Arthroplasty Today 29 (2024) 101414

Contents lists available at ScienceDirect

Arthroplasty Today

journal homepage: http://www.arthroplastytoday.org/

Original Research

Robotic Arm—Assisted Total Knee Arthroplasty Results in Smaller Femoral Components and Larger Tibial Baseplates Than the Manual Technique

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ARTICLE INFO

Article history:
Received 17 December 2023
Received in revised form
20 March 2024
Accepted 28 April 2024
Available online 9 August 2024

Keywords:
Robotic arm
Robotic surgery
Total knee arthroplasty
Computed tomography
Three-dimensional planning
Patient-specific

ABSTRACT

Background: Robotic systems for total knee arthroplasty (TKA) may utilize computed tomography three-dimensional modeling and intraoperative ligamentous balancing data to assist surgeons with implant size and position. This study evaluated the effect of such robotic systems on implant selection.
Methods: We reviewed 645 TKAs performed with a single prosthetic design at 2 academic medical centers between 2016 and 2022. A robotic system was utilized in 304 TKAs, 341 were conventionally instrumented. Implant sizing was compared between cohorts. Multivariate analyses assessed for confounding and effect modification on the basis of demographics.
Results: The 2 cohorts exhibited no significant differences in age ($P = .33$), weight ($P = .29$), or race ($P = .24$). The robotic-arm cohort had fewer women (58.9% vs 66.7% $P = .04$) and was taller on average (66.3 in vs 65.0 in $P < .001$). Mean polyethylene liner thickness was larger in the manual cohort (10.3 robotic and 10.6 manual; $P < .00$). On multivariate analysis, robotic-arm TKAs had larger tibial components ($P < .001$) and smaller femoral components ($P = .017$).
Conclusions: Robotic-arm assisted TKA with computed tomography—based three-dimensional planning was associated with a larger mean tibial component size and a smaller mean femoral component size when compared to conventionally instrumented TKAs. Observed differences likely reflect differences in the data informing implant size selection; effects on clinical outcomes warrant further study.

Introduction

Computed tomography (CT)-guided, robotic arm—assisted total knee arthroplasty (TKA) was introduced to improve accuracy in TKA by personalizing implant positioning and optimizing ligamentous balancing with the use of bony cuts and implant selection [1]. Robotic arm—assisted TKA may improve component selection size and position.

Appropriate implant selection, position, recreation of native joint biomechanics, and maximizing bony preservation, particularly in younger patients, are key components to improved patient outcomes and may be optimized through three-dimensional (3D) CT-based robotic arm—assisted TKA. The preoperative 3D plan created from CT imaging can optimize component size and position to avoid femoral notching, tibial or femoral bony overhang, and incomplete resection of bone surfaces [2]. Ligamentous balancing data may provide the ability to achieve more natural biomechanics by personalizing implant size and position to optimize gap balancing with the help of bony cuts, minimizing the need for soft-tissue releases, and reducing the incidence of postoperative instability.

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https://doi.org/10.1016/j.artd.2024.101414
2352-3441/

A properly sized and positioned femoral component approximates femoral condylar geometry to optimize knee biomechanics [3]. When using a single radius of curvature design, robotic arm control over femoral component flexion often results in a choice between 2 femoral sizes that can restore posterior condylar offset while avoiding notching of the femoral cortex. While larger femoral components may optimize coverage of cut bone, smaller femoral components allow lateralization of the implant as needed to optimize trochlear groove position and patellar tracking [4] and can avoid implant overhang.

Maximizing tibial baseplate size may optimize bony coverage and improves functional outcomes if tibial components are positioned in appropriate rotational alignment [5]. Appropriate rotational alignment also reduces aseptic loosening, the most common cause of postoperative implant failure in TKA [6].

