MJA
The Medical Journal of Australia

Supporting Information

Supplementary methods and results

Appendix to: Reilly JR, Myles PS, Wong D, et al. Hospital costs and factors associated with days alive and at home after surgery (DAH_{30}). *Med J Aust* 2022; doi: 10.5694/mja2.51658.

1. American Society of Anesthesiology (ASA) physical status classification (https://www.asahq.org/standards-and-guidelines/asa-physical-status-classification-system)

ASA physical status is a validated classification system in almost universal clinical use that is used by anaesthetists to assess a patient prior to surgery. ASA physical status is correlated with surgical and anaesthesia risk, with higher categories associated with poorer outcomes. The system is summarised in the table below. The ASA classification system:

1 = A normal healthy patient

2 = A patient with mild systemic disease

3 = A patient with severe systemic disease that limits activity

4 = A patient with severe systemic disease that is a constant threat to life

5 = A moribund patient not expected to survive more than 24 hours without surgical intervention

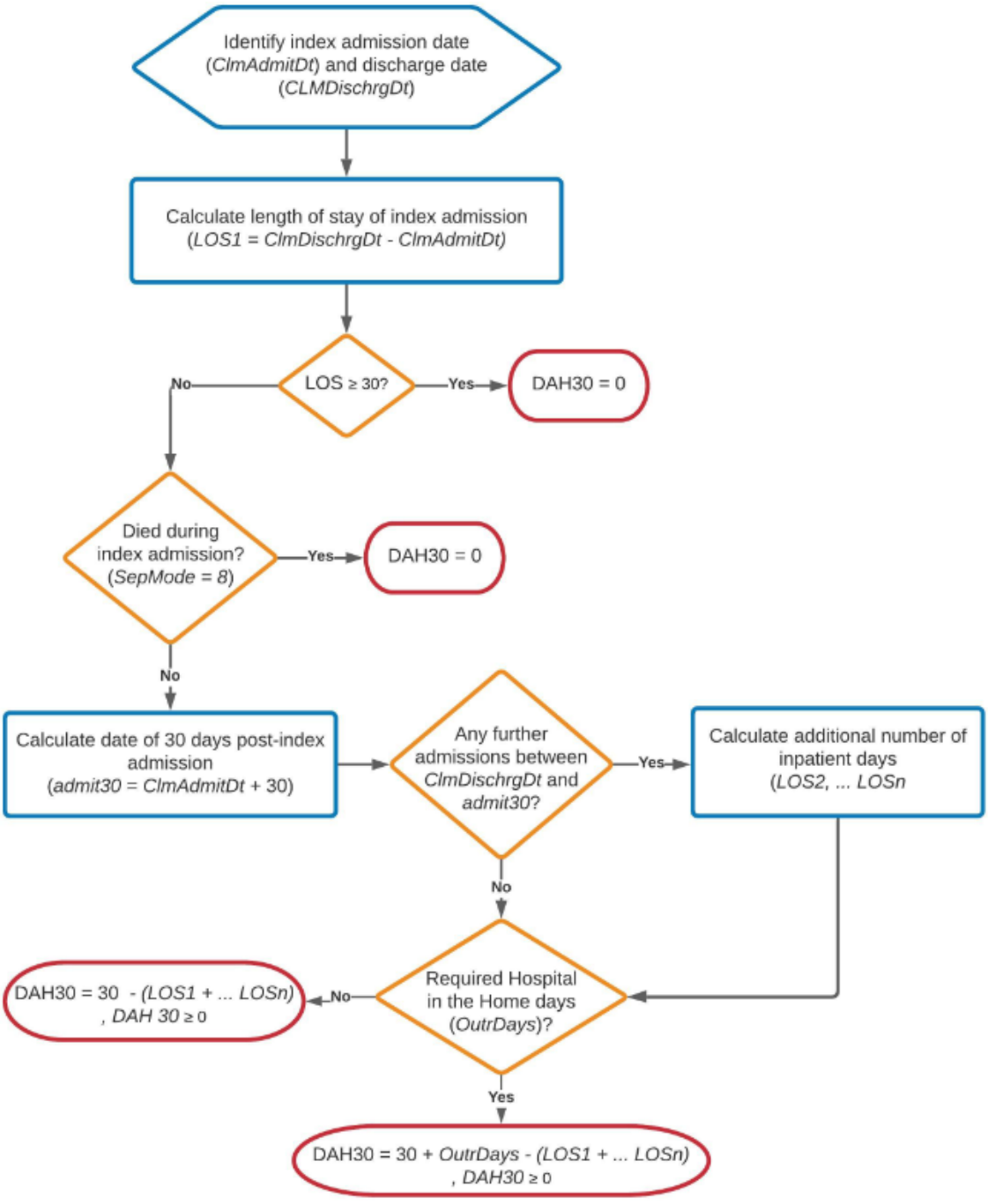
6 = Brain dead patient whose organs are being removed for donation

2. MBS codes for the five surgical procedures of interest

Procedure	**MBS codes**
Total knee joint replacement	49517, 49581, 49521, 49524, 49534
Total hip joint replacement	49315, 49318, 49321
Hemicolectomy	32000, 32003, 32006
Transurethral resection of the prostate	37203, 37224
Common femoral endarterectomy	33515, 33518, 33521, 33539, 33542, 34103

3. Calculation of days alive and at home during 30 days after surgery (DAH_{30})

DAH_{30} was calculated using mortality and hospitalisation data from the date of the index surgery (= Day 0). The algorithm used to derive DAH_{30}:



4. Charlson Comorbidity Index A score (CCI-A)

Each observation included 50 variables containing International Classification of Diseases, 10th edition, Australian Modification (ICD-10-AM) codes. These contain data on comorbid medical conditions that the patient either had prior to their admission or were diagnosed during the admission. Each consists of a five-character alphanumeric code associated with a specified condition. These codes were used to calculate the Charlson Comorbidity Index (CCI) A-score for each patient. The CCI is a validated score of selected comorbid conditions, used for predicting 10-year survival. It consists of two parts: A is a summary score of the selected conditions, while B is a score based on age. For the purposes of our investigation, only part A was used, as age was included in our analysis as a covariate.

