Appendix

Davies A, *et al. BMJ Open* 2025; 15:e086150. doi: 10.1136/bmjopen-2024-086150

Model parameters – health utility

Prosthesis	Procedure	EQ-5D-5L	Standard deviation
TSA	Pre-operative	0.34	
	Success Primary	0.76	0.18
	Success Revision	0.61	0.18
	Recovery Primary	0.66	0.18
	Recovery Revision	0.54	0.18
	Re-revision	0.54	0.18
	Pre-operative	0.34	0.18
Hemi	Pre-operative	0.35	
	Success Primary	0.64	0.22
	Success Revision	0.61	0.22
	Recovery Primary	0.58	0.22
	Recovery Revision	0.54	0.22
	Re-revision	0.54	0.18
	Pre-operative	0.35	0.18

Table 1. EQ-5D-5L utility scores.

Number of shoulders arthroplasties in each age group

Age group	Pre-matching		Post-matching	
	TSA	HA	TSA	HA
≤ 60 years	1471	746	1177	623
61 – 75 years	6002	2010	3714	1889
> 75 years	3008	1461	2323	1236

Table 2. Number of shoulder arthroplasties in each age group.

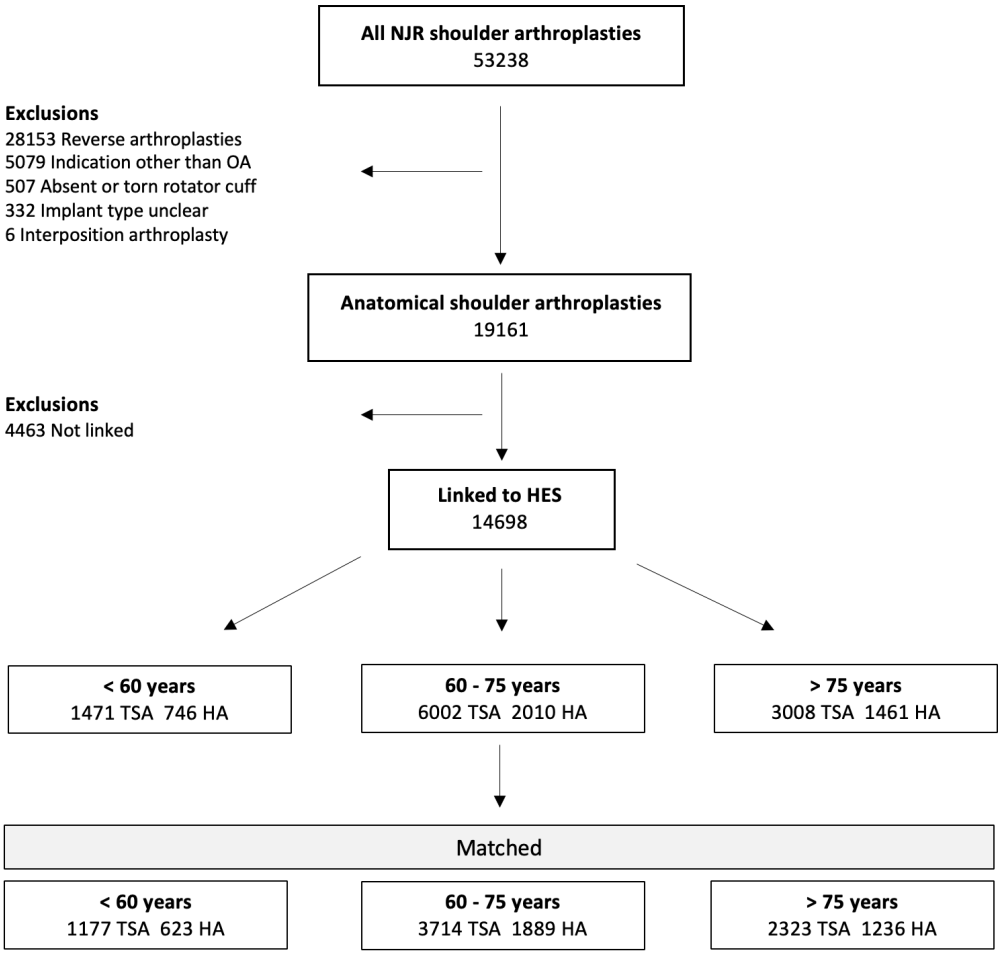

Figure 1. Study flow diagram. Adapted with consent from Davies et al (1).