This study investigated if component size varies in robotic arm—assisted primary TKA compared with manual TKA. Secondary questions examined if polyethylene liner thickness differs in robotic arm—assisted TKA compared with manual TKA. Surgeons' experience in visualizing implants overlayed over the 3D bony model led to the hypothesis that in primary robotic arm—assisted TKA, the tibial baseplate would be on average larger than that with manual TKA when accounting for patient demographics. With regard to the femoral component, an undersized component may increase the risk of femoral notching, whereas an oversized component may limit range of motion and cause discomfort [2]. An optimized femoral implant is one that would allow for maximal range of motion without compromising knee stability or impact forces during mechanical loading. In robotic arm—assisted TKA, it is possible to integrate ligamentous balancing data with implant position in order to approximate normal condylar geometry. This led to the secondary hypothesis that the femoral implant would differ with robotic arm—assisted TKA compared with traditional manual methods and that due to the improved modeling of ligamentous stability and the ability to avoid notching through femoral component flexion, the average femoral size with the robotic arm—assisted procedure was likely to be smaller. Finally, as ligament balancing data allow measurement of ligamentous laxity before bony resection, we further hypothesized that the mean polyethylene liner thickness would be smaller in robotic arm—assisted TKA.

Material and methods

This retrospective cohort study included all adult patients with symptomatic knee arthritis who underwent primary TKA using a specific brand of TKA implant (Triathlon; Stryker, Kalamazoo, MI) components with or without a specific robotic system (Mako; Stryker, Fort Lauderdale, FL) at 2 institutions between 2016 and 2022. The work was approved by the primary institution's institutional review board under submission #i21-01626, and institutional review board exemption was granted by the secondary institution, protocol ID 2000032115. Patients were identified via electronic medical record query. TKA procedures completed with the robotic system were designated the "robotic" cohort. TKA procedures completed utilizing conventional instrumentation were designated as the "manual" cohort.

Surgical data collected included surgical technique (manual or robotic arm assisted), size and type of the femoral component, size and type of the tibial component, and thickness of the polyethylene liner. Patients with incomplete data were excluded (Table 1). A total of 17 surgeons between institutions contributed patients. There were a mix of surgeons at each location that did all robotic total knees, a mix of robotic and manual total knees, and all manual total knees. Planned femoral flexion was at the discretion of the surgeon, as was combined flexion.

Surgical technique

Robotic arm assisted TKA

Robotic arm—assisted cases were performed using a robotic arm equipped with a sagittal power saw, controlled by the surgeon within the boundaries defined by haptic robotic system guidance. The system is guided by image-based navigation using a CT-based 3D bone model and a surgical plan with optical tracking arrays rigidly fixed to the femur and tibia for intraoperative component positioning and alignment [2]. The robotic system has a rigid arm that positions a sagittal saw blade at precise locations within the computer model's resection planes, while saw oscillation is controlled by the physician. Component position, alignment, and soft-tissue balance data can be collected during and at the end of the procedure. This allows for intraoperative modification of component positioning to assist with soft-tissue balancing based on gap measurement.

Manual TKA

Manual TKAs were performed via a medial parapatellar approach utilizing standard instrumentation. Femoral resection was performed with the femoral alignment guide and universal resection guide, with the magnitude of femoral resection increased or decreased at surgeon discretion. Femoral sizing was assessed initially with the femoral sizer, corrected for side, and confirmed later with trial implants. Anterior cortex, posterior condyle, and chamfer cuts were made with the standard cutting block. The decision between using cruciate retaining (CR) or posterior stabilized (PS) femoral components was made at the discretion of the operative surgeon. For PS knees, an appropriately sized box cutting guide was used. The extramedullary tibial resection guide was utilized for tibial preparation, with adjustments made for medial/lateral offset and tibial slope (0° or 3°). Tibial resection was performed with standard 9-mm and 2-mm styli. Adjustments were made to control for the amount of tibial bone resected. Patellar resurfacing was not standardized and was performed at surgeon discretion.

