower complications and ninety-day readmissions: a nationwide linked analysis. Int Orthop. 2020 Mar;44(3):471-6. Epub 2020 Jan 9.

26. U.S. National Library of Medicine. An evaluation of health outcomes for Mako hip replacement (HELLO). 2019 Feb 20. Accessed 2019 Oct 30. https://clinicaltrials.gov/ct2/show/NCT03846791

27. Rolfson O, Bohm E, Franklin P, Lyman S, Denissen G, Dawson J, Dunn J, Eresian Chenok K, Dunbar M, Overgaard S, Garellick G, Lübbeke A; Patient-Reported Outcome Measures Working Group of the International Society of Arthroplasty Registries. Patient-reported outcome measures in arthroplasty registries. Report of the Patient-Reported Outcome Measures Working Group of the International Society of Arthroplasty Registries Part II. Recommendations for selection, administration, and analysis. Acta Orthop. 2016 Jul;87(Suppl 1):9-23. Epub 2016 May 26.