

1 **Surgery and radiotherapy for symptomatic spinal metastases is more cost effective than**
2 **radiotherapy alone: a cost utility analysis in a UK spinal center.**

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18 **Keywords**

19 Cost, ICER, metastasis, QALY, spine, surgery

20

21 **Abbreviations**

22 EQ-5D-3L, EuroQol 5 Dimension 3L measure of health-related quality of life

23 FCE, Finished consultant episode

- 24 MSCC, Metastatic spinal cord compression
- 25 NHS, National Health Service
- 26 NICE, National Institute for Health and Care Excellence
- 27 PSSRU, Personal social services research unit
- 28 QALY, Quality adjusted life year
- 29

30 **Abstract**

31 Background

32 Surgery for symptomatic spinal metastases is effective at prolonging ambulation and life,
33 but may appear costly at first glance. We have studied the difference between the cost of surgery
34 and reimbursement received, as well as the cost-effectiveness of surgery in a UK tertiary referral
35 spinal center.

36 Methods

37 A cost versus reimbursement and cost-utility analysis was performed in a prospective
38 cohort of patients admitted for surgical treatment of spinal metastases. Outcome measures were
39 health-related quality of life using the EuroQol EQ-5D-3L, Frankel score, quality-adjusted life
40 years (QALYs), treatment and reimbursement costs.

41 Results

42 130 consecutive patients were prospectively recruited, of whom 92 had information
43 available for cost and reimbursement comparison, and 100 had information to complete cost
44 utility analysis. Median cost of hospital treatment per patient was £20,752; median
45 reimbursement received was £18,291, with a median shortfall of £1,967. Surgery in addition to
46 radiotherapy over a lifetime horizon was both more effective and less costly than radiotherapy
47 alone, and therefore was found to be cost-effective.

48 Conclusion

49 Our results demonstrate that reimbursement to hospitals for surgical management of
50 symptomatic spinal metastases in the UK is broadly in line with costs, and that there was an

51 overall saving as a result of community care costs being mitigated by patients walking for longer,
52 which is within the expected National Health Service (NHS) threshold. Surgery for metastatic
53 spinal tumors is effective and good value for money.

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59

60 **INTRODUCTION**

61 Spinal metastases occur in up to 75% of the most common cancers, including breast,
62 prostate and lung cancer,^{1,2} of which 26% may develop into skeletal related events including
63 pathological fracture and metastatic spinal cord compression (MSCC).³ In the UK, the National
64 Institute for Health and Care Excellence (NICE) have produced guidelines that promote surgical
65 management in around 70% of patients presenting with symptoms of MSCC.^{4,5} These guidelines
66 are supported by Patchell et al (2005), who demonstrated a higher percentage of people able to
67 mobilize, greater longevity of ambulation and better survival following surgical management in
68 conjunction with radiotherapy compared to radiotherapy alone as primary treatment.⁶ Despite
69 surgery, MSCC has a significant impact on quality of life and survival,⁷ and in tandem there are
70 significant hospital costs associated with the surgical management of symptomatic spinal
71 metastases, which we have previously reported as averaging £16,885 per patient,⁸ and when
72 combined with out of hospital costs may be as high as €87,814.⁹ Providing good value

73 healthcare, which is both high quality and affordable is vital to the sustainability of the NHS and
74 other publically funded health care systems.¹⁰ In today's tough economic climate there is an
75 emerging body of literature analyzing the cost-effectiveness of medical interventions to inform
76 process changes that promote efficiency.¹¹ Clinicians are in the optimal position to develop and
77 deliver changes to practice, maintaining the focus on high quality patient care.

78 Different financial metrics are available to assist with analysis. We have previously
79 reported the average in-hospital cost of surgically treating symptomatic spinal metastases in one
80 UK center.⁸ The difference between this and the reimbursement rate that the hospital receives
81 from the NHS centrally is important at local and national levels; this has not yet been determined
82 in patients with symptomatic spinal metastases. In other conditions, including hip and knee
83 revision surgery, there is a possible shortfall in reimbursement of between £861 and £4566 per
84 patient,^{12,13} which was suggested to be largely associated with a more complex patient case-mix
85 than the NHS average in the hospitals studied, with patients requiring more expensive or longer
86 treatment despite receiving the same, nationally-averaged, reimbursement tariff for that patient
87 group. This shortfall requires the departments in question to implement more efficient pathways,
88 or negotiate local variations to the tariff. As an additional incentive for some departments,
89 several tariffs are now reimbursed based on the cost of evidence-based, efficient, patient
90 pathways, rather than national average cost, and future tariffs may be split between health and
91 social care systems.¹⁴

92 At a national level, recommendations for healthcare service provision are based on cost
93 utility analysis, balancing cost of treatment with quality and length of life gained following
94 treatment, measured in quality adjusted life years (QALYs).¹⁵ Recommendations by the National
95 Institute for Health and Care Excellence (NICE) have implied an upper limit of £30,000/QALY