Statistical analyses

A Shapiro-Wilk test was used to determine data normality. Univariate analyses were conducted with Student's *t*-test and Pearson's chi-squared for normally distributed data. A Wilcoxon rank-sum (Mann-Whitney) test was used for nonparametric data. Multivariate analyses assessed for confounding and effect modification. Poisson modeling was used for multivariate analyses with

Table 1
Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
1. Skeletally mature patients (18 years or older)	1. Incomplete data: - No record TKA type (manual, robotic) - Incomplete demographic information - Incomplete implant information
2. Underwent total knee arthroplasty (TKA) at participating site within study timeframe	2. Unable to complete follow-up
3. Utilized Stryker Triathlon components	

TKA, total knee arthroplasty.

heteroskedasticity. Multicollinearity was assessed, and an interaction term was included to account for the observed relationship between implant size and patient height on multivariate modeling. Variance-covariance matrix of estimators was assessed and was robust. A *P*-value of .05 was established for statistical significance. All analyses were conducted using STATA MP version 16 (StataCorp LLC, College Station, TX).

The primary outcome evaluated was tibial and femoral component size. Secondary outcomes included polyethylene liner thickness and type. Implant size (tibial size 1-8, femur size 1-8, and polyethylene liner thickness 9-19 mm) was treated as a categorical variable. Sub-cohort analyses were conducted by gender and technique (CR and PS).

Results

There were 645 patients included in analyses: 341 in the manual and 304 in the robotic arm—assisted cohort. By technique, 174 knees were completed by PS, and 471 were completed by CR. Patient data, including age, gender, patient height, weight, and race, were collected. The robotic arm cohort had a somewhat lower proportion of women (58.9% vs 66.7%, $P = .04$), and the mean height was accordingly slightly greater in the robotic cohort (66.3″ vs 65.0″, $P < .00$; Table 2). There were no significant differences between cohorts with regard to patient age ($P = .33$), weight ($P = .29$), or race ($P = .24$; Table 2). Robotic arm—assisted knees were primarily CR (90.1%), whereas manual knees were both PS (42.2%) and CR (57.8%; Table 2). On univariate analysis, the mean tibial component size was significantly larger in the robotic cohort (4.3 robotic and 3.9 manual; $P = .01$; Table 2). Notably, the mean femoral component size was also significantly larger in the robotic cohort, 4.4 robotic vs 4.2 manual on univariate analysis, although this may be due to confounding as it contradicts the multivariate analysis ($P < .00$; Table 2). The mean polyethylene liner thickness was larger in the manual cohort (10.3 robotic vs 10.6 manual; $P < .00$; Table 2).

The robotic arm—assisted cohort had a greater percentage of knees in which both the femoral and tibial components were of the same size, 64% of the time for robotics and 50% for manual (Fig. 1). Concomitantly, the manual cohort had a larger femoral component compared with the tibial component a greater percentage of the time (40% manual vs 25% robotic). On rank sum test, these groups differed significantly, $P < .00$ (Fig. 1).

Component size and patient height were included as an interaction term in multivariate analysis due to observed collinearity. On multivariate analysis, TKAs performed via robotic arm assistance had larger tibial components ($P < .00$) and smaller femoral components ($P = .02$; Table 3). Femoral component size and patient height significantly predicated tibial component size; tibial component size and patient height significantly predicted femoral component size (Table 3). Women had a significantly smaller tibial component size ($P < .00$), and older patients had a significantly larger tibial components ($P < .00$; Table 3). On multivariate analysis that accounted for patient height, weight significantly predicted the larger tibial component size ($P < .00$) and larger femoral component size ($P < .00$; Table 3). On multivariate analysis, no tested metric (robotic or manual technique, weight, femur/tibia component size, patient height, age, gender) was significantly predictive of polyethylene liner thickness or type (CR vs PS).

When stratified by gender, multivariate analysis demonstrated that both men and women had larger tibial components when robotic TKA was performed ($P < .00$ and $P = .02$, respectively), and women had smaller femoral components ($P = .03$) with robotic surgery (Table 4). For both men and women, femoral component size and patient height were significantly predictive of tibial component size, and tibial component size and patient height were significantly predictive of femoral component size (Table 4).

Within the PS sub-cohort, robotic surgery was significantly predictive of a smaller femoral component size ($P = .049$; Table 5), although this included only 174 patients. Within the cruciate-retaining cohort, robotic surgery was significantly predictive of a larger tibial component size ($P = .001$; Table 6), which included 471 observations.