Scores associated with the conditions that constitute the Charlson Comorbidity Index A-Score:

Condition	**Score**
Prior myocardial infarction	1
Congestive heart failure	1
Peripheral vascular disease	1
Cerebrovascular disease	1
Dementia	1
Chronic pulmonary disease	1
Rheumatologic disease	1
Peptic ulcer disease	1
Mild liver disease	1
Diabetes	1
Hemiplegia	2
Moderate-to-severe renal disease	2
Diabetes with chronic complications	2
Cancer without metastases	2
Leukaemia	2
Lymphoma	2
Moderate or severe liver disease	3
Metastatic solid tumour	6
Acquired immunodeficiency syndrome	6

Based on the table above, it was necessary to determine which ICD-10-AM codes captured the relevant conditions. A programmatic approach was then used to filter these codes, assign the relevant score, and sum them for each patient admission.

Figure 1. Selection of Medibank Private data records for our analysis

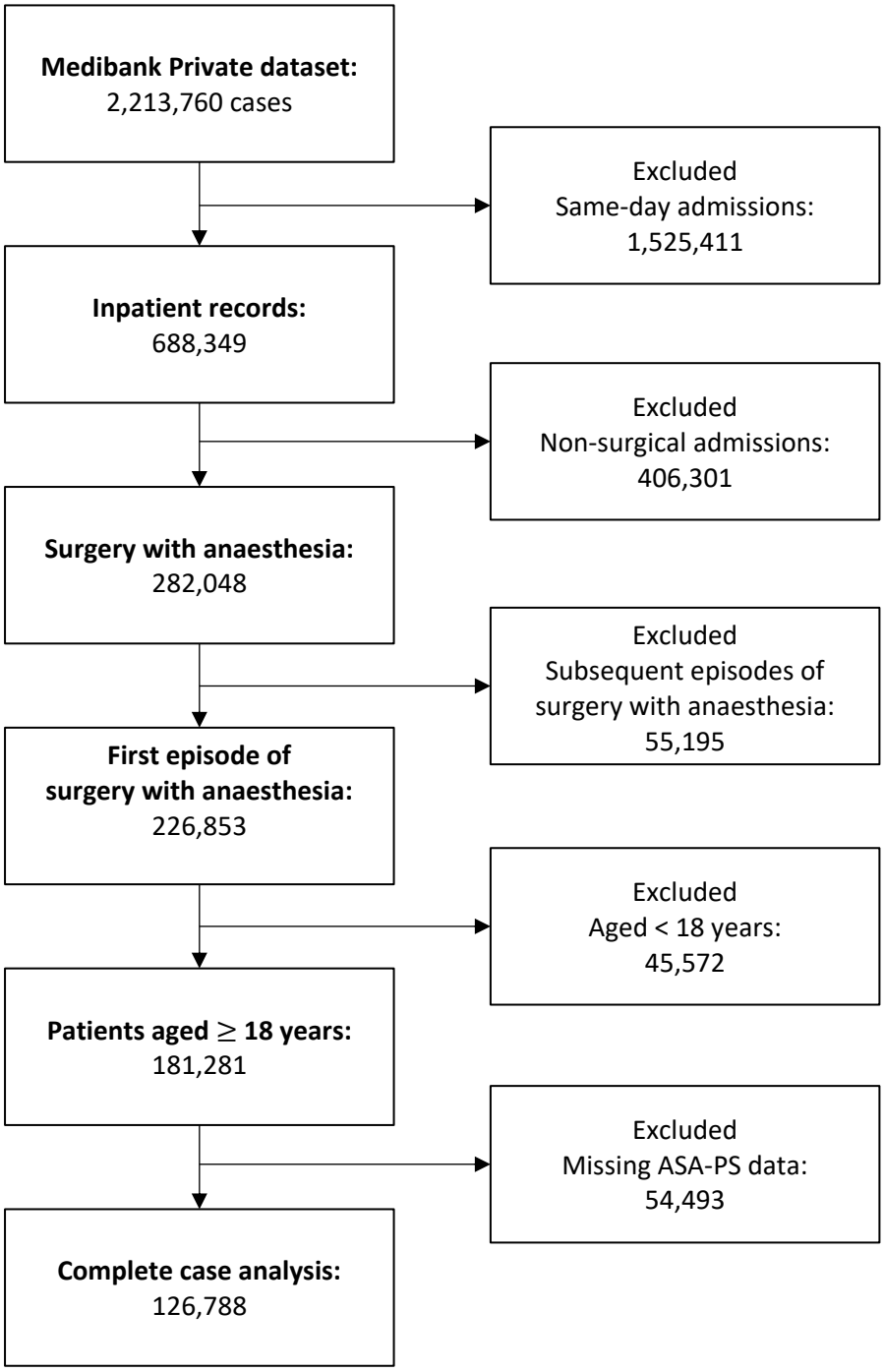


Figure 2. Covariate effects in the multivariate model across the distribution of DAH_{30} values