96 for NHS funded treatments,^{15,16} although there is considerable debate about the appropriateness
97 of this threshold,^{16,17} and a suggestion that populations may be willing to pay more for end of life
98 management than short term health problems.¹⁸ In patients with symptomatic spinal metastases,
99 cost of surgical management over a lifetime horizon has been found to be both more expensive,
100 and more effective than non-surgical management^{19,20}; the incremental cost per QALY gained
101 for surgery compared to radiotherapy alone has been estimated at \$250,307 by Furlan et al
102 (2012),¹⁹ which is significantly higher than the \$50,000 commonly used threshold in the US,²¹
103 whilst Miyazaki et al (2017) estimated it at \$42,003.²² There is a paucity of data in this area,²³
104 and methodologies differ significantly, giving rise to significant variations in cost effectiveness.
105 The former study looked at medical costs combined with estimated community palliative care
106 costs; these high input homecare costs may be reduced by successful surgical intervention,
107 improving cost effectiveness.

108 We have studied the cost effectiveness of the surgical treatment of MSCC at one London
109 center and aimed to determine if reimbursement was broadly in line with cost, and the cost
110 effectiveness of surgical treatment of metastatic spine disease.

111 **MATERIALS AND METHODS**

112 **Subjects**

113 Consecutive patients were prospectively recruited at a single NHS spinal tertiary referral
114 center in London if they required surgery for symptomatic spinal metastases from any known or
115 unknown primary cancer, verified by intra-operative histology. Patients were recruited between
116 2009 and 2015. Patients were included in the analysis if they were confirmed as having died, or
117 if they had at least 12 months of follow-up data and were confirmed alive in July 2015 following

118 a search of records of death, held centrally by Public Health England; those that were alive at
119 time of analysis were allocated a date of death of July 2015 in order to complete the analysis.
120 Exclusion criteria were inability to give written informed consent to participate, and age less than
121 18 years. Informed consent was obtained from all subjects and ethical approval was granted by
122 the UK National Research Ethics Service.

123 **Outcome measures**

124 Patient demographics, clinical and surgical details were collected during the index
125 admission. Frankel grade and EQ-5D-3L scores were collected pre-operatively, post-operatively,
126 at three, six, twelve months and every 12 months thereafter until death. A utility index suitable to
127 calculating QALYs was calculated from the EQ-5D-3L scores using the UK value set.²⁴

128 **Financial analysis**

129 All costs to the hospital, as described previously,⁸ as well as tariff reimbursed to the
130 hospital, including the Market Forces Factor, were extracted from the hospital's financial
131 databases for each subject from index admission until death; if still alive, data was collected up
132 to July 2015. Fifty percent of the cost data was used in our previous report⁸; the remainder of the
133 cost data and all the reimbursement data is newly reported here. For each subject, admissions
134 were retained that included a neurosurgical episode, and a manual search reduced admissions to
135 those including neurosurgical treatment of symptomatic spinal metastases using electronic
136 admission details and letters.

137 Each admission might include more than one finished consultant episode (FCE), for
138 example, medical oncology and neurosurgery. Although costs can be separated into each FCE,
139 reimbursement is usually allocated to the FCE carrying the heavier tariff only, for this reason,

140 both costs and reimbursements were summed across FCEs for each admission, including critical
141 care costs, to give a fully absorbed admission cost and admission tariff (reimbursement).

142 **Comparison of cost and reimbursement**

143 All costs and reimbursements were adjusted to 2015/16 financial year using the Personal
144 Social Services Research Unit (PSSRU) inflation figures.²⁵ Data were analyzed at patient level
145 by summing admissions, as spinal centers are likely to treat patients for symptomatic spinal
146 metastases throughout their disease course.

147 **Cost-utility analysis**

148 It is perhaps unethical to repeat a randomized controlled trial (RCT) of surgical treatment
149 vs. non-surgical management of symptomatic spinal metastases due to the superiority of surgical
150 management demonstrated in the RCT by Patchell et al (2005)⁶; as such, it was necessary to
151 model anticipated reimbursements of a matched, non-surgical, radiotherapy-only cohort, as well
152 as expected QALYs. This represents the alternative management strategy to surgery. All data
153 from our subject cohort was initially replicated, to create an identical, model, non-surgical group
154 to be as close as possible to an RCT-style control arm, with the same baseline as the surgical
155 group; survival was reduced to 79%, and ambulation to 11% based on the study by Patchell et al
156 (2005).⁶ This was considered to be more robust than comparison with a real world subject group
157 with symptomatic spinal metastases who didn't undergo surgery, as their baseline characteristics
158 are unlikely to match those of the surgery group.^{9,22}

159 It is expected that although the immediate hospital cost of surgically managing
160 symptomatic spinal metastases is high, surgical intervention may mitigate community costs in
161 the future by maintaining ambulation for a longer period, and as a result the community costs

162 were modeled for both surgical and non-surgical groups using the methods outlined in the MSCC
163 NICE economic analysis.²⁶ As both hospital reimbursement costs and community care costs
164 were analyzed, this study had an NHS and social care perspective over a lifetime horizon.