Discussion

To our knowledge, this study is the first to examine the effect of image-based robotic systems on implant sizing in TKA. This study suggests that a robotic arm—assisted technique with implant size selection informed by 3D CT planning resulted in the selection of larger tibial implants, which may maximize bone coverage, and

Table 2
Patient demographics and treatment modality.

	Manual	Robotic	*P*-value	Test
N	341	304		
Gender: Women, n (%)	227 (66.7)	179 (58.9)	**.04**	Chi2
Age, mean (range)	66.7 (35-89)	66 (38-87)	.33	*t*-test
BMI, mean (range)	32.4 (19.2-55.7)	31.3 (20.4-47.2)	**<.00**	Mann-Whitney
Height (in), mean (range)	65.1 (55-78)	66.3 (56-77)	**<.00**	Mann-Whitney
Women (in), mean (range)	63.0 (55-72)	63.8 (56-72)	**<.00**	*t*-test
Men (in), mean (range)	69.2 (60-78)	69.7 (64-75)	.22	*t*-test
Weight (lbs), mean (range)	198.8 (110-340)	195.9 (112-320)	.29	Mann-Whitney
Race, n (%)			.24	Chi2
Black	42 (12.3)	36 (11.8)		
Asian	13 (3.8)	4 (1.3)		
White	240 (70.4)	226 (74.3)		
Other/unknown	46 (13.5)	38 (12.5)		
PS or CR, n (%)			**<.00**	Chi2
Posterior stabilized	144 (42.2)	30 (9.9)		
Cruciate retaining	197 (57.8)	274 (90.1)		
Implant size				
Tibia size, mean (SD)	3.9 (1.4)	4.3 (1.7)	**.01**	ANOVA
Femur size, mean (SD)	4.2 (1.3)	4.4 (1.6)	**<.00**	ANOVA
Polyethylene liner size (mm), mean (SD)	10.6 (1.9)	10.3 (1.6)	**<.00**	ANOVA

ANOVA, analysis of variance; BMI, body mass index; CR, cruciate retaining; PS, posterior stabilized.
Values of significance are bolded.

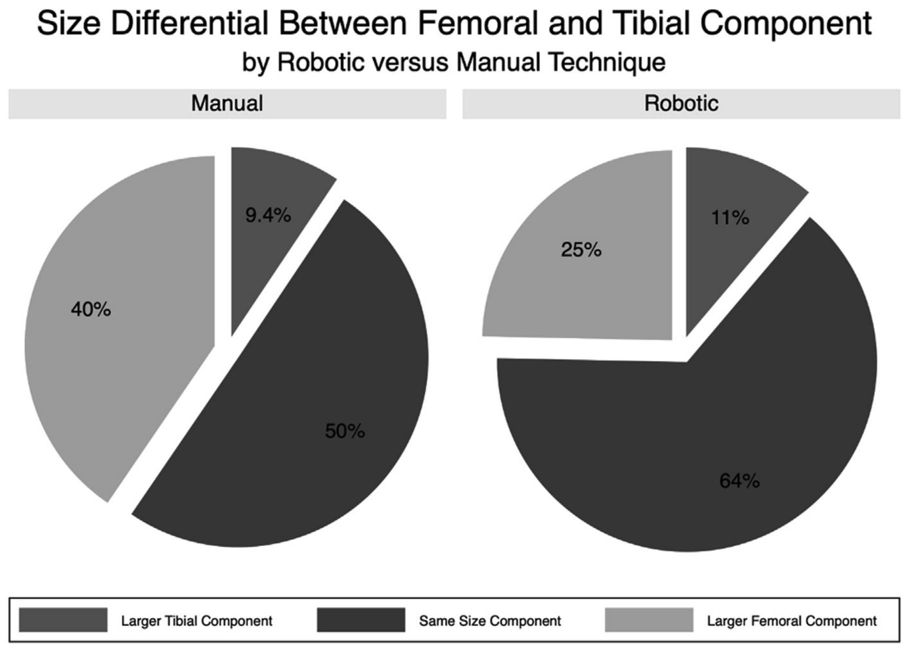

Figure 1. This figure compares the relative size of the femoral to tibial component when stratified by manual vs robotic technique. Notably, the robotic cohort had same-sized components a greater percentage of the time (64% vs 50% manual) and concomitantly a larger femoral component for a smaller percentage of the time (25% vs 40% manual). On rank sum test, these groups differ significantly, $P < .00$.

