Healthcare Improvement Scotland | SHTG Advice on health technologies

SHTG Assessment
October 2023

The cost-effectiveness of the Scottish Hip Fracture Audit

What were we asked to look at?

The Scottish Health Technologies Group (SHTG) was asked by the Scottish Hip Fracture Audit Quality Improvement & Research Sub-Group Committee to explore the cost-effectiveness of the Scottish Hip Fracture Audit (SHFA).

Why is this important?

The SHFA is designed to drive optimal delivery of care against 12 Scottish standards. Attainment of these standards is thought to be associated with positive outcomes for patients with hip fracture, including reduced length of stay and also reduced mortality.

The SHFA was established in 1993 and ran continuously to 2008. No audits were undertaken between 2008 and 2012, after which it recommenced, and from 2016, it has developed into a continuous audit. Each year, the care of approximately 7,000 patients with hip fracture is covered by the audit. The estimated cost of a hip fracture in Scotland is not publicly available. In England the cost is approximately £8,342 per case requiring intervention.[1]

What was our approach?

Publicly available data from the audit were not sufficient to determine the economic value of the audit. Instead we conducted an economic evaluation using individual patient level data from the SHFA. This was shared with us via a Data Sharing Agreement with Public Health Scotland (PHS). We explored the economic value of improved compliance with the audit standards over time, in particular with regard to survival (additional expected numbers of surviving patients) and length of hospital stay (additional expected bed days avoided by patients able to leave).

More information about SHTG Assessments can be found on our website.

What next?

Our Assessment will be sent to the Scottish Hip Fracture Audit Quality Improvement & Research Sub-Group Committee to inform audit provision and budget setting from 2023/24 onwards. The Assessment will be circulated to NHSScotland, PHS and Scottish Government staff involved in the SHFA.

Key findings

1. Compliance with SHFA standards is significantly associated with improved patient survival following a hip fracture, after taking into account other factors such as age, gender, year of audit, hospital site and readmissions.
    - For every 1% increase in the proportion of SHFA standards being met, our model predicts the odds of survival at 30 days were increased by 7.2% (95%CI: 6.9% to 7.5%).
    - Given the proportion of patients who survive a hip fracture in Scotland is already over 90%, an individual patient's probability of survival is unlikely to be notably affected by further improvements in compliance.
2. Compliance with SHFA standards is significantly associated with reduced length of stay and associated costs, taking into account age, gender, year of audit, COVID-19 and hospital site into consideration.
    - For every 1% increase in the proportion of SHFA standards being met, the length of stay costs associated with a hip fracture are reduced by 0.7%, equating to a saving of approximately £643 per patient.
3. The cost of running the audit since 2016 (i.e. 6 year costs) is between £3,048,000 and £4,686,000, depending on additional local co-ordinator costs. The modelled saving over 6 years is £30,989,395, resulting in a return on investment between £6.61 and £10.17 for every £1 invested.
4. These returns are not constant over time. It can become harder to achieve additional gains in survival after the standards have already enabled NHS Boards to change the way they provide care in order to meet the standards routinely. The impact of COVID-19 pandemic (particularly on length of stay data) also remains unclear at this stage.
5. It was not possible using the available data to explain the relative contribution of each of the standards on the outcomes of interest.

Contents

Introduction

The population of patients with hip fracture is a mostly frail group with historically high rates of morbidity and mortality. Approximately 7,000 people fall and break their hip in Scotland every year.[2] Estimates predict that this number will increase significantly over the next 10 years associated with an aging and increasingly frail and co-morbid population.[3] The cost of hip fracture care is approximately £2 billion across the UK per year,[4] escalating with the anticipated rises in hip fracture incidence.

One approach to providing high quality care is through provision and assessment of national standards, such as the Scottish Standards of Hip Fracture Care, governed by the Scottish Hip Fracture Audit (SHFA). Attainment of these standards has previously been associated with positive outcomes for hip fracture patients, such as reduced length of stay, a higher likelihood of discharge to place of domicile and reduced mortality.[5]

The cost-effectiveness of the audit has never been established and given the financial constraints facing the NHS, it is important to consider this with regard to the preservation and function of the SHFA. Previous financial constraints paused the audit for a four year period, after which data collection took several more years to recommence; illustrating the potential for longer-term cost consequences of funding decisions made in the shorter-term.