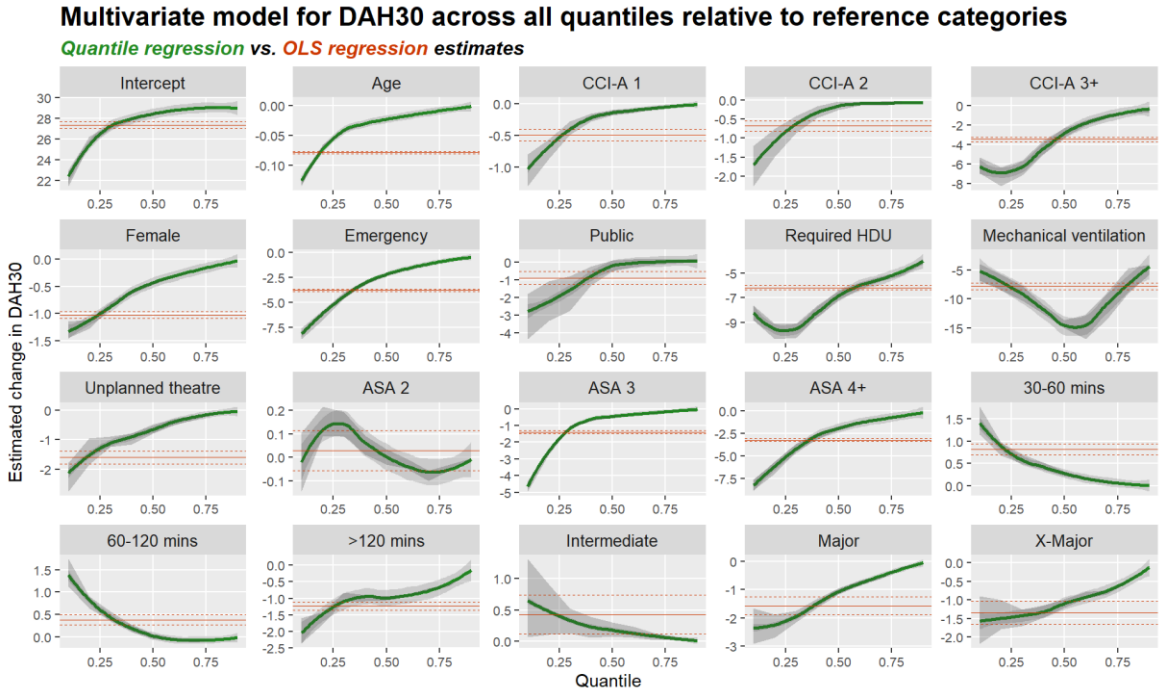


Figure 3. DAH_{30} *v* patient age: spline regression

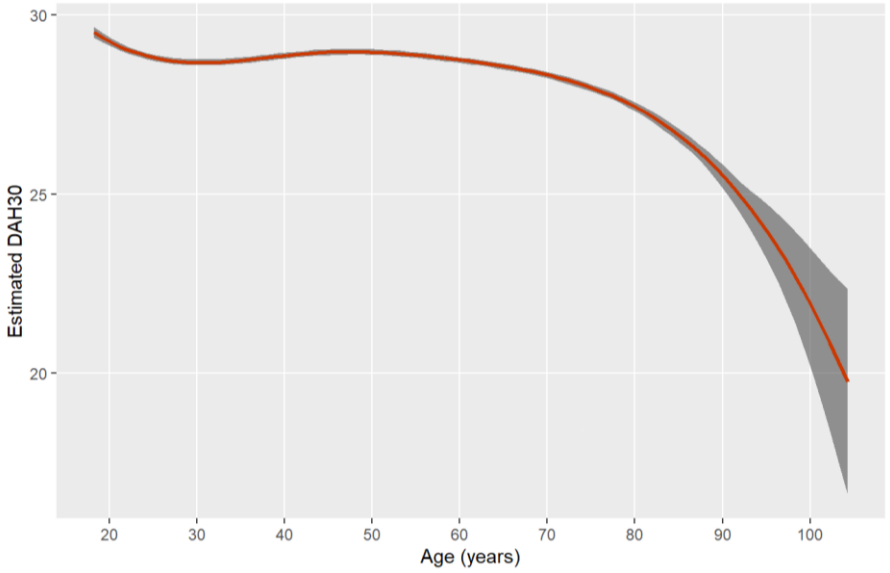


Figure 4. DAH_{30} *v* surgery duration: spline regression

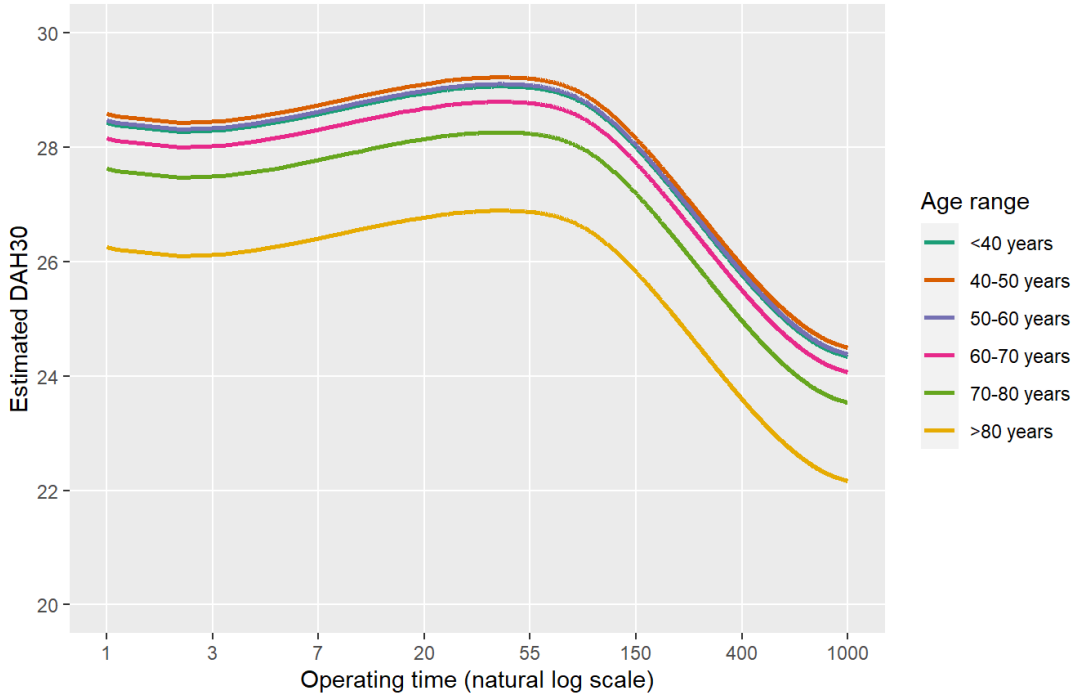


Table 1. Multivariate regression, with or without B-spline regression for age

	With spline regression		Without spline regression	
Term	**Estimate**	**95% CI**	**Estimate**	**95% CI**
Intercept	29.517	[29.445 , 29.589]	28.456	[28.365, 28.547]
Charlson Comorbidity Index A score				
1	-0.095	[-0.127 , -0.062]	-0.142	[-0.181 , -0.103]
2	-0.067	[-0.151 , 0.018]	-0.141	[-0.230 , -0.052]
3+	-2.498	[-2.94 , -2.057]	-2.808	[-3.253 , -2.363]
Patient sex (ref. Male)				
Female	-0.376	[-0.399 , -0.354]	-0.437	[-0.460 , -0.414]
Binary covariates				
Emergency	-2.062	[-2.180, -1.943]	-2.192	[-2.323 , -2.061]
Public	-0.205	[-0.488 , 0.078]	-0.162	[-0.515 , 0.191]
HDU/ICU	-6.890	[-7.207 , -6.573]	-6.794	[-7.105 , -6.483]
Mechanical ventilation	-14.292	[-14.617 , -13.968]	-14.473	[-14.820 , -14.130]
Unplanned theatre	-0.604	[-0.759 , -0.449]	-0.633	[-0.821 , -0.444]