smaller femoral components, which may better recreate the natural biomechanics of the knee, minimize overhang, and allow lateralization to improved patellar tracking. We hypothesize that femoral components are smaller within the robotic cohort because we are better able to manipulate the position of the component, safely adding more rotation or flexion, thereby allowing for smaller resection depths. In addition, robotics may allow for better planning with the anterior femoral cut, helping prevent overstuffing of the patellofemoral compartment.

Table 3
Multivariate regression of total knee arthroplasty implant size with respect to manual vs robotic technique.

Characteristic	Impact	95% CI	*P* value
Larger tibial component			
Robotic	0.04	0.02, 0.06	**<.00**
Femoral component/Height			
Femur 1-2, height 65″-78″	0.28	0.07, 0.49	**<.01**
Femur 3, height 55″-65″	0.43	0.33, 0.52	**<.00**
Femur 3, height 65″-78″	0.50	0.37, 0.63	**<.00**
Femur 4, height 55″-65″	0.64	0.55, 0.74	**<.00**
Femur 4, height 65″-78″	0.71	0.61, 0.80	**<.00**
Femur 5-6, height 55″-65″	0.85	0.76, 0.95	**<.00**
Femur 5-6, height 65″-78″	0.90	0.81, 0.99	**<.00**
Femur 7-8, height 65″-78″	1.14	1.04, 1.24	**<.00**
Weight (lbs)	0.001	0.00, 0.001	**<.00**
Patient age	0.002	0.001, 0.004	**<.00**
Women	−0.15	−0.19, −0.12	**<.00**
Larger femoral component			
Robotic	−0.03	−0.052, −0.005	**.02**
Tibial component/Height			
Tibia 1-2, height 65″-78″	−0.17	−0.22, −0.11	**<.00**
Tibia 3, height 55″-65″	0.32	0.27, 0.38	**<.00**
Tibia 3, height 65″-78″	0.37	0.29, 0.46	**<.00**
Tibia 4, height 55″-65″	0.54	0.48, 0.60	**<.00**
Tibia 4, height 55″-65″	0.58	0.52, 0.64	**<.00**
Tibia 5-6, height 55″-65″	0.04	0.65, 0.79	**<.00**
Tibia 5-6, height 65″-78″	0.78	0.71, 0.85	**<.00**
Tibia 7-8, height 65″-78″	1.03	0.96, 1.09	**<.00**
Weight (lbs)	0.001	0.00, 0.001	**<.00**
Patient age	0.001	−0.001, 0.002	.25
Women	−0.03	−0.064, 0.006	.11

On multivariate modeling, a multicollinearity assessment revealed a collinear relationship between the implant size and patient height. As such, an interaction term was included to account for this effect [18]. As such, the data are presented in normally-distributed height groupings (eg, height 65″-78″) to account for the fact that height is a continuous variable. Values of significance are bolded.

CT-based preoperative planning for TKAs has been gaining acceptance for its accurate preoperative predictions of femoral and tibial component size. A recent study examining CT-based preoperative planning for implant size selection found 99% intraobserver agreement within one size for femoral component selection and 90% intraobserver agreement within one size for tibial component selection [7]. Two-dimensional preoperative templating utilizing preoperative radiographs alone has also been shown to have high intraobserver reliability up to 90% within one size [8]. However, within the extant data, there is a broad spread of preoperative reliability demonstrated, particularly with relation to the accuracy of sizing-marker placement on radiographs and magnification error that is overcome with CT-based planning [9]. Cost also remains a factor; robotic arm–assisted TKAs expensive compared with the manual technique but may have improved cost-effectiveness for quality of life–adjusted measures [10].