165 *Inpatient reimbursement tariff*

166 Reimbursements, rather than costs, were used for the cost utility analysis, as this analysis
167 is more pertinent to commissioning at the national level. All tariffs reimbursed were adjusted to
168 2015/2016 financial year,²⁵ and discounting at 3.5% was applied cumulatively to successive
169 years in line with current recommendations by NICE.¹⁵ Reimbursements for inpatient stays,
170 including critical care admissions, were then summed to generate total reimbursement per
171 patient.

172 Non-surgical management of symptomatic spinal metastases is likely to incorporate radiotherapy
173 treatment.⁴ The NICE guidance suggests that this is unlikely to be significantly different to that
174 received by surgical patients.²⁶ Based on this, radiotherapy costs for the surgical cohort were
175 analyzed, and the average allocated as an ‘inpatient reimbursement’ to the non-surgical group.
176 This is expected to be an underestimation of costs as initial diagnostic costs in a medical
177 oncology episode were not included.

178 *Community care tariff*

179 The NICE MSCC economic analysis sets out a methodology for calculating community
180 care costs including home care support, community nursing and GP input; these costs are
181 currently not available for direct analysis at the subject level in the same way as hospital
182 reimbursements are. Expected costs are based on the PSSRU’s database of community care

183 costs,²⁵ inflated to the 2015/2016 financial year, and then discounted following the index year as
184 with the hospital costs.¹⁵

185 For our surgical group, discharge destinations were known (Table 1). Subjects who did
186 not go straight home, or to a nursing home were allocated their eventual destination based on
187 their ability to mobilize at discharge, those that were able to walk (Frankel D or E) were
188 expected to go home, and those that were unable to walk were expected to be cared for at a
189 nursing home. In line with NICE guidance, subjects were expected to continue to be cared for at
190 their discharge location until death.²⁶

191 Those who went home were allocated a low cost community tariff for the duration of
192 their ability to walk (£177/week), and a medium cost tariff for the duration that they were unable
193 to walk (£989/ week). Regardless of which tariff they were on at the end of their lives, a high
194 cost tariff was allocated for the final two weeks for palliative care (£1481/week). Packages
195 included increasing levels of social services home care support, as well as increasing levels of
196 community nursing and GP visits. Those that were cared for at a nursing home were allocated a
197 single tier tariff for the period of their survival including nursing care costs, accommodation,
198 ancillary costs and operator profit, regardless of ambulation status (£729/week), (Figure 1).²⁶

199 For the model non-surgical group, community care costs were initially calculated for both
200 discharge destination alternatives, as above. For each non-surgical subject, community care cost
201 was calculated as a percentage of home cost, plus a percentage of a nursing home cost, totaling
202 100%. This was dependent on their matched subject's ambulation status at admission (Figure 2).

203 For both groups, we conducted an additional analysis of community costs using the 2008
204 NICE figures for home and nursing home healthcare costs, inflated to 2015/2016, as an

205 alternative modeling method. This analysis was carried out as a sensitivity analysis to give a
206 range of possible costs, to make the analysis more robust.

207 *QALYs*

208 In the surgical cohort, QALYs from index admission until death, i.e. the lifetime horizon,
209 were calculated using the EQ-5D index gathered during follow-up. On death, patients were
210 allocated an EQ-5D index of zero. QALYs were calculated as the area under the line connecting
211 EQ-5D index points (Figure 3). Subjects who were still alive in July 2015 were pragmatically
212 allocated an EQ-5D index of 0 from that point.

213 In the non-surgical cohort, QALYs were predicted to remain static initially, as any
214 improvement seen in the surgical group is thought to be related to the surgical intervention.
215 Given the non-surgical group's expected shorter ambulation and lifespan, health utility was
216 modeled as declining from the same time point as the surgical group, with survival being
217 shortened to 79% as discussed previously (Figure 3).⁶

218 Sensitivity analyses were performed to identify if there would have been a significant
219 change in the results if this method resulted in an under or overestimation of non-surgical
220 QALYs (Figure 3). Sensitivity analysis one represented that the initial analysis underestimated
221 QALYs. QALYs were calculated in this scenario as being maintained at pre-operative levels
222 until the known QALYs from the matched surgical subject became lower than pre-operative
223 levels, and the non-surgical QALY curve was expected to follow that deterioration, with survival
224 being reduced to 79% of the surgical subject. Sensitivity analysis two represented that the initial
225 analysis overestimated QALYs. QALYs were calculated as deteriorating linearly from pre-