ASA physical status (ref. 1)				
2	-0.056	[-0.073 , -0.038]	0.002	[-0.022 , 0.026]
3	-0.399	[-0.432 , -0.366]	-0.472	[-0.52 , -0.424]
4+	-1.589	[-1.829 , -1.35]	-1.932	[-2.16 , -1.705]
Operating time (ref. <30 mins)				
30-60 mins	0.198	[0.153 , 0.243]	0.266	[0.218 , 0.315]
60-120 mins	-0.060	[-0.104 , -0.015]	0.005	[-0.043 , 0.053]
>120 mins	-1.115	[-1.175 , -1.055]	-1.001	[-1.06 , -0.941]
Surgical severity (ref. Minor)				
Intermediate	0.167	[0.119 , 0.216]	0.175	[0.104 , 0.246]
Major	-1.038	[-1.097 , -0.978]	-1.069	[-1.149 , -0.990]
Complex major	-1.086	[-1.153 , -1.02]	-1.104	[-1.188 , -1.020]
State (ref. VIC)				
QLD	0.233	[0.208 , 0.259]	0.258	[0.228 , 0.289]
NSW	0.059	[0.019 , 0.100]	0.057	[0.018 , 0.096]
SA & NT	0.078	[0.052 , 0.104]	0.116	[0.064 , 0.167]
WA	0.156	[0.127 , 0.185]	0.223	[0.192 , 0.253]
TAS	-0.019	[-0.069 , 0.032]	0.014	[-0.053 , 0.081]
ACT	0.177	[0.090, 0.265]	0.219	[0.133 , 0.305]

ASA=American Society of Anesthesiologists; HDU=high dependency unit; ICU=intensive care unit.

Table 2. Complete case analysis and analysis with imputation of ASA physical status (dichotomised) for missing data