Matching process

Components of the matching process were varied to achieve the optimal match as defined by the lowest standardised mean difference (SMD) between each variable pre- and post-matching. The lowest SMDs were achieved when patients were matched on the linear predictor (log odds of the propensity score) using a ratio of 1 HA to 2 TSA, greedy matching without replacement and a calliper width of 0.2.

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Characteristics pre and post matching – subgroup aged 60 years or less

	Pre-matching			Post-matching		
Characteristic	TSA	HA	SMD	TSA	HA	SMD
Age (mean, SD)	54.5 (5.4)	52.0 (7.4)	0.382	53.8 (5.7)	53.6 (5.7)	0.042
Gender (number, %)						
Male	767 (52.1)	481 (64.5)	0.252	681 (57.9)	382 (61.3)	0.071
Female	704 (47.9)	265 (35.5)		496 (42.1)	241 (38.7)	
ASA (number, %)						
I	283 (19.2)	203 (27.2)	0.197	248 (21.1)	144 (23.1)	0.054
II	950 (64.6)	422 (56.6)		724 (61.5)	377 (60.5)	
III	230 (15.6)	118 (15.8)		200 (17.0)	99 (15.9)	
IV	8 (0.5)	3 (0.4)		5 (0.4)	3 (0.5)	
Rotator cuff (number, %)						
Attenuated/normal	1460 (99.3)	730 (97.9)	0.117	1166 (99.1)	617 (99.0)	0.003
Repaired	11 (0.7)	16 (2.1)		11 (0.9)	6 (1.0)	
Operating surgeon (number, %)						
Consultant	1369 (93.1)	704 (94.4)	0.168	1117 (94.9)	593 (95.2)	0.016
SpR/ST3-ST8	46 (3.1)	30 (4.0)		39 (3.3)	20 (3.2)	
Speciality doctor	31 (2.1)	4 (0.5)		8 (0.7)	4 (0.6)	
F1-ST2	0 (0.0)	1 (0.1)		0 (0.0)	0 (0.0)	
Other	25 (1.7)	7 (0.9)		13 (1.1)	6 (1.0)	
Surgical assistant (number, %)						
Consultant	121 (8.2)	59 (7.9)	0.012	95 (8.1)	45 (7.2)	0.032
Other	1350 (91.8)	687 (92.1)		1082 (91.9)	578 (92.8)	
Surgical approach (number, %)						
Deltopectoral	1369 (93.1)	704 (94.4)	0.213	1096 (93.1)	573 (92.0)	0.071
Deltoid detachment	4 (0.3)	1 (0.1)		1 (0.1)	1 (0.2)	
Other	2 (0.1)	0 (0.0)		0 (0.0)	0 (0.0)	
Posterior	3 (0.2)	2 (0.3)		3 (0.3)	2 (0.3)	
Superior (Mackenzie)	69 (4.7)	63 (8.4)		66 (5.6)	40 (6.4)	
Trans-deltoid	24 (1.6)	13 (1.7)		11 (0.9)	7 (1.1)	
Unit type (number, %)						
NHS	1440 (97.9)	735 (98.5)	0.048	1159 (98.5)	613 (98.4)	0.006
Independent	31 (2.1)	11 (1.5)		18 (1.5)	10 (1.6)	
Cases / yr (mean, SD)	9.3 (5.5)	8.2 (4.9)	0.198	8.5 (5.0)	8.4 (5.0)	0.033
Charlson Comorbidity Index(mean, SD)	0.8 (1.3)	0.8 (1.3)	0.006	0.8 (1.3)	0.8 (1.3)	0.025
Deprivation level (number, %)						
Least deprived	314 (21.6)	180 (24.3)	0.080	268 (22.8)	149 (23.9)	0.032
Less deprived	401 (27.6)	185 (25.0)		314 (26.7)	160 (25.7)	
More deprived	391 (26.9)	205 (27.7)		323 (27.4)	172 (27.6)	
Most deprived	349 (24.0)	170 (23.0)		272 (23.1)	142 (22.8)	

Table 3. Characteristics pre- and post-matching, patients age 60 years or less.