226 operative levels until death at 79% of the surgical patients' survival. For all QALY calculations,
227 discounting was applied to all years after the index year at 3.5% as recommended by NICE.¹⁵

228 **Statistical analysis**

229 All statistical analysis was carried out in Stata v.12 (Statacorp LP, College Station, TX,
230 USA). Descriptive details were generated for demographics; financial and QALY data included
231 medians and IQR because of skewness of the data; means were generated as recommended by
232 Thompson and Barber (2000)²⁷ and to enable comparison with other studies. The Wilcoxon
233 signed rank test was used to assess for significant differences in cost and reimbursement, the
234 spearman correlation coefficient was used to analyze relationships between cost per QALY (the
235 Incremental Cost Effectiveness Ratio, ICER) and survival time. Significance level was set at
236 $P=.05$.

237 Only subjects with both cost and reimbursement data were used in that comparison
238 analysis and only those with reimbursement and QALY data were used in the cost-utility
239 analysis. Where subjects were unavailable for follow-up of EQ-5D-3L scores, the EQ-5D index
240 was assumed to have improved or deteriorated linearly to the next known point.

241 **RESULTS**

242 During the period of the study, 130 consecutive patients were recruited, of whom 92 had
243 information available to complete cost and reimbursement comparison, and 100 had information
244 available to complete the cost utility analysis.

245 **Inpatient cost and reimbursement analysis**

246 In this group, 47 were male (51.1%) and mean age was 60.6 years (SD 14.0). The
247 majority of patients were not paralyzed at admission (n=64, 69.6%). Median survival was 5.6

248 months (IQR 2.5-15.9), mean was 9.8 months (SD 9.6). Of the 22 subjects that were still alive at
249 analysis (24%), median length of follow-up was 25.0 months (IQR 23.8-36.1), mean was 27.3
250 months (SD 9.6).

251 Median cost per surgical patient was £20,752 (IQR £11,550-£30,825; mean £24,445; SD
252 £17,526), and median reimbursement income received was £18,291 (IQR £17,002-22,089; mean
253 £21,213; SD £13,163), a median shortfall of £1,967 (IQR shortfall £7,387-saving £5,339)
254 (Figure 4). Statistical analysis revealed that the difference between cost and reimbursement was
255 statistically significant ($p=.05$).

256 **Cost utility analysis**

257 In the surgery group, 49% of subjects were male ($n=49$), and average age was 59.8 years
258 (SD 14.2). 69 subjects (69%) were able to walk at admission, and 74 subjects (77%) at discharge
259 for a median of 13 months (IQR 4.0, 34.0); of those unable to walk at admission, 13 (44.8%)
260 regained the ability to walk (Table 1 and Figure 5). Median survival was 6.1 months (IQR 2.5,
261 17.9), mean 10.9 months (SD 11.1); ability to mobilize on discharge had a significant survival
262 advantage, increasing survival to median 7.7 months (IQR 3.9, 19.0), mean 13.0 (SD 11.8). For
263 those still alive, median follow-up was 24.9 months (IQR 12.6, 36.1) mean 24.8 (SD 11.8).

264 After discounting was applied, median reimbursement tariff for hospital admission was
265 £18,291 (IQR £17,002; 21,768), the mean was £20,950 (SD £12,693), as expected this was
266 higher than the median due to skewness. For patients undergoing post-operative radiotherapy to
267 the same spinal level, the mean reimbursement was £6,338, which was applied to the non-
268 surgical group.

269 Median community cost was £15,512 for the surgical cohort (IQR £6,440, 29,299), the
270 mean was £21,955 (SD £21,600). All ambulant patients were cared for at home whilst only
271 23.8% of non-ambulant patients were cared for at home (Table 1). The median total tariff for this
272 group was £35,431 (IQR 25,055, 49,701), mean £42,904 (SD £24,768).

273 Community care tariffs were modeled for the non-surgical group. 69 patients (69%) were
274 able to walk at admission, and were allocated the home care costs appropriate to their ambulation
275 length and survival. The remaining patients' tariff was comprised 23.8% home care tariff, and
276 76.2% nursing home tariff (Figure 2). The median community tariff was £38,802 (IQR £13,085-
277 83,893; mean £49,404; SD £43,646), and the median total tariff was £45,141 (IQR £19,423,
278 90,231; mean £55,743; SD £43,646). The median incremental cost difference was £1,107 more
279 expensive for the surgical group (IQR £38,391 cheaper, £11,702 more expensive), mean £12,839
280 cheaper for the surgical group (SD £37,896) (Table 2).

