Analyzing Economics and Cost-Effectiveness of Robotic-Arm Assisted Total Knee Arthroplasty

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INTRODUCTION: Amidst a growing emphasis on cost-effectiveness in health care, this systematic review evaluates the economic implications of Computed Tomography (CT)-based robotic-arm assisted Total Knee Arthroplasty (TKA) and Uncompartmentalized Knee Arthroplasty (UKA), as compared to traditional surgical procedures. The primary aim is to analyze the 1) costs associated with these interventions, to understand their 2)economic impact, and to provide a comprehensive overview of the 3)cost-effectiveness of these robotic procedures.

METHODS: Twenty health economic studies comparing robotic-arm assisted (rJA) procedures with conventional techniques were reviewed. The evaluation thoroughly examined the methodologies of these studies, how they defined their economic impacts, which costs were included in their analysis, and from which stakeholder perspectives the costs were being analyzed.

RESULTS: In total, 83% of studies reported economic advantages with rJA. These include shorter stays (rTKA: 1.2 days versus 1.6 days, $P < 0.0001$; rUKA: 1.8 days versus 2 days, $P = 0.0047$), and 90-day care episode cost savings (rTKA: $14,189 versus $15,586, $P < 0.001$; rTKA 90-day EOC: $15,630 versus $17,721, $P < 0.001$). Lower 2-year revision rates for rUKA (0.81% versus 5.28%, $P = 0.002$) and fewer rTKA patients discharged to nursing facilities were noted.

DISCUSSION AND CONCLUSION: The review substantiates the cost-effectiveness of rJA in lower extremity arthroplasty, showcasing significant cost savings ($P < 0.05$) across care episodes, reduced length of hospital stays, decreased readmissions, and lower post-discharge service usage. This encourages future research to focus on cost mitigation strategies, enhanced patient outcomes, and the role of post-discharge cost impacts on rJA. Ultimately, the study highlights the potential for substantial payor benefits through the promotion of CT-based robotic technology.

Table 1. CT Scan-Guided, 3-Dimensional, Robotic-Arm Assisted Unicompartmental Knee Arthroplasty

	Cool et al. 2019	*Clement et al. 2019*
Analysis type	Commercial payor (US)	Markov model (UK)
Robot Cost Inclusion	No	Yes
CT-scan Cost Inclusion	No	Yes
M Total (n)	492	-
R Total (n)	246	-
LOS – M	2	
LOS – R	1.8	
Index procedure costs – M	$26,307	
Index procedure costs – R	$25,786	
Post D/C costs – M		
Post D/C costs – R		
90 day EOC cost – M		
90 day EOC cost – R		
% use of HH services – M		
% use of HH services - R		
# of HH visits – M		
# of HH visits – R		
cost of home health – M		
cost of home health – R		
outpatient rehab costs – M		
outpatient rehab costs – R		
revision % - M (1 year)	5.28%	1.10%
revision % - R (1 year)	0.81%	0.50%
Increase in QALYs – M		12.2
Increase in QALYs – R		13.59
ICER- R ($/QALY)		$1,298

manual; R: robot; LOS: length of stay; D/C: discharge; EOC: episode of care; HH: home healthcare; QALY: quality-adjusted life-year; ICER: incremental cost-effectiveness ratio

Table 2a. CT Scan-Guided, 3-Dimensional, Robotic-Arm Assisted Total Knee Arthroplasty