Robotic arm–assisted TKA has also gained traction for its value in achieving optimal coronal alignment [11-13] and its potential for improved intraoperative compartment balancing [14]. A 2020 cohort of 60 robotic arm–assisted vs traditional TKAs found that robotic arm–assisted TKAs had significantly improved accuracy of tibial and femoral implant positioning without increased postoperative complication risk [15]. A 2020 systematic review of robotic arm–assisted TKA which reported on 11 studies that commented on implant placement with robotic arm–assisted TKAs demonstrated a decrease in technical errors; improvements in component positioning including tibial slope, tibial alignment, and decreased variance; and improvements in varus knee deformity correction [16]. Optimization of tibial and femoral component sizing, in conjunction with improved accuracy and improvement in

Table 4
Regression model of total knee arthroplasty implant size with respect to manual vs robotic technique—by gender.

Characteristic	Impact	95% CI	*P* value
Women			
Larger tibial component			
Robotic	0.13	0.02, 0.25	**.02**
Femur size/Height (In)			
Size 1-2, 65″-78″	0.58	0.06, 1.11	**.03**
Size 3, 55″-65″	0.95	0.76, 1.14	**<.00**
Size 3, 65″-78″	1.32	0.87, 1.77	**<.00**
Size 4, 55″-65″	1.60	1.40, 1.80	**<.00**
Size 4, 65″-78″	1.88	1.65, 2.11	**<.00**
Size 5-6, 55″-65″	2.46	2.20, 2.72	**<.00**
Size 5-6, 65″-78″	2.60	2.33, 2.86	**<.00**
Size 7-8, 65″-78″	4.99	4.17, 5.81	**<.00**
Weight (lbs)	0.002	0.001, 0.004	**<.01**
Patient age	0.009	0.19, 1.38	**<.01**
Larger femoral component			
Robotic	−0.13	−0.25, −0.01	**.03**
Tibia size/Height (In)			
Size 1-2, 65″-78″	−0.36	−1.04, 0.31	.29
Size 3, 55″-65″	0.87	0.71, 1.04	**<.00**
Size 3, 65″-78″	1.10	0.82, 1.37	**<.00**
Size 4, 55″-65″	1.68	1.48, 1.87	**<.00**
Size 4, 65″-78″	1.89	1.67, 2.11	**<.00**
Size 5-6, 55″-65″	2.49	2.14, 2.82	**<.00**
Size 5-6, 65″-78″	2.581	2.84, 2.88	**<.00**
Size 7-8, 65″-78″	5.378	4.21, 2.88	**<.00**
Weight (lbs)	0.003	0.001, 0.004	**<.00**
Patient age	0.006	−0.001, 0.01	.15
Men			
Larger tibial component			
Robotic	0.25	0.083, 0.41	**<.00**
Femur size/Height (In)			
Size 3, 55″-65″	1.16	−0.61, 2.92	.19
Size 3, 65″-78″	0.95	−0.58, 2.48	.22
Size 4, 55″-65″	2.37	1.06, 3.67	**<.00**
Size 4, 65″-78″	2.35	1.08, 3.63	**<.00**
Size 5-6, 55″-65″	3.01	1.72, 4.30	**<.00**
Size 5-6, 65″-78″	3.33	2.08, 4.59	**<.00**
Size 7-8, 65″-78″	4.74	3.47, 6.01	**<.00**
Weight (lbs)	0.003	0.001, 0.005	**<.01**
Patient age	0.008	−0.002, 0.02	.32
Larger femoral component			
Robotic	−0.01	−0.28, 0.09	.31
Tibia size/Height (In)			
Size 3, 55″-65″	0.84	−1.11, 2.78	.40
Size 3, 65″-78″	0.88	−0.81, 2.56	.31
Size 4, 55″-65″	2.15	0.71, 3.59	**<.00**
Size 4, 65″-78″	2.22	0.81, 3.62	**<.00**
Size 5-6, 55″-65″	3.020	2.14, 2.82	**<.00**
Size 5-6, 65″-78″	3.33	1.95, 4.72	**<.00**
Size 7-8, 65″-78″	4.845	3.44, 6.25	**<.00**
Weight (lbs)	0.002	−0.001, 0.004	.20
Patient age	−0.001	−0.01, 0.009	.74