281 The NICE 2008 economic guidance reports that weekly community care tariffs were £91
282 for an ambulant patient, £1,351 for non-ambulant, £1,918 for a palliative patient and £567 for
283 patients cared for in nursing homes. When inflated to 2015/2016, this resulted in higher
284 community care costs, particularly for non-ambulant patients. The total median tariffs using this
285 approach were £32,002 (IQR £24,357, 42,612; mean £42,819; SD £32,002) for the surgical
286 group, and £62,854 (IQR £22,846, 112,276; mean £76,958; SD £64,220) for the non-surgical
287 group. The median incremental cost difference was £7,069 cheaper for the surgical group (IQR
288 £69,396 cheaper, £10,531 more expensive), mean £34,139 cheaper (SD £63,506) (Table 2).

289 QALYs were calculated for the surgical group. Health utility scores were available for 99
290 of 100 subjects at baseline (99%), 60 of 82 subjects alive at three months (73%), 44 of 65

291 survivors at six months (68%), 38 of 51 survivors at 12 months (75%), 23 of 28 survivors at 24
292 months (82%), 8 of 14 survivors at 36 months (57%) and 1 of 3 survivors at 48 months (33%).
293 Data was missing where patients were unavailable for follow-up, frequently due to deteriorating
294 health, or where patients were uncontactable. Initial health utility was median 0.33 (0.18, 0.69),
295 mean 0.41 (SD 0.30). The discounted median QALYs were 0.28 (IQR 0.04-0.99) the mean was
296 0.64 (SD 0.76). For the non-surgical group they were calculated as median 0.13 (IQR 0.02-0.50),
297 mean 0.32 (SD 0.41), with a median incremental QALY difference of 0.09 (IQR 0.01, 0.54;
298 mean 0.32; SD 0.45). The two sensitivity analyses returned QALYs of median 0.17 (IQR 0.02-
299 0.53) and 0.12 (0.02-0.36) respectively with median incremental differences of 0.06 and 0.13,
300 and mean differences of 0.27 and 0.38 (Figure 3).

301 Surgery is less costly than no surgery based on the mean, and only marginally more
302 costly based on the median, it is also the more effective strategy based on the QALY mean and
303 median, and therefore it must be cost effective as it dominates over no surgery.

304 The correlations between ambulation time, $r=-0.87$, or survival time, $r=-0.73$, and cost
305 per QALY were significant ($P<.01$ for both), indicating that it is the mitigation of community
306 costs which increases the cost effectiveness of surgery in this patient group (Figure 6).

307 **DISCUSSION**

308 **Principle findings**

309 Symptomatic spinal metastases represent a significant clinical and economic burden. Our
310 study is the first in the world to investigate the cost utility of surgical management of
311 symptomatic spinal metastases using prospectively collected health utility data, and the first
312 health utility study for MSCC in the UK. There is a perception amongst surgeons that hospitals

313 in the UK are under-reimbursed for the work they carry out under the current system; we found a
314 significant median shortfall of £1,967 between the cost of surgery and the reimbursement to the
315 hospital. Our results show that over a lifetime horizon, from the NHS and social care perspective,
316 surgery is less costly and more effective than non-surgical management. This saving is within the
317 expected threshold set by NICE,¹⁵ suggesting surgical management is good value for money, as
318 well as being clinically effective.⁶

319 **Strengths and weaknesses of the study**

320 This study has overcome several hurdles of other health economic studies by completing
321 a prospective study and collecting both cost and health utility data without recourse to searches
322 by HRG coding. However, imputational models were still required to estimate community care
323 costs, as this is not currently collected at the patient level, and to estimate QALY and cost data
324 for a comparative non-surgical cohort. We also recognize that choice of discharge destination is
325 multi-factorial, but chose this method to replicate the NICE economic analysis.²⁶ A limitation is
326 that the effect of recent advances in radiotherapy techniques that may prolong ambulation or
327 survival may be under-represented, one recent study showed 25% of subjects improved with
328 non-surgical treatment, although there was a mean drop in health utility.²² These limitations were
329 mitigated where possible by using a conservative estimate of surgical QALYs and non-surgical
330 costs, and performing sensitivity analyses; censoring data from patients who were alive in July
331 2015 will have resulted in a conservative estimate of cost per QALY, as cost efficiency is
332 strongly correlated with survival time (Figure 6). As this was a single center study, it is possible
333 that some in-hospital costs may have been missed if subjects had further intervention in other
334 hospital Trusts.

335 **Comparison to existing literature**

336 The hospital costs of surgical and radiotherapy management are slightly higher than
337 previously reported by our group (£20,752 vs. £16,885), which is likely to be due the inclusion
338 of oncology admissions attached to neurosurgical episodes.⁸ The reimbursement, £18,291, is also
339 higher than other published material: Body et al (2013)²⁸ reported reimbursement tariffs of
340 €15.048, and a NICE analysis reported likely costs of £13,094 in 2008,²⁶ these differences are
341 perhaps due to the different methodologies, and changing time periods of the studies.^{8,29}