Characteristics pre and post matching – subgroup aged 61-75 years

	Pre-matching			Post-matching		
Characteristic	TSA	HA	SMD	TSA	HA	SMD
Age (mean, SD)	69.0 (4.0)	69.0 (4.1)	0.003	69.0 (4.1)	68.9 (4.1)	0.013
Gender (number, %)						
Male	1913 (31.9)	692 (34.4)	0.054	1262 (34.0)	652 (34.5)	0.011
Female	4089 (68.1)	1318 (65.6)		2452 (66.0)	1237 (65.5)	
ASA (number, %)						
I	480 (8.0)	170 (8.5)	0.077	313 (8.4)	157 (8.3)	0.019
II	4252 (70.8)	1369 (68.1)		2526 (68.0)	1290 (68.3)	
III	1259 (21.0)	461 (22.9)		865 (23.3)	435 (23.0)	
IV	11 (0.2)	10 (0.5)		10 (0.3)	7 (0.4)	
Rotator cuff (number, %)						
Attenuated/normal	5945 (99.1)	1961 (97.6)	0.116	3660 (98.5)	1865 (98.7)	0.016
Repaired	57 (1.5)	49 (2.4)		54 (1.5)	24 (1.3)	
Operating surgeon (number, %)						
Consultant	5465 (91.1)	1838 (91.4)	0.077	3404 (91.7)	1735 (91.8)	0.009
SpR/ST3-ST8	120 (2.0)	23 (1.1)		205 (5.5)	101 (5.3)	
Speciality doctor	289 (4.8)	111 (5.5)		60 (1.6)	31 (1.6)	
Other	128 (2.1)	38 (1.9)		45 (1.2)	22 (1.2)	
Surgical assistant (number, %)						
Consultant	540 (9.0)	192 (9.6)	0.019	377 (9.1)	177 (9.4)	0.010
Other	5462 (91.0)	1818 (90.4)		3377 (90.9)	1712 (90.6)	
Surgical approach (number, %)						
Deltopectoral	5569 (92.8)	1771 (88.1)	0.189	3379 (91.0)	1733 (91.7)	0.045
Deltoid detachment	9 (0.1)	3 (0.1)		7 (0.2)	3 (0.2)	
Other	12 (0.2)	4 (0.2)		7 (0.2)	4 (0.2)	
Posterior	10 (0.2)	6 (0.3)		8 (0.2)	5 (0.3)	
Superior (Mackenzie)	283 (4.7)	180 (9.0)		246 (6.6)	108 (5.7)	
Trans-deltoid	119 (2.0)	46 (2.3)		67 (1.8)	36 (1.9)	
Unit type (number, %)						
NHS	5901 (98.3)	1985 (98.8)	0.037	3669 (98.8)	1864 (98.7)	0.010
Independent	101 (1.7)	25 (1.2)		45 (1.2)	25 (1.3)	
Cases / yr (mean, SD)	9.8 (5.6)	8.2 (5.3)	0.304	8.5 (5.1)	8.2 (5.1)	0.060
Charlson Comorbidity Index(mean, SD)	1.1 (1.6)	1.1 (1.5)	0.001	1.1 (1.5)	1.1 (1.5)	0.009
Deprivation level (number, %)						
Least deprived	1655 (28.0)	611 (30.5)	0.073	1114 (30.0)	581 (30.8)	0.022
Less deprived	1945 (32.9)	598 (29.9)		1096 (29.5)	560 (29.6)	
More deprived	1417 (24.0)	483 (24.1)		917 (24.7)	451 (23.9)	
Most deprived	887 (15.0)	311 (15.5)		587 (15.8)	297 (15.7)	

Table 4. Characteristics pre- and post-matching, patients age 61-75 years.