	Complete case analysis		Imputed model	
Term	**Estimate**	**95% CI**	**Estimate**	**95% CI**
Intercept	28.801	[28.742 , 28.860]	28.749	[28.669 , 28.829]
Age category (ref. <40 years)				
40-50 years	0.165	[0.137 , 0.192]	0.211	[0.175 , 0.246]
50-60 years	0.037	[0.010 , 0.064]	0.098	[0.069 , 0.128]
60-70 years	-0.273	[-0.305 , -0.241]	-0.166	[-0.196 , -0.136]
70-80 years	-0.824	[-0.876 , -0.771]	-0.617	[-0.664 , -0.571]
>80 years	-2.235	[-2.373 , -2.097]	-1.698	[-1.817 , -1.579]
American Society of Anesthesiologists physical status (ref. 1/2)				
ASA 3+	-0.438	[-0.470 , -0.407]	-0.429	[-0.471 , -0.386]
Patient sex (ref. Male)				
Female	-0.347	[-0.372 , -0.322]	-0.347	[-0.373 , -0.321]
State (ref. VIC)				
ACT	0.215	[0.185 , 0.246]	0.144	[0.115 , 0.172]
NSW	0.033	[0 , 0.066]	0.041	[0.008 , 0.074]
QLD	0.069	[0.035 , 0.102]	0.027	[-0.017 , 0.072]
SA & NT	0.148	[0.112 , 0.184]	0.108	[0.073 , 0.142]
TAS	-0.006	[-0.082 , 0.070]	-0.116	[-0.182 , -0.05]
WA	0.177	[0.106 , 0.248]	0.137	[0.064 , 0.21]
Urgency (ref. Elective)				
Emergency	-2.149	[-2.264 , -2.033]	-1.752	[-1.843 , -1.662]
Hospital type (ref. Private)				
Public	-0.217	[-0.572 , 0.138]	-0.379	[-0.674 , -0.084]
Charlson A-score (ref. 0)				
1	-0.101	[-0.130 , -0.072]	-0.147	[-0.182 , -0.111]
2	-0.085	[-0.157 , -0.013]	-0.290	[-0.381 , -0.200]
3+	-2.692	[-3.114 , -2.271]	-3.001	[-3.376 , -2.626]
Surgical severity (ref. Minor)				
Intermediate	0.193	[0.143 , 0.243]	0.168	[0.100 , 0.237]
Major	-1.015	[-1.077 , -0.953]	-1.027	[-1.101 , -0.954]
Complex major	-1.078	[-1.144 , -1.011]	-0.879	[-0.958 , -0.800]
Higher acuity covariates				
High dependency/intensive care unit	-7.407	[-7.729 , -7.085]	-6.424	[-6.623 , -6.224]
Mechanical ventilation	-14.419	[-14.757 , -14.082]	-15.396	[-16.331 , -14.461]
Unplanned theatre	-0.558	[-0.725 , -0.392]	-0.505	[-0.639 , -0.371]
Operating time (ref. <30 mins)				
30-60 mins	0.175	[0.142 , 0.208]	0.214	[0.175 , 0.253]
60-120 mins	-0.067	[-0.098 , -0.037]	-0.022	[-0.060 , 0.016]
>120 mins	-1.108	[-1.156 , -1.061]	-1.156	[-1.211 , -1.102]

Table 3. Multivariate quantile regression analysis for first and third centiles of DAH_{30}

	25th centile		Median		75th centile	
Term	**Estimate**	**95% CI**	**Estimate**	**95% CI**	**Estimate**	**95% CI**
Intercept	26.674	[26.227 , 27.121]	28.456	[28.365, 28.547]	29.058	[29.034, 29.082]
Age (continuous)						
Age, centred at mean 59 years	-0.053	[-0.054, -0.051]	-0.023	[-0.024, -0.022]	-0.008	[-0.009, -0.008]
Charlson comorbidity A Score (ref. 0)						
1	-0.519	[-0.638, -0.4]	-0.142	[-0.181, -0.103]	-0.051	[-0.066, -0.036]
2	-0.776	[-1.106, -0.446]	-0.141	[-0.23, -0.052]	-0.039	[-0.074, -0.004]
3+	-6.842	-7.431, -6.252]	-2.808	[-3.253, -2.36]	-0.853	[-0.989, -0.717]
Binary covariates						
Female	-1.023	[-1.073, -0.973]	-0.437	[-0.46, -0.414]	-0.164	[-0.174, -0.154]
Emergency admission	-5.190	[-5.505, -4.875]	-2.192	[-2.323, -2.061]	-0.939	[-0.991, -0.888]
Public hospital	-2.101	[-2.617, -1.585]	-0.162	[-0.515, 0.191]	0.059	[-0.032, 0.149]
Required HDU	-9.974	[-10.441, -9.507]	-6.794	[-7.105, -6.483]	-5.289	[-5.478, -5.1]
Mechanical ventilation	-7.784	[-8.765, -6.803]	-14.473	[-14.82, -14.126]	-9.355	[-11.458, -7.252]
Unplanned theatre	-1.062	[-1.242, -0.882]	-0.633	[-0.821, -0.444]	-0.170	[-0.226, -0.114]
ASA physical status (ref. 1)						
2	0.178	[0.129, 0.227]	0.002	[-0.022, 0.026]	-0.064	[-0.073, -0.056]
3	-1.539	[-1.688, -1.391]	-0.472	[-0.52, -0.424]	-0.190	[-0.204, -0.177]
4+	-5.247	[-5.752, -4.743]	-1.932	[-2.16, -1.705]	-0.720	[-0.824, -0.617]
Operating time (ref. <30 mins)						
30-60 mins	0.663	[0.585, 0.742]	0.266	[0.218, 0.315]	0.055	[0.046, 0.065]
60-120 mins	0.590	[0.512, 0.668]	0.005	[-0.043, 0.053]	-0.092	[-0.099, -0.085]
>120 mins	-1.192	[-1.322, -1.063]	-1.001	[-1.06, -0.941]	-0.635	[-0.648, -0.622]
Surgical severity (ref. minor)						
Intermediate	0.366	[-0.07, 0.802]	0.175	[0.104, 0.246]	0.060	[0.037, 0.083]
Major	-2.202	[-2.64, -1.764]	-1.069	[-1.149, -0.99]	-0.393	[-0.422, -0.365]
Complex major	-1.531	[-1.974, -1.088]	-1.104	[-1.188, -1.02]	-0.649	[-0.684, -0.614]
State (ref. VIC)						
QLD	0.625	[0.551, 0.7]	0.258	[0.228, 0.289]	0.058	[0.046, 0.07]
NSW	-0.140	[-0.231, -0.05]	0.057	[0.018, 0.096]	0.027	[0.015, 0.039]
SA or NT	0.666	[0.589, 0.743]	0.116	[0.064, 0.167]	-0.013	[-0.027, 0.001]
WA	0.790	[0.715, 0.865]	0.223	[0.192, 0.253]	0.045	[0.034, 0.056]
TAS	0.601	[0.463, 0.738]	0.014	[-0.053, 0.081]	-0.040	[-0.071, -0.01]
ACT	0.479	[0.256, 0.702]	0.219	[0.133, 0.305]	0.114	[0.09, 0.137]

ASA=American Society of Anesthesiologists; HDU=high dependency unit; ICU=intensive care unit.