	Cotter et al. 2020	Mont et al. 2021	Pierce et al. 2020	Cool et al. 2019	Tompkins et al. 2022	Fang et al. 2022
Analysis type	Hospital (US)	Medicare (US)	Private payor (US)	Medicare (US)	Hospital (US)	Hospital (US)
Robot Cost Inclusion	Yes	No	No	No	Yes	Yes*
CT scan Cost Inclusion	No	No	No	No	No	No
M Total (n)	139	2,595	1,785	2,595	2,392	1,795
R Total (n)	147	519	357	519	2,392	263
90 day EOC cost - M	$17,721	$20,960	$32,253	$20,960		
90 day EOC cost - R	**$15,630**	**$18,568**	**$28,204**	**$18,568**	NA	NA
LOS-M	1.6	2.5	2.7	2.5	1.84	2.1
LOS-R	1.2	1.8	1.8	1.8	1.76	1.8
Index procedure costs - M	$15,586	$13,024	$24,069	$13,024	$16,330	X
Index procedure costs - R	$14,189	$12,384	$21,347	$12,384	$21,006	1.1X
Post D/C costs - M	$2,134	$6,978	$8,189	$6,978		
Post D/C costs - R	$1,441	$5,234	$6,857	$5,234		
% D/C to SNF/rehab - M	8.60%	21.70%	6.10%	28.20%	5.00%	6.30%
% D/C to SNF/rehab - R	4.10%	12.50%	1.70%	15.20%	5.00%	1.50%
Cost of SNF - M		$7,947				
Cost of SNF - R		$7,201				
% use of HH services - M		62.70%	69.20%		29.00%	
% use of HH services - R		61.30%	67.00%		38.00%	
# of HH visits - M		14		14.3		
# of HH visits - R		11.7		11.9		
Cost of home health - M		$3,536		$3,536		
Cost of home health - R		$3,045		$3,045		
Outpatient rehab costs - M	$746		$2,494			
Outpatient rehab costs - R	$802		$2,272			
Readmission-M (90d)	4.30%	7.80%		7.80%	4.90%	
Readmission-R (90d)	2.70%	5.20%		5.20%	1.20%	
Readmission avg costs - M	$305			$9,696		
Readmission avg costs - R	$73.37			$10,570		
% Utilizing ED in 90 days post D/C - M	7.90%	13.30%	9.00%	13.30%		
% Utilizing ED in 90 days post D/C - R	8.80%	11.20%	9.00%	11.20%		
ED costs in 90 days post D/C - M	$147	$736	$4,179	$736		
ED costs in 90 days post D/C - R	$57	$614	$7,033	$614		
Revision % - M (1 year)						
Revision % - R (1 year)						
In hospital PPFx - M	0.70%					
In hospital PPFx - R	0.00%					

M: manual; R: robot; LOS: length of stay; D/C: discharge; SNF: skilled nursing facility; EOC: episode of care; HH: home healthcare; QALY: quality-adjusted life-year; PPFx: periprosthetic fracture; ICER: incremental cost-effectiveness ratio
*Disposables included

Table 2b. CT Scan-Guided, 3-Dimensional, Robotic-Arm Assisted Total Knee Arthroplasty

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Analysis type	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Robot Cost Inclusion	Yes	No	No	Yes	Yes
CT scan Cost Inclusion	Yes	No	Yes	No	No
M Total (n)		[illegible]	[illegible]	[illegible]	
R Total (n)		[illegible]	[illegible]	[illegible]	
90 day EOC cost - M		[illegible]	[illegible]	[illegible]	[illegible]
90 day EOC cost - R		[illegible]	[illegible]	[illegible]	
LOS - M		[illegible]	[illegible]	[illegible]	
LOS - R		[illegible]	[illegible]	[illegible]	
Index procedure costs - M	[illegible]	[illegible]	[illegible]		[illegible]
Index procedure costs - R	[illegible]	[illegible]	[illegible]		[illegible]
Post D/C costs - M		[illegible]	[illegible]	[illegible]	[illegible]
Post D/C costs - R		[illegible]	[illegible]	[illegible]	[illegible]
% D/C to SNF/rehab - M				[illegible]	
% D/C to SNF/rehab - R				[illegible]	
Cost of SNF - M			[illegible]		
Cost of SNF - R			[illegible]		
% use of HH services - M		[illegible]			
% use of HH services - R		[illegible]			
# of HH visits - M					
# of HH visits - R					
Cost of home health - M		[illegible]	[illegible]		
Cost of home health - R		[illegible]	[illegible]		
Outpatient rehab costs - M		[illegible]			
Outpatient rehab costs - R		[illegible]			
Readmission-M (90d)		[illegible]			
Readmission-R (90d)		[illegible]			
Readmission avg costs - M			[illegible]		
Readmission avg costs - R			[illegible]		
% utilizing ED in 90 days post D/C - M					
% utilizing ED in 90 days post D/C - R					
Total discounted cost - M					[illegible]
Total discounted cost - R					[illegible]
Revision % - M (1 year)	[illegible]	[illegible]			
Revision % - R (1 year)	[illegible]	[illegible]			
In hospital PPFx - M		[illegible]			
In hospital PPFx - R		[illegible]			
Increase in QALYs - M	[illegible]				[illegible]
Increase in QALYs - R	[illegible]				[illegible]
ICER - R ($/QALY)	[illegible]				[illegible]