Characteristics pre and post matching – subgroup aged > 75 years

	Pre-matching			Post-matching		
Characteristic	TSA	HA	SMD	TSA	HA	SMD
Age (mean, SD)	80.1 (3.5)	80.9 (3.9)	0.221	80.4 (3.6)	80.4 (3.6)	0.016
Gender (number, %)						
Male	584 (19.4)	236 (16.2)	0.085	410 (17.6)	220 (17.8)	0.004
Female	2424 (80.6)	1225 (83.8)		1913 (82.4)	1016 (82.2)	
ASA (number, %)						
I	120 (4.0)	70 (4.8)	0.092	103 (4.4)	57 (4.6)	0.019
II	2013 (66.9)	914 (62.6)		1492 (64.2)	797 (64.5)	
III	854 (28.4)	466 (31.9)		712 (30.7)	372 (30.1)	
IV	21 (0.7)	11 (0.8)		16 (0.7)	10 (0.8)	
Rotator cuff (number, %)						
Attenuated/normal	2966 (98.6)	1429 (97.8)	0.060	2284 (98.3)	1216 (98.4)	0.005
Repaired	42 (1.4)	32 (2.2)		39 (1.7)	20 (1.6)	
Operating surgeon (number, %)						
Consultant	2666 (88.6)	1308 (89.5)	0.163	2076 (89.4)	1118 (90.5)	0.069
SpR/ST3-ST8	71 (2.4)	11 (0.8)		133 (5.7)	74 (6.0)	
Speciality doctor	154 (5.1)	102 (7.0)		82 (3.5)	33 (2.7)	
Other	117 (3.9)	40 (2.7)		32 (1.4)	11 (0.9)	
Surgical assistant (number, %)						
Consultant	288 (9.6)	162 (11.1)	0.050	232 (10.0)	123 (10.0)	0.001
Other	2720 (90.4)	1299 (88.9)		2091 (90.0)	1113 (90.0)	
Surgical approach (number, %)						
Deltopectoral	2757 (91.7)	1323 (90.6)	0.176	2135 (91.9)	1141 (92.3)	0.071
Deltoid detachment	4 (0.1)	2 (0.1)		3 (0.1)	2 (0.2)	
Other	1 (0.0)	2 (0.2)		1 (0.0)	2 (0.2)	
Posterior	4 (0.1)	8 (0.5)		4 (0.2)	1 (0.1)	
Superior (Mackenzie)	153 (5.1)	104 (7.1)		134 (5.8)	70 (5.7)	
Trans-deltoid	89 (3.0)	22 (1.5)		46 (2.0)	20 (1.6)	
Unit type (number, %)						
NHS	2953 (98.2)	1435 (98.2)	0.004	2283 (98.3)	1215 (98.3)	0.002
Independent	55 (1.8)	26 (1.8)		40 (1.7)	21 (1.7)	
Cases / yr (mean, SD)	10.7 (5.9)	8.6 (5.8)	0.364	9.5 (5.4)	9.2 (6.0)	0.066
Charlson Comorbidity Index(mean, SD)	1.4 (1.8)	1.4 (1.8)	0.018	1.4 (1.7)	1.4 (1.7)	0.013
Deprivation level (number, %)						
Least deprived	990 (33.4)	491 (33.7)	0.079	799 (34.4)	420 (34.0)	0.020
Less deprived	952 (32.2)	436 (30.0)		708 (30.5)	377 (30.5)	
More deprived	699 (23.6)	337 (23.2)		547 (23.5)	288 (23.3)	
Most deprived	320 (10.8)	191 (13.1)		269 (11.6)	151 (12.2)	

Table 5. Characteristics pre- and post-matching, patients age over 75 years.

Model parameters for revision and reoperation in patients aged 60 years and younger – Weibull regression relative hazard

Explanatory variables	Coefficient	Standard Deviation
ln(shape param.) ln(κ)	0.0086	0.0770
Cons (β_0)	-3.4911	0.8001
Age (β_1)	-0.0148	0.0144
Male (β_2)	-0.2287	0.1755
implant-hemi (β_3)	0.7419	0.1839

Table 6. Model parameters – revision, patients aged 60 years and younger

Explanatory variables	Coefficient	Standard Deviation
ln(shape param.) ln(κ)	-0.2743	0.0884
cons$(\boldsymbol{\beta_0})$	-3.4562	0.9107
age$(\boldsymbol{\beta_1})$	-0.0116	0.0165
male$(\boldsymbol{\beta_2})$	-0.1812	0.1982
implant-hemi$(\boldsymbol{\beta_3})$	0.7119	0.2051

Table 7. Model parameters – reoperation, patients aged 60 years and younger

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Model parameters for revision and reoperation in patients aged 61-75 – Weibull regression relative hazard