The SHFA began in 1993 and collects annual data on compliance with standards in hip fracture care, as well as outcomes for patients (for example, length of stay, readmissions at 14 days, survival at 30 and 60 days). The 12 Standards for Hip Fracture Care are shown in *Table 1* Standard 9 has two components that we considered as individual variables in this analysis. Data were provided from 2016 onwards.

Table 1: SHFA Standards

Standard Number	Standard Description
Standard 1	Patients with a hip fracture are transferred from the Emergency Department to the Orthopaedic ward within 4 hours
Standard 2	Patients who have a clinical suspicion or confirmation of a hip fracture have the "Big Six" interventions/treatments before leaving the Emergency Department 1. Provision of Pain Relief 2. Screening for Delirium 3. Early Warning Score (EWS) system 4. Full Blood Investigation and Electrocardiogram 5. Intravenous Fluids Therapy 6. Pressure Area Care

Standard 3	Every patient with a hip fracture receives the "inpatient bundle of care" within 24 hours of admission 1. 1. Delirium Screening within 24 hours of ward admission and assessment of Cognitive Function 2. Falls Assessment within 24 hours of ward admission 3. Food, Fluids and Nutritional Assessment within 24 hours of ward admission 4. Pressure Area Assessment within 24 hours of ward admission
Standard 4	Nutritional assessment and support must be an integral part of the acute and immediate care for hip fracture patients
Standard 5	No patients are repeatedly fasted in preparation for surgery.
Standard 6	Patients undergo surgical repair of their hip fracture within 36 hours of admission
Standard 7	Cemented hemi-arthroplasty implants are standard
Standard 8	Every patient who is identified locally as being frail, receives comprehensive geriatric assessment within three days of admission
Standard 9.1 and 9.2	Mobilisation has begun by the end of the first day after surgery (9.1) and every patient has physiotherapy assessment by end of day two (9.2)
Standard 10	Every patient has a documented Occupational Therapy Assessment commenced by the end of day three post admission
Standard 11	Every patient who has been admitted and diagnosed with a hip fracture has an assessment or a referral for their bone health within 60 days
Standard 12	Every patient's recovery is optimised by a multidisciplinary team approach such that they are discharged back to their original place of residence within 30 days from the date of admission

In order to determine the economic value of the SHFA, we considered data published on the SHFA website. While this demonstrated positive trends in terms of compliance with standards over time, and reduced interquartile ranges for compliance with the standards year-on-year, it was not possible to estimate the economic value of the audit from the aggregate data due for the following reasons:

- it is not clear what proportion of length of stay changes over time occurred within the non-acute (lower costs) sector compared with the acute setting (higher costs)
- the confounding effect of COVID-19 (that is, a sudden change in access to services) meant that the analysis needed to take into account the numbers of patients being admitted with hip fractures on a month-to-month basis
- compliance with each standard at the aggregate level could be spuriously correlated with one or more of the outcomes, because outcomes are influenced by factors other than audit compliance (for example, age and year of treatment). Regression

analysis, which can account for these factors, is required to understand how each of the standards contributes to the outcomes.

We were provided with data on:

- compliance with each of the standards (yes, no or "not applicable") across Scotland
- patients' age, sex, hospital attended, audit year, acute hospital length of stay, any further non-acute hospital length of stay, any readmission within 14 days, and patient survival at both 30 and 60 days, and
- the cost of running the SHFA.

Research question

What is the cost-effectiveness of the SHFA in terms of survival and length of stay costs avoided?

Cost-Effectiveness

Methods

The evaluation took the form of a cost-consequence analysis; separately comparing costs against each outcome of interest (survival at 30 days, survival at 60 days, acute length of stay, total length of stay and readmission within 14 days).[6] As the cost of a bed day can be applied to length of hospital stay it was possible to describe this outcome in terms of costs avoided, or return on investment.