On multivariate modeling, a multicollinearity assessment revealed a collinear relationship between the implant size and patient height. As such, an interaction term was included to account for this effect [18]. As such, the data are presented in normally-distributed height groupings (eg, height 65″-78″) to account for the fact that height is a continuous variable. Values of significance are bolded.

component positioning from robotic arm–assisted TKAs, is a potential avenue to improve results of TKAs. An optimally patient-matched implant size in appropriate position should result in improved ligament balance with fewer releases, hopefully leading to faster recovery time and improved knee kinematics with better long-term function.

Limitations to this study include its retrospective nature and lack of patient outcome data. Due to the retrospective nature, there was considerable variability that existed between the groups, including the use of CR vs PS, polyethylene type, anterior or posterior referencing, and the surgeon performing the surgery. As this was retrospective in nature, most of the surgeons performed either

Table 5
Poisson regression model of total knee arthroplasty implant size with respect to manual vs robotic technique—for posterior stabilized cohort total: 174 observations.

Characteristic	Impact	95% Confidence interval		*P*-value
Tibial component size				
Robotic	0.027	−0.03	0.353	.084
Femur size/Height (In)				
Size 1-2, 65″-78″	0.291	−0.089	0.134	.671
Size 3, 55″-65″	0.392	0.016	0.041	.767
Size 3, 65″-78″	0.539	0.165	0.005	.914
Size 4, 55″-65″	0.594	0.214	0.002	.974
Size 4, 65″-78″	0.732	0.352	0	1.111
Size 5-6, 55″-65″	0.834	0.46	0	1.208
Size 7-8, 65″-78″	1.031	0.651	0	1.41
Weight (lbs)	0	0	0.086	**.001**
Gender (M base)	−0.168	−0.228	0	−.107
Patient age	0.003	0.001	0.011	**.005**
Femoral component size				
Robotic	−0.003	0.917	−0.054	**.049**
Tibia size/Height (In)				
Size 3, 55″-65″	0.214	0	0.126	.301
Size 3, 65″-78″	0.278	0	0.154	.403
Size 4, 55″-65″	0.423	0	0.335	.511
Size 4, 65″-78″	0.42	0	0.324	.516
Size 5-6, 55″-65″	0.6	0	0.484	.716
Size 5-6, 65″-78″	0.685	0	0.578	.792
Size 7-8 65″-78″	0.883	0	0.764	1.002
Weight (lbs)	0.001	0.027	0	**.001**
Gender (M base)	0.014	0.645	−0.045	.073
Patient age	0	0.842	−0.002	**.002**

On multivariate modeling, a multicollinearity assessment revealed a collinear relationship between the implant size and patient height. As such, an interaction term was included to account for this effect [18]. As such, the data are presented in normally-distributed height groupings (eg, height 65″-78″ to account for the fact that height is a continuous variable. Male gender is the base case. Values of significance are bolded.

Table 6
Poisson regression model of total knee arthroplasty implant size with respect to manual vs robotic technique—for cruciate retaining cohort total: 471 observations.