Explanatory variables	Coefficient	Standard Deviation
ln(shape param.) ln(κ)	-0.0093	0.0577
cons$(\boldsymbol{\beta_0})$	-2.3988	1.0769
age$(\boldsymbol{\beta_1})$	-0.0364	0.0155
male$(\boldsymbol{\beta_2})$	-0.2432	0.1406
implant-hemi$(\boldsymbol{\beta_3})$	0.7705	0.1351

Table 8. Model parameters – revision, patients aged 61-75 years

Explanatory variables	Coefficient	Standard Deviation
ln(shape param.) ln(κ)	-0.3712	0.0738
cons$(\boldsymbol{\beta_0})$	-1.9527	1.3465
age$(\boldsymbol{\beta_1})$	-0.0423	0.0194
male$(\boldsymbol{\beta_2})$	0.0052	0.1685
implant-hemi$(\boldsymbol{\beta_3})$	0.7238	0.1732

Table 9. Model parameters – reoperation, patients aged 61-75 years

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Model parameters for revision and reoperation in patients aged over 75 – Weibull regression relative hazard

Explanatory variables	Coefficient	Standard Deviation
ln(shape param.) ln(κ)	-0.2516	0.1009
cons$(\boldsymbol{\beta_0})$	-2.9861	2.8146
age$(\boldsymbol{\beta_1})$	-0.1008	0.0354
male$(\boldsymbol{\beta_2})$	0.0674	0.2745
implant-hemi$(\boldsymbol{\beta_3})$	0.4997	0.2294

Table 10. Model parameters – revision, patients aged over 75 years

Explanatory variables	Coefficient	Standard Deviation
ln(shape param.) ln(κ)	-0.4855	0.1252
cons$(\boldsymbol{\beta_0})$	-0.7671	3.3247
age$(\boldsymbol{\beta_1})$	-0.0595	0.0285
male$(\boldsymbol{\beta_2})$	0.3546	0.1524
implant-hemi$(\boldsymbol{\beta_3})$	0.9318	0.2918

Table 11. Model parameters – reoperation, patients aged over 75 years

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Cost-effectiveness acceptability curve in men

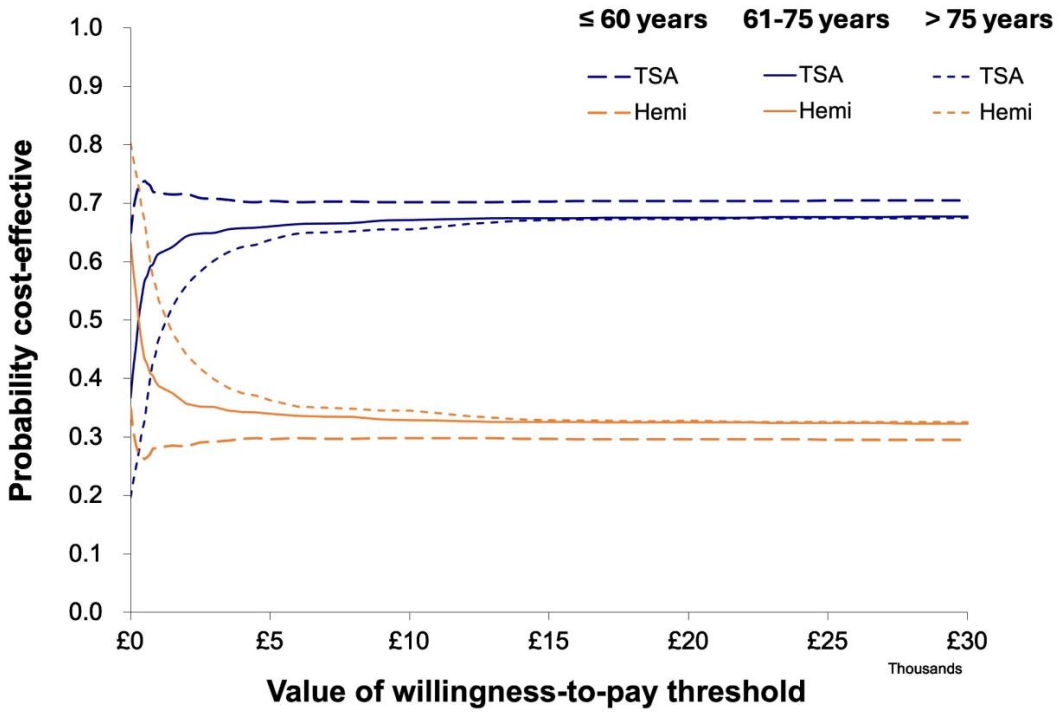

Figure 2. Cost-effectiveness acceptability curve in men.