Demographic variables included in the model were: age, sex, year, month of hospital attendance and hospital site. Data analysis covered admissions between May 2016 and December 2021. Decisions were required to account for the effect of COVID-19 from March 2020, particularly during the lockdown periods, and how to deal with "not applicable" data where the standard did not apply for that patient, rather than the care provided not meeting the standard.

The national cost of providing the SHFA was provided by PHS and Scottish Government colleagues as £3,048,000 per annum.[7] This does not include all Local Audit Co-ordinator costs. The extent to which salary costs were covered by the national funding varied across NHS Boards and ranged between 29% to 94%, and there was variation across boards in the Agenda for Change pay bands of staff employed as Local Audit Co-ordinators, as their wider job roles/skills varied.

To estimate length of stay costs, we applied net bed day costs for the relevant audit year to length of stay variables.[8] Prices were inflated to 2022 prices using gross domestic product (GDP) deflators from the Office for National Statistics (ONS) as recommended on the PHS website.[9] Unit costs were applied to each hospital site based on their NHS Board averages. Bed day costs for orthopaedics were used for all acute bed days. Long-stay geriatric rehabilitation bed days were used as a proxy for non-acute bed days, as no specific long-stay rehabilitation facilities were available. For non-acute costs, average non-acute bed day costs were used because some NHS Boards did not have long-stay geriatric facilities to use as a proxy.

To account for the impact of COVID-19 lockdowns on the services provided, an additional dichotomous variable was created that applied a value of "1" for the lockdown months of March, April and May 2020 and January, February and March 2021, otherwise "0". To account for varying levels of restrictions and access to health services between the lockdowns, and following the lifting of the second COVID-19 lockdown in 2021, we created an alternative variable, ranging from 0 to 1 whereby the values for lockdown months were "1", but for June 2020, December 2020 and April 2021 was 0.8, for July 2020, November 2020 and May 2021 was 0.6, for August 2020, October 2020 and June 2021 was 0.4, for September 2020 and July 2021 was 0.2, otherwise zero. This was an arbitrary process to try and accommodate the fact that even though a lockdown was not in place, hospital activity during those months may still be expected to be in recovery (that is, not back to pre-COVID-19 levels).

R Studio was used for the regression analysis.[10]

A main effects logistic regression was performed on the outcome of survival at 30 days (as the dependent variable) to estimate the effect of the proportion of standards met, taking into account: age, sex, year, hospital code (that is, the hospital attended), whether or not the patient was readmitted within 14 days, acute length of stay and non-acute length of stay.

Costs were transformed into both log costs and cube root costs so they could be in linear models to estimate the effect (for surviving patients) of the proportion of all standards met on length of stay costs. The analysis took into account age, sex, year, proximity of the month of admission to either of the COVID-19 lockdowns, the proportion of the length of stay in the acute setting, and hospital attended.

Results

Observed summary statistics from the data are provided in *Table 2* below.

Table 2: Observed outcomes for patients included in the dataset

Variable	2016*	2017	2018	2019	2020	2021
Number of standards included in Scottish Hip Fracture Audit	12	12	12	12	12	13
Mean (SD) number of standards met	6.6 (2.03)	7.6 (2.12)	7.9 (2.09)	8.3 (2.07)	8.5 (2.08)	8.7 (2.19)
Mean (SD) percentage of included standards being met	55.0% (0.17)	63.5% (0.18)	65.4% (0.17)	68.9% (0.17)	70.5% (0.17)	66.5% (0.17)
Patients seen	3,946	6,675	7,149	7,366	6,969	7,797
Survival at 30 days (% of all patients seen)**	3,558 (90.2%)	5,858 (87.8%)	6,439 (90.1%)	6,718 (91.2%)	6,369 (91.4%)	7,179 (92.1%)
Survival at 60 days (% of all patients seen)	3,378 (85.6%)	5,557 (83.3%)	6,157 (86.1%)	6,415 (87.1%)	5,980 (85.8%)	6,787 (87.0%)
Median (Interquartile range [IQR]) acute length of stay	10 IQR: 7-15	9 IQR: 6-13	9 IQR: 6-13	9 IQR: 6-13	9 IQR: 6-14	10 IQR: 7-15
Median (IQR) non-acute length of stay for all patients seen	0 IQR: 0-28	0 IQR: 0-27	0 IQR: 0-26	0 IQR: 0-25	0 IQR: 0-6	0 IQR: 0-5
Median (IQR) non-acute length of stay for patients with non-acute length of stay >0 days only	30 (IQR: 17-45)	27 (IQR: 15-44)	27 (IQR: 15-44)	26 (IQR: 14-43)	20 (IQR: 12-31)	20 (IQR: 12-30)
Total acute bed days	50,077	73,540	76,752	79,356	80,894	96,217
Total non-acute bed days	54,586	89,075	95,443	96,596	41,376	44,627