Characteristic	Impact.		95% Confidence interval	*P*-value
Tibial component size				
Robotic	0.048	0.02	0.076	**.001**
Femur size/Height (In)				
Size 1-2, 65″-78″	0.288	0.079	0.496	**.007**
Size 3, 55″-65″	0.445	0.345	0.545	**.000**
Size 3, 65″-78″	0.508	0.356	0.66	**.000**
Size 4, 55″-65″	0.649	0.552	0.747	**.000**
Size 4, 65″-78″	0.716	0.616	0.817	**.000**
Size 5-6, 55″-65″	0.86	0.755	0.965	**.000**
Size 5-6, 65″-78″	0.897	0.798	0.995	**.000**
Size 7-8, 65″-78″	1.14	1.045	1.251	**.000**
Weight (lbs)	0.001	0	0.001	**.001**
Gender (M base)	−0.149	−0.186	−0.111	**.000**
Patient age	0.002	0.001	0.004	**.01**
Femoral component size				
Robotic	−0.026	−0.055	0.003	.083
Tibia size/Height (In)				
Size 1-2, 65″-78″	−0.134	−0.198	−0.07	**.000**
Size 3, 55″-65″	0.342	0.274	0.409	**.000**
Size 3, 65″-78″	0.391	0.283	0.499	**.000**
Size 4, 55″-65″	0.559	0.484	0.634	**.000**
Size 4, 65″-78″	0.616	0.546	0.687	**.000**
Size 5-6, 55″-65″	0.757	0.673	0.84	**.000**
Size 5-6, 65″-78″	0.795	0.716	0.873	**.000**
Size 7-8, 65″-78″	1.05	0.972	1.139	**.000**
Weight (lbs)	0	0	0.001	**.023**
Gender (M base)	−0.047	−0.091	−0.003	**.038**
Patient age	0.001	0	0.003	.166

On multivariate modeling, a multicollinearity assessment revealed a collinear relationship between the implant size and patient height. As such, an interaction term was included to account for this effect [18]. As such, the data are presented in normally-distributed height groupings (eg, height 65″-78″) to account for the fact that height is a continuous variable. Male gender is the base case. Values of significance are bolded.

manual or robotic TKA, but not both. These things all may impact implant sizing. In our sub-cohort study, both the CR and PS groups did show the same variation in sizing between manual and robotic TKA, which leads us to believe that our findings are independent of femoral implant type. A prospective randomized design may improve baseline differences between cohorts but raises ethical and patient discretionary concerns. Blinding in such studies would also be technically impossible to achieve, as surgeon participation would be required. In addition, because of the retrospective nature, we are unable to assess why surgeons made the choices of sizes or implant morphology collected in this dataset. Future prospective research may include linking these analyses to patient-reported objective and subjective outcome data and functional tests such as timed up and go or stair-climbing tests [17], as well as implant survivorship. The majority of available data pertains to early postoperative outcomes and clinical course [16]; future research may also wish to address long-term outcomes and whether image-based robotic systems add value over imageless robotic systems to justify the cost and radiation of preoperative CT scans.

Conclusions

Robotic arm–assisted TKA with 3D planning based on a preoperative CT scan resulted in selection of slightly larger tibial components and smaller femoral components relative to manual TKA using conventional instruments, particularly in women. These findings suggest possible benefits of CT-based 3D planning and robotic arm assistance, which may optimize TKA implant sizing and merit further investigation.

Funding

This study was funded by an investigator-initiated grant from Stryker Orthopedics.

Conflicts of interest

Authors of this article consult for a variety of companies, including Stryker, Smith & Nephew, and Depuy, and are on multiple Committee Leadership Positions, including American Association of Hip and Knee Surgeons, American Academy of Orthopaedic Surgeons, Eastern Orthopaedic Association, and Connecticut Orthopaedic Society.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2024.101414.

CRediT authorship contribution statement

Jenna Bernstein: Writing – review & editing, Validation, Supervision, Resources, Investigation, Funding acquisition, Data curation, Conceptualization. **Matthew Hepinstall:** Writing – review & editing, Visualization, Validation, Supervision, Methodology, Data curation, Conceptualization. **Claire Donnelley:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis. **Vinaya Rajahraman:** Project administration, Methodology, Data curation. **Daniel Waren:** Project administration, Investigation, Data curation. **Ran Schwarzkopf:** Writing – review & editing, Visualization, Validation, Supervision, Resources. **Daniel Wiznia:** Writing – review & editing, Validation, Supervision, Resources, Methodology, Data curation, Conceptualization.

Acknowledgments

The authors acknowledge Neelab Nasraty's assistance with chart review and data collection.

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