Cost estimations

Implant costs calculated from the NJR EMBED database

Implant	Mean cost (£)	Standard deviation (£)
TSA	2306.9	381.9
HA	1652.7	535.0

Table 12. Implant costs calculated from the NJR EMBED database.

Difference in the duration of operating time for HA and TSA

An estimation of the duration of a TSA was taken from a large healthcare database (2). The mean length of a TSA was 108.30 minutes (SD 35.60 minutes). Assuming a ratio of 1:1.3 for HA:TSA (table 13) the mean duration of a HA was estimated as 83.31 minutes for an overall mean difference of 24.99 minutes. The standard deviation of the duration of a HA was assumed to be the same as a TSA (35.60 minutes).

Study	Mean operating time (minutes)		Ratio of duration of surgery TSA : HA
	TSA	HA	
Lo et al (3)	157.3	118.4	1.33
Gartsman et al (4)	98	63	1.56
Singh et al (5)	163.3	127.7	1.28
	147.8	121.9	1.21
	114.4	87.1	1.31

Table 13. Duration of operating time TSA and HA.

Duration of TSA (SD) from Testa et al	108.30 min (35.60)
Estimated ratio duration HA to TSA	1 : 1.3
Estimated duration of HA (SD)	83.31 min (24.37)
Difference in mean duration	24.99 min

The cost of an operating theatre per minute was estimated from values submitted to NHS Scotland (6). After accounting for inflation these were £18.61 per minute. The total cost difference between TSA and HA due to theatre time was £18.61*24.99 = £465.11.

Total difference in mean cost

The total difference in mean cost was the difference in the cost of the implants and the costs of theatre time.

Implant mean cost difference	£654.19
Theatre time mean cost difference	£465.11
Total difference	£1119.30

Cost of a HA = reimbursement value - (mean difference / 2) = 6016 – (1119.30/2) = £6575.65

Cost of a TSA = reimbursement value + (mean difference / 2) = 6016 + (1119.30/2) = £5456.35

The standard deviation of the total implant cost for TSA and HA was calculated from the combined variance of the costs of the implant and costs of theatre time.

Overall cost estimations

Implant	Mean cost (£)	Standard deviation (£)
TSA	6575.65	851.7
HA	5456.35	764.8
Revision shoulder (cost code HN86a)	8396	840
Re-revision shoulder (cost code HN86a)	8396	840
Reoperation (cost code HT54B)	2510	251

Table 14. Overall cost estimations

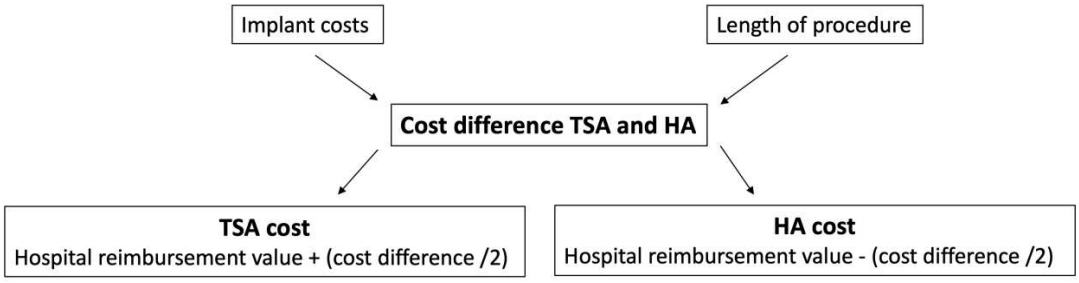

Figure 3. Adjustment of baseline cost, plus additional costs. TSA – total shoulder arthroplasty, HA – Hemiarthroplasty.