*Data from 2016 are from May onwards

**in the models below the proportion of surviving patients at 30 days may be higher than figures reported here as the models exclude patients where there are missing data for any of the variables

The average number of standards being met increased year-on-year. Patient survival improved year-on-year, and total acute bed days increased each year since 2016. Median acute length of stay and non-acute length of stay remained stable over time across all patients in the cohort. Median non-acute length of stay has fallen consistently over time, particularly since the pandemic, and the proportion of standards being met fell in 2021 to a level not seen since before 2019, although this is likely due to an additional standard being added in 2021, raising the number of achievable standards from 12 to 13.

The observed spread of values for compliance with the SHFA is shown in the boxplots in *Figure 1a* (number of standards being met) and *Figure 1b* (proportion of standards being met).

Figure 1a: Boxplot of the number of standards met since 2016

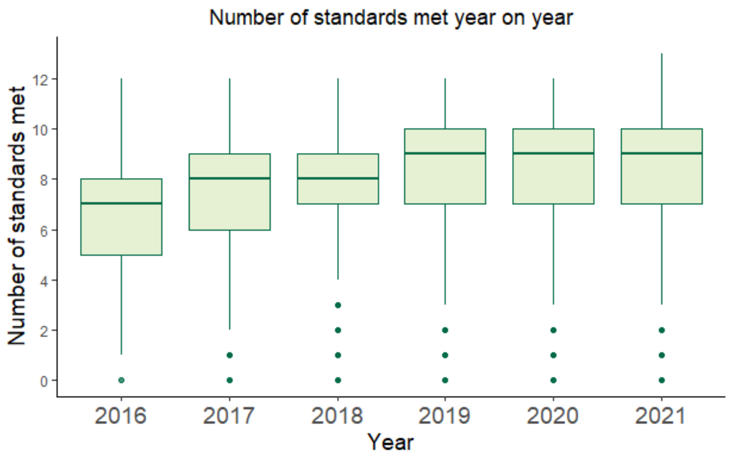
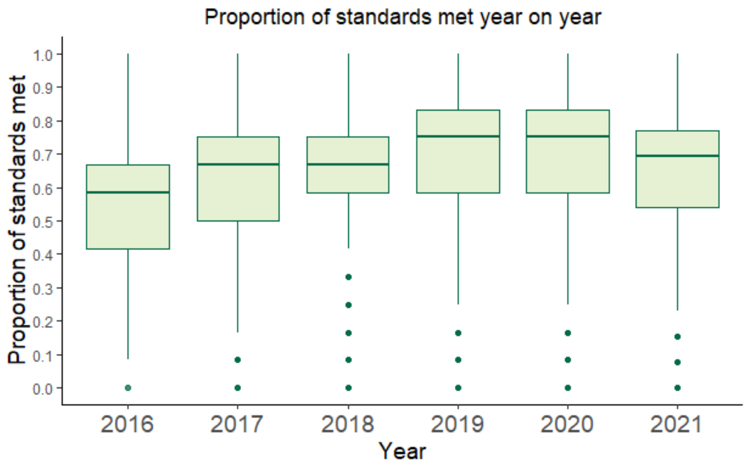


Figure 1b: Boxplot of the proportion of standards met since 2016



The observed data indicate regression analyses were required to ensure all relevant variables influencing the outcomes of survival and length of stay among SHFA patients were considered simultaneously. The results of the regression analysis help to identify the specific effect that the observed change in compliance with the standards over time has on the relevant outcomes for patient care, that is, survival and length of stay.