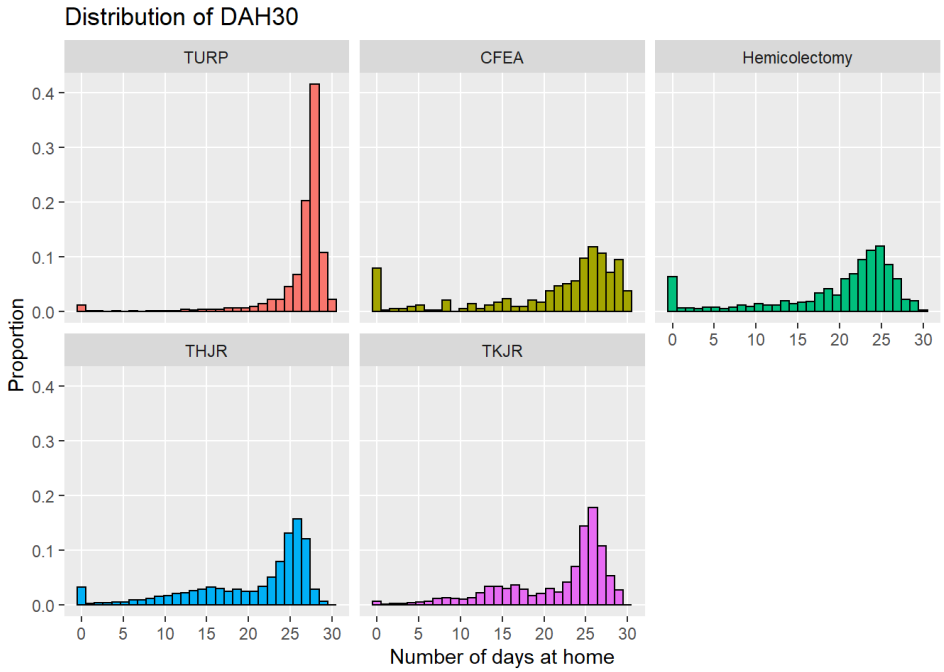
Table 4. DAH_{30} for specific surgical procedures (complete cases only), with case characteristics

Characteristic	Overall	TURP	CFEA	Hemicolectomy	THR	TKR
Patients	**14,364**	**4,009**	**337**	**1,498**	**6,943**	**1,577**
DAH_{30} (days), median (IQR)	25 (19, 27)	28 (26, 28)	25 (19, 27)	23 (17, 25)	24 (16, 26)	25 (17, 26)
Patient age	70 (63, 77)	72 (66, 78)	73 (64, 79)	70 (60, 78)	70 (62, 76)	68 (61, 75)
Patient sex						
M	8,739 (61%)	4,008 (100%)	213 (63%)	692 (46%)	3,091 (45%)	735 (47%)
F	5,625 (39%)	1 (<0.1%)	124 (37%)	806 (54%)	3,852 (55%)	842 (53%)
ASA physical status						
1	1,646 (11%)	492 (12%)	16 (4.7%)	190 (13%)	816 (12%)	132 (8.4%)
2	6,889 (48%)	1,895 (47%)	53 (16%)	583 (39%)	3,511 (51%)	847 (54%)
3	5,395 (38%)	1,514 (38%)	220 (65%)	644 (43%)	2,444 (35%)	573 (36%)
4+	434 (3.0%)	108 (2.7%)	48 (14%)	81 (5.4%)	172 (2.5%)	25 (1.6%)
Admission type						
Elective	13,547 (94%)	3,802 (95%)	318 (94%)	1,306 (87%)	6,640 (96%)	1,481 (94%)
Emergency	817 (5.7%)	207 (5.2%)	19 (5.6%)	192 (13%)	303 (4.4%)	96 (6.1%)
Charlson comorbidity A score						
0	11,081 (77%)	2,726 (68%)	237 (70%)	1,036 (69%)	5,772 (83%)	1,310 (83%)
1+	3,283 (23%)	1,283 (32%)	100 (30%)	462 (31%)	1,171 (17%)	267 (17%)
Hospital type						
Public	44 (0.3%)	9 (0.2%)	3 (0.9%)	20 (1.3%)	11 (0.2%)	1 (<0.1%)
Private	14,320 (100%)	4,000 (100%)	334 (99%)	1,478 (99%)	6,932 (100%)	1,576 (100%)
Operating time						
<1 h	2,410 (17%)	1,915 (48%)	42 (12%)	176 (12%)	218 (3.1%)	59 (3.7%)
1-2 h	6,013 (42%)	1,824 (45%)	92 (27%)	309 (21%)	3,016 (43%)	772 (49%)
2-2.5 h	2,759 (19%)	190 (4.7%)	46 (14%)	258 (17%)	1,936 (28%)	329 (21%)
>2.5 h	3,182 (22%)	80 (2.0%)	157 (47%)	755 (50%)	1,773 (26%)	417 (26%)
State						
VIC	5,234 (36%)	1,446 (36%)	122 (36%)	562 (38%)	2,431 (35%)	673 (43%)
ACT	260 (1.8%)	55 (1.4%)	5 (1.5%)	15 (1.0%)	169 (2.4%)	16 (1.0%)
NSW	2,880 (20%)	981 (24%)	49 (15%)	285 (19%)	1,415 (20%)	150 (9.5%)
QLD	3,167 (22%)	918 (23%)	73 (22%)	411 (27%)	1,438 (21%)	327 (21%)
SA/NT	1,044 (7.3%)	193 (4.8%)	11 (3.3%)	74 (4.9%)	510 (7.3%)	256 (16%)
TAS	532 (3.7%)	139 (3.5%)	13 (3.9%)	49 (3.3%)	311 (4.5%)	20 (1.3%)
WA	1,247 (8.7%)	277 (6.9%)	64 (19%)	102 (6.8%)	669 (9.6%)	135 (8.6%)