342 A shortfall between cost and reimbursement has been noted in other surgical areas,
343 including hip and knee revision surgery, which have a shortfall of up to £4,566.¹² This was
344 suggested to be a result of a more complex case mix. However, shortfalls may also be due partly
345 to variations in hospital efficiency. The reimbursement tariff is created from an average of costs
346 of admissions for patients undergoing similar procedures across the country, adjusted for market
347 forces, as costs vary throughout the country. Trusts may also negotiate local changes to the tariff
348 in some instances. Other specialist centers suggest that they are able to generate lower costs, and
349 therefore a more beneficial cost: reimbursement ratio, as a result of their frequent management of
350 a specialist patient group, which is possible in this cohort as it is based at a regional center for
351 spinal surgery. It is notable that reimbursement is not expected to directly repay each department
352 pro rata; instead variations are expected across departments, which should balance across a
353 hospital trust.¹⁴

354 Our calculation showing an overall lifetime saving following surgery in addition to
355 radiotherapy, from the NHS and social care perspective (i.e. the tariff), is significantly lower than
356 the only previous estimate using data with a comparable non-surgical group, by Furlan et al

357 (2012) of US\$250,307 per QALY,¹⁹ as well as an estimate using groups with different baseline
358 characteristics (\$42,003 per QALY).²² Whilst in this study the baseline demographic and clinical
359 measures were similar to those used in Furlan et al.'s study, based on data from Patchell (2005),⁶
360 ambulation and survival length, as well as estimated cost methodology are likely to have
361 contributed to the difference. Median duration of ambulation (152 vs. 122 days) and survival
362 (185 vs. 126 days) were greater in this report; survival time in more recent studies confirms a
363 trend to improving survival time following surgical intervention in this patient group.²² The
364 discrepancy in cost is also likely to be related to the methodology used; this has previously been
365 reported to be a significant barrier to the comparison of health utility studies.²⁹ The study by
366 Furlan et al. estimated community care costs based on the cost of palliative care, either at home
367 or at a nursing home; combined hospital and community costs were estimated as mean \$583,809
368 for a surgical patient and \$554,323 for a non-surgical patient.¹⁹ The economic guidance by the
369 National Institute for Health and Clinical Excellence (2008) used in this study, suggested that it is
370 more likely that some patients will require a lower level of support for the majority of their
371 survival (depending on ambulation status), and only need palliative care in the final weeks of
372 life; this results in a significant difference in the estimation of community care costs and
373 therefore cost per QALY²⁶. Our costs of £42,904 for the surgical cohort and £55,743 for the non-
374 surgical cohort are significantly lower, and more closely relate to those of other recent studies;
375 Tipsmark et al (2015) estimated costs of up to €87,814 and €36,616 for surgical and non-surgical
376 groups over a lifetime horizon,⁹ whilst Miyazaki et al (2017) estimated costs of \$25,770 and
377 \$8,615 over one year.²² Both studies calculated costs using different methodologies, the first was
378 based on an insurance register, the second from medical remuneration points. The mitigation of
379 community care costs as a result of longer survival post-surgery is clearly seen in Figure 6.

380 The methodology for generating QALYs was also different in our and Furlan et al.'s study.¹⁹ We
381 collected prospective EQ-5D data throughout the subjects' life, whereas Furlan et al. created an
382 estimated health utility generated from interviewing the general population using the time trade-
383 off technique. Furlan et al. used health utilities from the Harvard University Catalogue from the
384 US and the Health Outcomes Data- health utility list from the UK and multiplied by the period of
385 time the patient was affected, which would not take into account deterioration during the lifetime
386 horizon that was demonstrated in our study. Based on a health utility value of 0.388, Furlan et al.
387 described mean QALYs for radiotherapy only as 0.46 (95% 0.06-3.41), mean QALYS for
388 surgery and radiotherapy 0.57 (95% 0.13-2.24). The mean initial health utility in our study pre-
389 operatively was 0.41, whilst mean lifetime QALYS were 0.64 for patients undergoing surgery
390 and 0.32 for patients undergoing radiotherapy only. Miyazaki et al (2017) describe QALYS at
391 one year as 0.433 for their surgical group; that cohort had a lower health status (0.036) and lower
392 level of ambulation (54.8%) at baseline than in our study (0.41 and 69% respectively),
393 furthermore, their patients had tumors with a higher grade of malignancy than in this study, the
394 first two factors are known predictors of quality of life, and the latter is a prediction of survival
395 after surgery,^{7,30} and may account for the lower QALYS gained compared to our study.

396 **Implications for clinicians**

397 Our study has demonstrated a small discrepancy between the cost to the hospital and the
398 reimbursement from the government for treating this patient group; we have previously reported
399 that ward cost is the greatest factor in total hospital costs, promoting the implementation of
400 methods to reduce hospital length of stay. Our result shows that surgery in addition to
401 radiotherapy is more effective and less expensive than radiotherapy alone over a lifetime
402 horizon, and despite longer survival, the gain in QALYS following surgery outweighs any costs

403 from the longer follow-up, particularly as ambulation is prolonged. The cost per QALY is within
404 the implied UK threshold for NHS funding,¹⁵ supporting managers in commissioning surgical
405 services for patients with symptomatic spinal metastases.