M: manual; R: robot; LOS: length of stay; D/C: discharge; SNF: skilled nursing facility; EOC: episode of care; HH: home healthcare; QALY: quality-adjusted life-year; PPFx: periprosthetic fracture; ICER: incremental cost-effectiveness ratio

Table 3. CT Scan-Guided, 3-Dimensional, Robotic-Arm Assisted Total Hip Arthroplasty

	Emara et al. 2021	Kirchner et al. 2021	Pierce et al. 2021	Clement et al. 2022	Barsoum et al. 2022	Maldonado et al. 2021
Analysis type	Nat'l Inpatient Sample (US)	Nat'l Inpatient Sample (US)	Medicare (US)	Markov model (UK)	Private payor (US)	Markov model (UK)
Robot Cost Inclusion	No	No	No	Yes	No	No
CT scan Cost Inclusion	No	No	No	Yes	Yes	No
M Total (n)	128,356	758	4,670	512	14,460	
R Total (n)	32,092	758	938	48	3615	555
90 day EOC cost - M			$20,519		$40,828	
90 day EOC cost - R			**$19,734**		**$39,062**	
LOS - M	2.3	2.8	2.5		1.8	
LOS - R	2.2	2.7	2.3		1.6	
Index procedure costs - M	$17,266	$18,258	$12,665	$6,895	$33,284	
Index procedure costs - R	$18,416	$20,046	$12,827	$8,579	$31,749	
Post D/C costs - M			$7,854		$7,544	
Post D/C costs - R			$6,907		$7,313	
Cost saving						$945
Private insurance saving						$1,810
% DC to SNF/rehab - M	18.50%		35.60%		1.80%	
% DC to SNF/rehab - R	17.40%		27.10%		1.60%	
% use of HH services - M			64.90%		30.00%	
% use of HH services - R			72.90%		35.10%	
Cost of home health - M					$373	
Cost of home health - R					$402	
% utilizing ED in 90 days post D/C - M		13.50%				
% utilizing ED in 90 days post D/C - R		13.60%				
ED costs in 90 days post D/C - M			$786			
ED costs in 90 days post D/C - R			$715			
Revision % - M (1 year)				0.39%		
Revision % - R (1 year)				0.39%		
In hospital PPFx - M	0.50%					
In hospital PPFx - R	0.20%					
Increase in QALYs - M						
Increase in QALYs - R				1.06		0.04
ICER - R ($/QALY)				$2,612		

M: manual; R: robot; LOS: length of stay; D/C: discharge; SNF: skilled nursing facility; EOC: episode of care; HH: home healthcare; QALY: quality-adjusted life-year; PPFx: periprosthetic fracture; ICER: incremental cost-effectiveness ratio

Table 4. Other Comparison Studies

	Kolessar et al. 2022	Varughese et al. 2022
	Hospital and private payor (US)	Hospital (AUS)
Robot Cost Inclusion	Yes	Yes
CT-scan Cost Inclusion	Yes	Yes
M UKA Total (n)	6	
M TKA Total (n)	58	120
R UKA Total (n)	19	120
R TKA Total (n)	85	
LOS – M UKA	1.6	
LOS – R UKA	1.4	
LOS – M TKA	1.8	
LOS – R TKA	1.8	
Average Saving for Robot		$7,179
In hospital costs – M UKA	$3,287	
In hospital costs – R UKA	$4,025	1.8
In hospital costs – M TKA	$4,087	4.8
In hospital costs – R TKA	$4,668	
90-day EOC cost – M UKA	$1,239	
90-day EOC cost – R UKA	$1,051	
90-day EOC cost – M TKA	$1,602	
90-day EOC cost – R TKA	$1,196	
% use of HH services – M UKA	83%	
% use of HH services – R UKA	17%	
% use of HH services – M TKA	29%	
% use of HH services – R TKA	6%	
# of HH visits – M UKA	5	
# of HH visits – R UKA	5	
# of HH visits – M TKA	17	
# of HH visits – R TKA	5	
Cost of home health – M	$609	
Cost of home health – R	$241	
Outpatient rehab costs – M	$482	
Outpatient rehab costs – R	$137	
Opioids – R UKA (MME)		125.0
Opioids- M TKA (MME)		522.1

D/C: discharge; EOC: episode of care; HH: home healthcare; QALY: quality-adjusted life-year; ICER: incremental cost-effectiveness ratio; MME: morphine milligram equivalent.