Change in costs and QALYs by age for male patients aged 60 years and younger

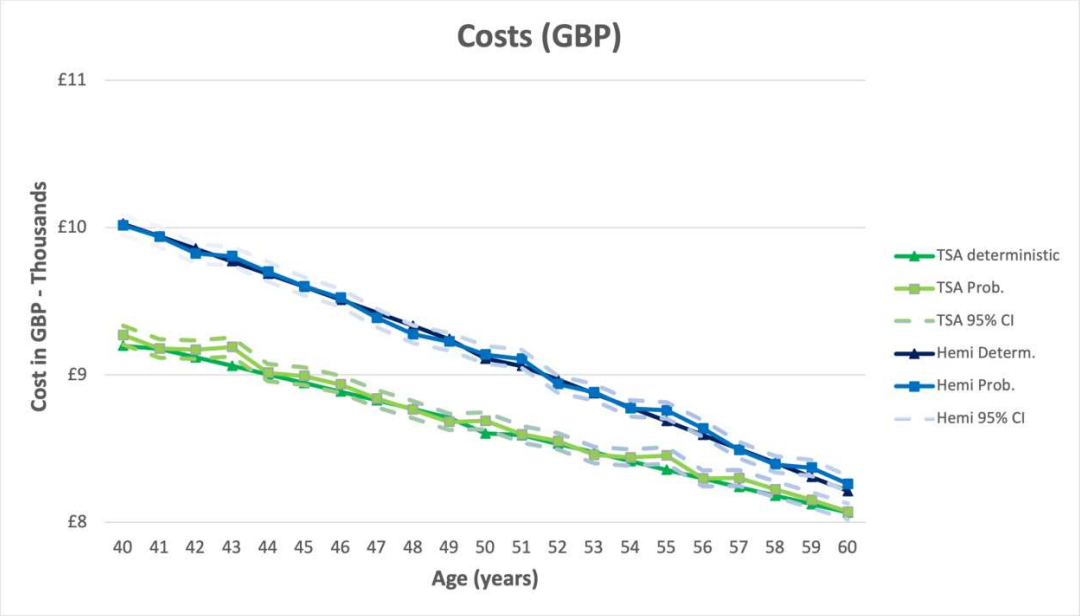

Figure 4. Costs by age for male patients aged 60 years and younger. The same trend was seen in the female cohort.

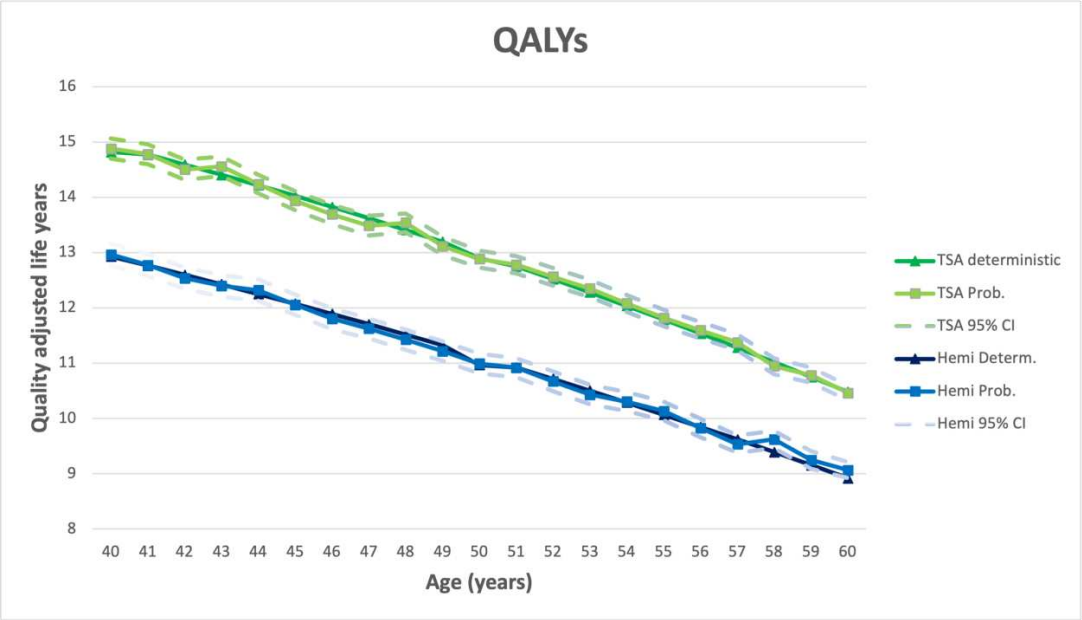

Figure 5. Quality-adjusted life years by age for male patients aged 60 years and younger. The same trend was seen in the female cohort.