406 **Future research**

407 Given the significant initial cost outlay in surgical management compared to non-surgical
408 management, it is vital for cost utility studies in the future to calculate community health care
409 costs as well as hospital costs, as the mitigation of the community costs at the wider health and
410 social care level will have a significant impact on the cost per QALY. Ability to directly extract
411 both health and social care economic data at the patient level will increase the robustness of
412 future studies.¹⁰

413 **CONCLUSION**

414 Our results demonstrate that reimbursement to a tertiary referral hospital for surgical
415 management of symptomatic spinal metastases in the UK is broadly in line with costs, and that
416 as a result of community care costs being mitigated by a greater percentage of ambulant patients
417 with better quality of life, surgery for MSCC is both effective and good value for money.

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References

1. Coleman RE. Metastatic bone disease: clinical features, pathophysiology and treatment strategies. *Cancer Treat. Rev.* 2001;27:165-176.
2. Coleman RE. Clinical features of metastatic bone disease and risk of skeletal morbidity. *Clin. Cancer Res.* 2006;12:6243s-6249s.
3. Pockett RD, Castellano D, McEwan P, Oglesby A, Barber BL, Chung K. The hospital burden of disease associated with bone metastases and skeletal-related events in patients with breast cancer, lung cancer, or prostate cancer in Spain. *European journal of cancer care.* 2010;19:755-760.
4. National Institute for Health and Clinical Excellence. Metastatic spinal cord compression: diagnosis and management of adults at risk of and with metastatic spinal cord compression. NICE guideline (CG75). 2008; <http://www.nice.org.uk/guidance/cg75>. Accessed 08/06/2017.
5. National Institute for Health and Clinical Excellence. National costing report: Metastatic spinal cord compression. 2008; <http://www.nice.org.uk/guidance/cg75/resources/costing-report-pdf-242009821>. Accessed 07/06/2017.
6. Patchell RA, Tibbs PA, Regine WF, Payne R, Saris S, Kryscio RJ, Mohiuddin M, Young B. Direct decompressive surgical resection in the treatment of spinal cord compression caused by metastatic cancer: a randomised trial. *The Lancet.* 2005;366:643-648.
7. Choi D, Fox Z, Albert T, Arts M, Balabaud L, Bunger C, Buchowski JM, Coppes MH, Depreitere B, Fehlings MG, Harrop J, Kawahara N, Martin-Benlloch JA, Massicotte EM, Mazel C, Oner FC, Peul W, Quraishi N, Tokuhashi Y, Tomita K, Verlaan JJ, Wang M, Crockard HA. Prediction of Quality of Life and Survival After Surgery for Symptomatic Spinal Metastases: A Multicenter Cohort Study to Determine Suitability for Surgical Treatment. *Neurosurgery.* 2015;77:698-708.
8. Turner I, Minhas Z, Kennedy J, Morris S, Crockard A, Choi D. Cost of Surgery for Symptomatic Spinal Metastases in the United Kingdom. *World Neurosurg.* 2015;84:1235-1243.
9. Tipsmark LS, Bunger CE, Wang M, Morgen SS, Dahl B, Sogaard R. Healthcare costs attributable to the treatment of patients with spinal metastases: a cohort study with up to 8 years follow-up. *BMC Cancer.* 2015;15:354.
10. Porter M. What Is Value in Health Care? *N. Engl. J. Med.* 2010;363:2477-2481.
11. O'Reilly J, Busse R, Hakkinen U, Or Z, Street A, Wiley M. Paying for hospital care: the experience with implementing activity-based funding in five European countries. *Health economics, policy and law.* 2012;7:73-101.
12. Kallala R, Vanhegan I, Ibrahim M, Sarmah S, Haddad F. Financial analysis of revision knee surgery based on NHS tariffs and hospital costs does it pay to provide a revision service? *Bone & Joint Journal.* 2015;97:197-201.
13. Vanhegan I, Malik A, Jayakumar P, Islam SU, Haddad F. A financial analysis of revision hip arthroplasty The economic burden in relation to the national tariff. *Journal of Bone & Joint Surgery, British Volume.* 2012;94:619-623.
14. Department of Health Payment by Results Team. A simple guide to payment by results. In: Finance, ed2012.
15. National Institute for Health and Care Excellence. Guide to the methods of technology appraisal 2013 (PMG9). 2013; <http://www.nice.org.uk/process/pmg9/chapter/foreword>. Accessed 07/06/2017.
16. Claxton K, Martin S, Soares M, Rice N, Spackman E, Hinde S, Devlin N, Smith PC, Sculpher M. Methods for the estimation of the National Institute for Health and Care Excellence cost-effectiveness threshold. *Health Technol. Assess.* 2015;19:1-542.