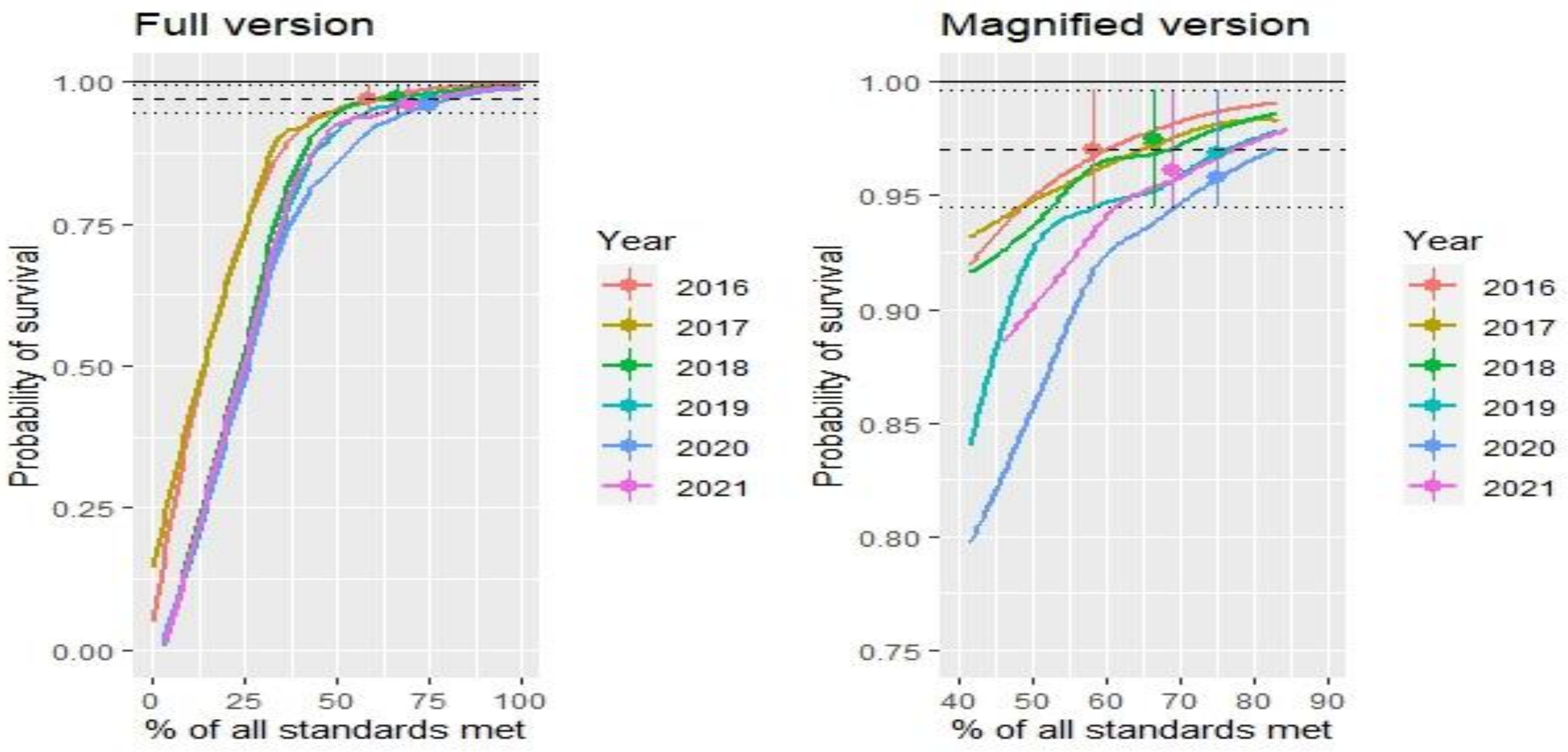
The relationship between survival at 30 days and the number/proportion of standards met

Correlation coefficients and details of the main effects logistic regression analysis are provided in *Appendix 2*. The results indicate that 30-day survival is significantly associated with the proportion of standards being met. The coefficient for the proportion of standards met in the survival model (see *Appendix 2 Figure 1b)* is 0.0696 (95%CI: 0.0671 to 0.0722). Converted from the *log* odds of survival (because logistic regression was used), a 1% improvement in the proportion of standards being met increases the odds of survival by 7.2% (95%CI: 6.9 to 7.5%), adjusting for other factors.