CHEERS 2022 Checklist

Topic	No.	Item	Location where item is reported
Title			
	1	Identify the study as an economic evaluation and specify the interventions being compared.	Page 1
Abstract			
	2	Provide a structured summary that highlights context, key methods, results, and alternative analyses.	Pages 2&3
Introduction			
Background and objectives	3	Give the context for the study, the study question, and its practical relevance for decision making in policy or practice.	Pages 4&5
Methods			
Health economic analysis plan	4	Indicate whether a health economic analysis plan was developed and where available.	Submitted to the National Joint Registry
Study population	5	Describe characteristics of the study population (such as age range, demographics, socioeconomic, or clinical characteristics).	Page 6
Setting and location	6	Provide relevant contextual information that may influence findings.	Page 6
Comparators	7	Describe the interventions or strategies being compared and why chosen.	Page 4
Perspective	8	State the perspective(s) adopted by the study and why chosen.	Page 6
Time horizon	9	State the time horizon for the study and why appropriate.	Page 6
Discount rate	10	Report the discount rate(s) and reason chosen.	Page 10
Selection of outcomes	11	Describe what outcomes were used as the measure(s) of benefit(s) and harm(s).	Pages 7-9
Measurement of outcomes	12	Describe how outcomes used to capture benefit(s) and harm(s) were measured.	Pages 7-9
Valuation of outcomes	13	Describe the population and methods used to measure and value outcomes.	Pages 7-11

Topic	No.	Item	Location where item is reported
Measurement and valuation of resources and costs	14	Describe how costs were valued.	Pages 9&10, appendix
Currency, price date, and conversion	15	Report the dates of the estimated resource quantities and unit costs, plus the currency and year of conversion.	Pages 9&10, appendix
Rationale and description of model	16	If modelling is used, describe in detail and why used. Report if the model is publicly available and where it can be accessed.	Pages 6-8, 10&11
Analytics and assumptions	17	Describe any methods for analysing or statistically transforming data, any extrapolation methods, and approaches for validating any model used.	Pages 7-11
Characterising heterogeneity	18	Describe any methods used for estimating how the results of the study vary for subgroups.	Page 11
Characterising distributional effects	19	Describe how impacts are distributed across different individuals or adjustments made to reflect priority populations.	Page 11
Characterising uncertainty	20	Describe methods to characterise any sources of uncertainty in the analysis.	Pages 10&11
Approach to engagement with patients and others affected by the study	21	Describe any approaches to engage patients or service recipients, the general public, communities, or stakeholders (such as clinicians or payers) in the design of the study.	Page 21
Results			
Study parameters	22	Report all analytic inputs (such as values, ranges, references) including uncertainty or distributional assumptions.	Page 14
Summary of main results	23	Report the mean values for the main categories of costs and outcomes of interest and summarise them in the most appropriate overall measure.	Page 12
Effect of uncertainty	24	Describe how uncertainty about analytic judgments, inputs, or projections affect findings. Report the effect of choice of discount rate and time horizon, if applicable.	Pages 12-17
Effect of engagement with patients and others affected by the study	25	Report on any difference patient/service recipient, general public, community, or stakeholder involvement made to the approach or findings of the study	Not reported
Discussion			

Topic	No.	Item	Location where item is reported
Study findings, limitations, generalisability, and current knowledge	26	Report key findings, limitations, ethical or equity considerations not captured, and how these could affect patients, policy, or practice.	Pages 18-20
Other relevant information			
Source of funding	27	Describe how the study was funded and any role of the funder in the identification, design, conduct, and reporting of the analysis	Page 21
Conflicts of interest	28	Report authors conflicts of interest according to journal or International Committee of Medical Journal Editors requirements.	Page 21

From: Husereau D, Drummond M, Augustovski F, et al. Consolidated Health Economic Evaluation Reporting Standards 2022 (CHEERS 2022) Explanation and Elaboration: A Report of the ISPOR CHEERS II Good Practices Task Force. Value Health 2022;25. doi:10.1016/j.jval.2021.10.008

References

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