- 473 17. Raftery J. NICE's cost-effectiveness range: should it be lowered? *Pharmacoeconomics*.
474 2014;32:613-615.
- 475 18. Pinto-Prades J-L, Sánchez-Martínez F-I, Corbacho B, Baker R. Valuing QALYs at the end of life.
476 *Soc. Sci. Med.* 2014;113:5-14.
- 477 19. Furlan JC, Chan KK, Sandoval GA, Lam KC, Klinger CA, Patchell RA, Laporte A, Fehlings MG. The
478 combined use of surgery and radiotherapy to treat patients with epidural cord compression due
479 to metastatic disease: a cost-utility analysis. *Neuro-oncology*. 2012;14:631-640.
- 480 20. Thomas KC, Nosyk B, Fisher CG, Dvorak M, Patchell RA, Regine WF, Loblaw A, Bansback N, Guh
481 D, Sun H, Anis A. Cost-effectiveness of surgery plus radiotherapy versus radiotherapy alone for
482 metastatic epidural spinal cord compression. *Int.J.Radiat.Oncol.Biol.Phys.* 2006;66:1212-1218.
- 483 21. Neumann PJ, Cohen JT, Weinstein MC. Updating cost-effectiveness—the curious resilience of
484 the \$50,000-per-QALY threshold. *N. Engl. J. Med.* 2014;371:796-797.
- 485 22. Miyazaki S, Kakutani K, Sakai Y, Ejima Y, Maeno K, Takada T, Yurube T, Terashima Y, Ito M,
486 Kakiuchi Y, Takeoka Y, Hara H, Kawamoto T, Sakashita A, Okada T, Kiyota N, Kizawa Y, Sasaki R,
487 Akisue T, Minami H, Kuroda R, Nishida K. Quality of life and cost-utility of surgical treatment for
488 patients with spinal metastases: prospective cohort study. *Int. Orthop.* 2017;41:1265-1271.
- 489 23. Fehlings MG, Nater A, Holmer H. Cost-effectiveness of Surgery in the Management of Metastatic
490 Epidural Spinal Cord Compression: A Systematic Review. *Spine (Phila Pa 1976)*. 2014;39:S99-
491 S105.
- 492 24. Szende A, Oppe M, de Charro F. Comparative review of timetrade-off value sets. In: Szende A,
493 Oppe M, Devlin N, eds. *EQ-5D value sets: inventory, comparative review and user guide*.
494 Netherlands: Springer Netherlands; 2007.
- 495 25. PSSRU. PSSRU Unit Costs of Health and Social Care 2014. 2014; [http://www.pssru.ac.uk/project-
496 pages/unit-costs/2014/](http://www.pssru.ac.uk/project-pages/unit-costs/2014/). Accessed 09/03/2016.
- 497 26. National Institute for Health and Clinical Excellence. *An economic evaluation of treatments for
498 people with suspected metastatic spinal cord compression (CG75)*. 2008.
- 499 27. Thompson S, Barber J. How should cost data in pragmatic randomised trials be
500 analysed? *BMJ*. 2000;320:197-200.
- 501 28. Body JJ, Chevalier P, Gunther O, Hechmati G, Lamotte M. The economic burden associated with
502 skeletal-related events in patients with bone metastases secondary to solid tumors in Belgium.
503 *Journal of medical economics*. 2013;16:539-546.
- 504 29. Alvin MD, Miller JA, Lubelski D, Rosenbaum BP, Abdullah KG, Whitmore RG, Benzel EC, Mroz TE.
505 Variations in cost calculations in spine surgery cost-effectiveness research. *Neurosurg. Focus*.
506 2014;36:E1.
- 507 30. Balain B, Jaiswal A, Trivedi J, Eisenstein S, Kuiper J, Jaffray D. The Oswestry Risk Index. An aid in
508 the treatment of metastatic disease of the spine. . *Bone Joint J*. 2013;95:210-216.
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512 **Figure Captions:**

513 Figure 1. Calculation strategy for community care costs for surgical group.

514 Figure 2. Calculation of community care costs for non-surgical group.

515 Figure 3. QALY calculations. QALYs were calculated as the area under the curve. Solid line
516 represents patients treated with surgery, and dashed line is non-surgical series with sensitivity
517 analyses (dotted lines).

518 Figure 4. Admission cost and admission income in GBP. The box shows the 25th, 50th and 75th
519 percentiles, the whiskers encompass values within 1.5 IQR of the closest quartile, outliers are
520 represented as markers.

521 Figure 5. Ambulation status of patients over time based on Frankel Score: A-C, not walking; D-
522 E, walking.

523 Figure 6. Cost per QALY correlation with A: survival, $r=-0.73$, $P<.01$ and B: ambulation, $r=-$
524 0.87 , $P<.01$.