From the observed data the proportion of standards being met in clinical practice ranged from a minimum of 55.0% (in 2016) to a maximum of 70.5% (in 2020). The observed proportion of patients surviving in 2016 (the base year in the model) was 90.2%, rising to 92.1% in 2021.

This apparent difference in the modelled odds of survival as a result of increased proportion of standards being met, compared with the clinical impact of the standards on survival rates seen in the observed data is shown below in *Figure 2a and 2b*. *Figure 2a* shows the proportion of standards being met from 0 to 100% on the horizontal axis and the proportion of patients surviving, from 0 to 1 on the vertical axis. The odds of survival increase as the proportion of standards increases, as shown by the slope of the lines (in colour for each year), but the higher the proportion of standards being met, the smaller the realised marginal gains in survival are likely to be. *Figure 2b* (a magnified version of *Figure 2a*) illustrates the effect of meeting a higher proportion of standards at a level where the proportion of surviving patients is close to that observed in clinical practice. The difference in the modelled proportion of patients expected to survive in each year is not significantly different from the 95% confidence interval (dotted horizontal black lines) around the median survival (dashed horizontal black line) estimate for the base year of 2016.

Figures 2a and 2b – Proportion of standards met and modelled probability of survival (full and magnified)



The relationship between length of stay (including length of stay costs) and the number/ proportion of standards met

We attempted to conduct a generalised linear model (GLM) on length of stay as measured in bed days, to estimate an incremental cost-effectiveness ratio (ICER) for the cost per additional acute and/or non-acute bed day avoided. The skewed nature of length of stay data, plus the truncation of audit follow-up of length of stay after 59 days created difficulties in specifying a model that did not violate the required regression assumptions, and we were not able to pursue the GLM. Further explanation of this is provided in *Appendix 2*.

Instead, we conducted the regression using length of stay costs (rather than length of stay in days) as the dependent variable. Two transformations of the cost data were considered, a log transformation of length of stay costs and a cube root transformation. Results were very similar for both models but the log transformation was chosen as it was a slightly better fit in terms of the adjusted R^2 value for the model, and is easier to interpret than the cube root transformation which requires the Chain Rule.