ASA=American Society of Anesthesiologists; IQR = interquartile range; TURP=transurethral resection of the prostate; CFEA=common femoral endarterectomy; THR=total hip replacement; TKR=total knee replacement

Figure 5. DAH_{30} data distributions for five specific surgical procedures

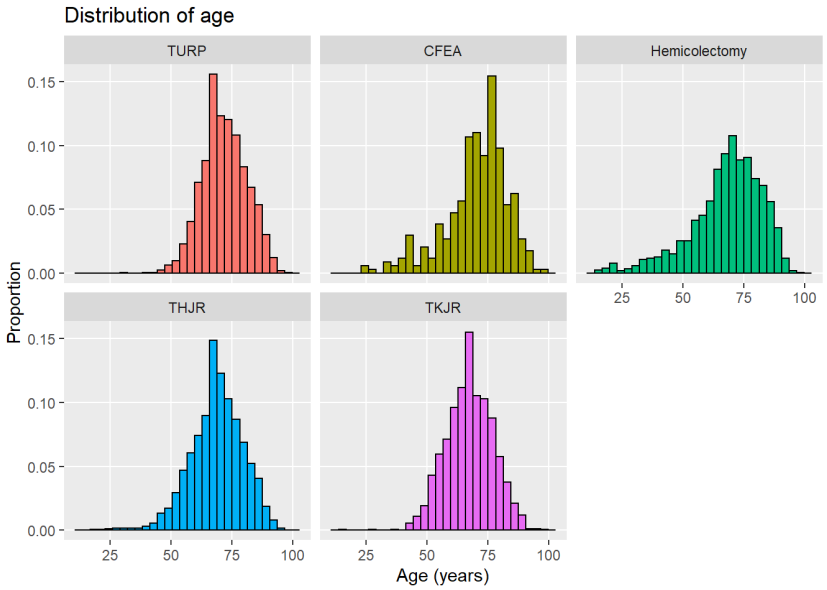
The figure below illustrates the distribution of DAH_{30} across the five procedures. The most striking difference is the DAH_{30} for patients undergoing prostate surgery with a more pronounced left skew indicating longer time at home after the procedure. This may be due to the less invasive nature of the procedure relative to the others, which may mean shorter post-procedural recovery time.



TURP=transurethral prostatectomy; CFEA=common femoral endarterectomy; THJR=total hip joint replacement; TKJR=total knee joint replacement

Figure 6. Patient age distribution for five specific surgical procedures

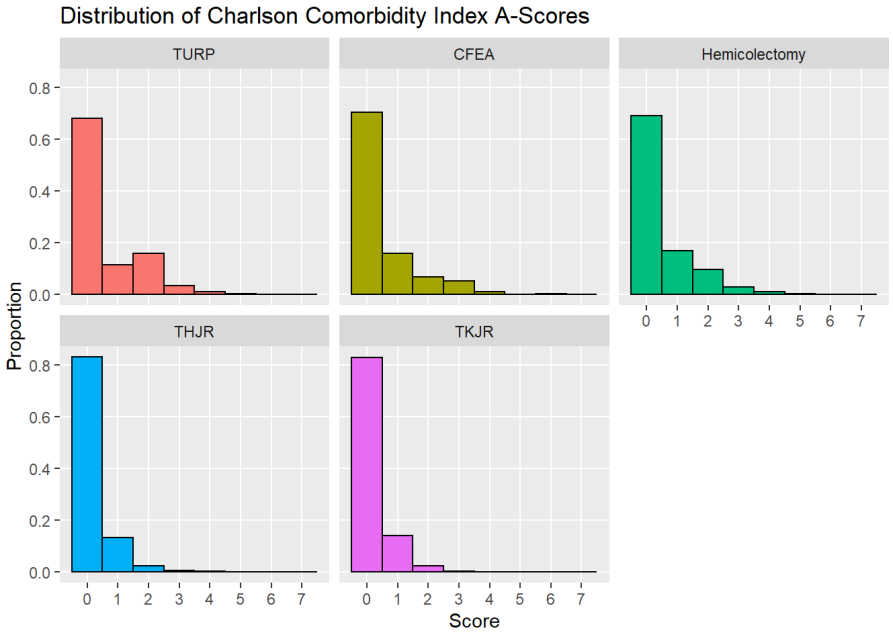
The age distribution amongst the five procedures is notable for a wider left tail amongst patients undergoing femoral endarterectomy and hemicolectomy. This indicates that these are procedures that may be performed on younger patients; joint replacements and prostate surgery are more likely to be performed for conditions that become more prevalent with increasing age.



TURP=transurethral prostatectomy; CFEA=common femoral endarterectomy; THJR=total hip joint replacement; TKJR=total knee joint replacement

Figure 7. Proportion of cases according to Charlson Comorbidity Index

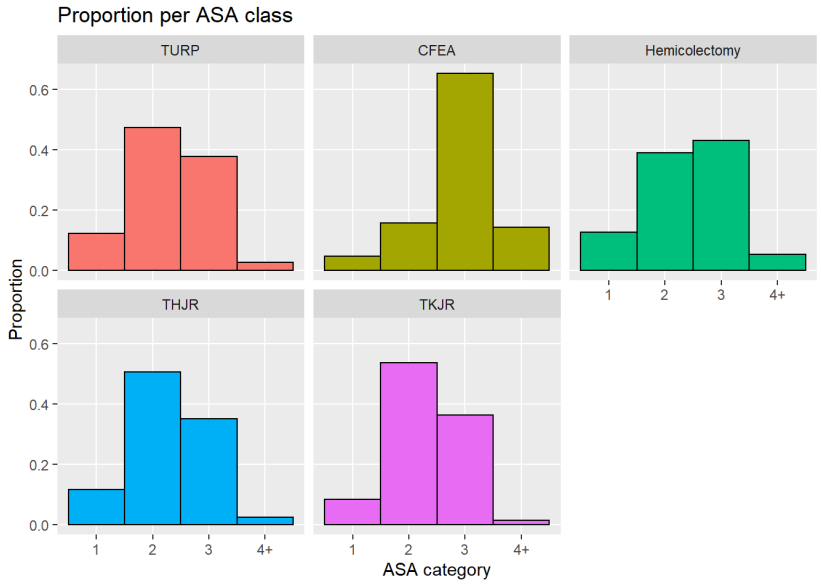
The majority of patients included in the analysis had a CCI-A score of 0, with the highest proportion of these in patients undergoing joint replacement (>80%). This indicates a low estimated 10-year mortality. It is also the justification for dichotomising CCI-A into 0 vs 1+ due to the relatively low numbers of patients who scored on the CCI-A scale.



TURP=transurethral prostatectomy; CFEA=common femoral endarterectomy; THJR=total hip joint replacement; TKJR=total knee joint replacement

Figure 8. Proportion of cases according to ASA physical status

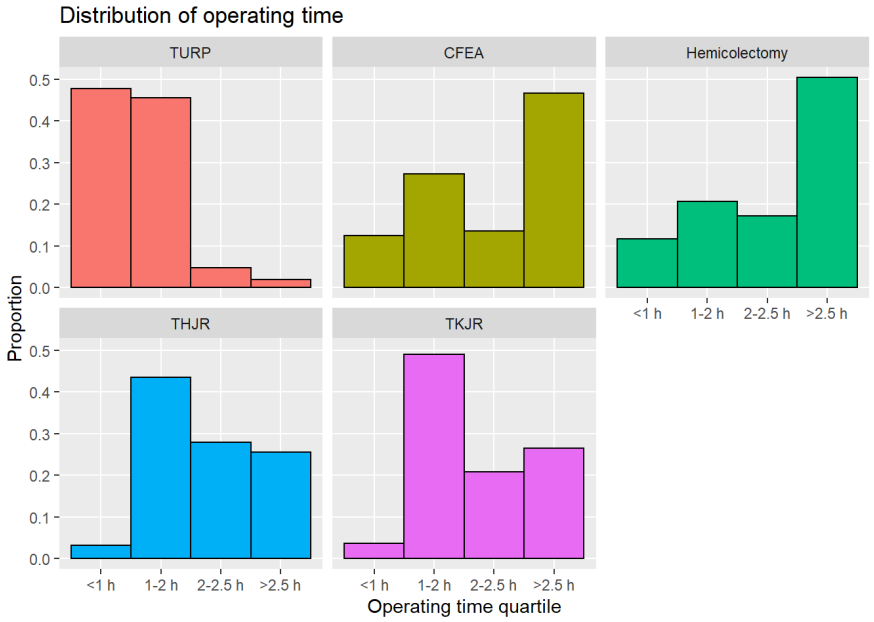
The distribution of ASA physical status was similar between the procedures with the exception of femoral endarterectomy. For this procedure, there was a relatively large proportion classified as ASA 3. This may be because CFEA is performed for vascular disease, and is therefore more likely to be associated with diseases such as diabetes mellitus and coronary artery disease that would increase an individual's ASA physical status class.



TURP=transurethral prostatectomy; CFEA=common femoral endarterectomy; THJR=total hip joint replacement; TKJR=total knee joint replacement

Figure 9. Distribution of operating time for five specific surgical procedures

Operating time varied widely between the procedures, which may be an indication of the relative complexity of the patients and / or the relative technical difficulty of the procedures.



TURP=transurethral prostatectomy; CFEA=common femoral endarterectomy; THJR=total hip joint replacement; TKJR=total knee joint replacement

Table 6. DAH_{30} and hospital costs: multivariate analysis

Term	Estimate	95% CI
(Intercept)	18321	17760, 18898
DAH_{30}	0.958	0.957, 0.959
Patient age, years	1.002	1.002, 1.002
Female sex	0.957	0.952, 0.962
State (ref. VIC)		
QLD	0.955	0.948, 0.962
NSW	0.930	0.923, 0.937
SA or NT	0.919	0.909, 0.929
WA	1.051	1.042, 1.061
TAS	0.977	0.962, 0.993
ACT	0.965	0.947, 0.983
Emergency surgery	0.912	0.904, 0.921
Public hospital	0.354	0.343, 0.366
1	0.987	0.979, 0.994
2	1.010	0.999, 1.022
3+	1.009	0.990, 1.028
2	1.049	1.042, 1.057
3	1.077	1.068, 1.086
4+	1.227	1.209, 1.246
Intermediate	0.882	0.859, 0.906
Major	1.273	1.240, 1.307
Complex major	1.462	1.423, 1.502
HDU/ICU admission	1.710	1.683, 1.737
Post-operative mechanical ventilation	1.399	1.334, 1.467
Unplanned reoperation	1.143	1.122, 1.165
30-60 minutes	1.128	1.117, 1.140
60-120 minutes	1.468	1.453, 1.483
>120 minutes	1.962	1.942, 1.982

R-squared = 0.589
HDU=high dependency unit; ICU-intensive care unit.