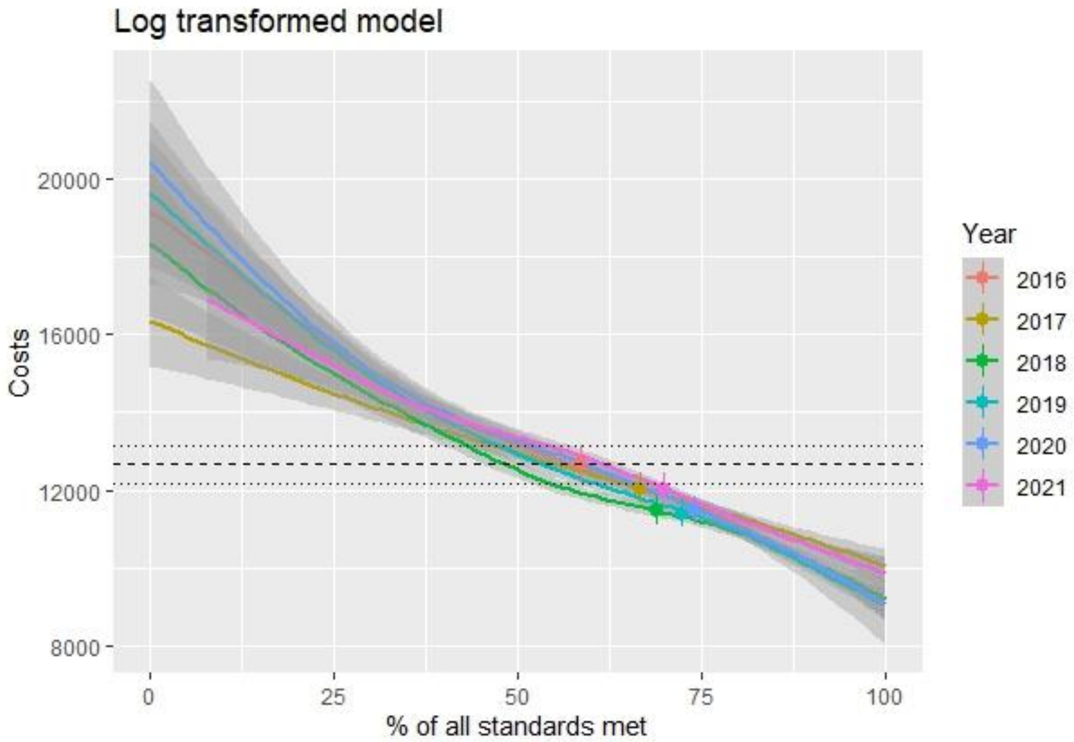
The log transformation of the data showed that an increase in the proportion of standards being met resulted in a statistically significant reduction in overall (acute and non-acute) length of stay costs. For every percentage increase in the proportion of standards being met log length of stay costs were reduced by 0.7%. The median length of stay costs overall for those who survived at 30 days in 2016 was £12,315.20. The proportion of standards met increased from 55.0% in 2016 to 66.5% in 2021. Based on an increase of 11.5% we would expect on average to see an 8.05% reduction in resource costs which equates to £991 per person.

The corresponding fitted model results included other categorical variables in the model (for example: sex, year and hospital attended). The resource saving predicted by the log fit was £643 per case (95%CI: £558 to £733) between 2016 and 2021.

Across all surviving patients in the model since 2016, the reduction in costs represents a total resource saving of £30,989,395 (95%CI: £27,793,490 to £34,436,725) predicted by the log transformation.

Figure 3 illustrates the relationship between the proportion of standards met and length of stay costs. The adjusted R^2 value for the model was 24.73.

Figure 3: The modelled relationship between the proportion of standards met and costs over time using log transformation



Return on investment

The annual cost of conducting the audit is approximately £508,000 per annum. Over the six years since 2016 this equates to £3,048,000. Based on the total estimated saving since 2016 of £30,989,395 (95%CI: £27,793,490 to £34,436,725) predicted by the log transformation, return on investment for every pound providing the audit is approximately £10.17 (95%CI: £9.12 and £11.30) in avoided length of stay costs.

This cost of the audit does not include the cost of local co-ordinator time, due to an absence of required data. Not including local co-ordinator costs risks underestimating the true cost of providing the audit. We conducted a sensitivity analysis to estimate the effect of including hypothesised local co-ordinator costs. We conducted 100 simulations that independently applied random (normal distribution used) Agenda for Change pay bands between bands 3 and 7, a random whole time equivalent (WTE) amount (beta distribution used with a mean of 0.5 - since we have no prior information what proportion of a local co-ordinator's time is involved in co-ordinating the SHFA), and a proportion of the co-ordinator salary costs between 29% and 94% (normal distribution used) that would already be covered from the national funding estimated above (so would not be an additional cost).

Results indicate the hypothesised cost of including local co-ordinator involvement (assuming each hospital site in the audit employs their own co-ordinator) ranged from £215,839 to £350,705 with a mean (standard deviation) cost of £272,321 (£24,765). This means the annual cost of providing the audit would rise to approximately £781,000 annually (that is, £4,686,000 since the audit recommenced), and the return on investment would be reduced to £6.61 (95%CI £5.93 to £7.35 for every £1 invested.

Assessing the impact(s) of the individual standards

It was not possible to consider the impact of the individual standards in isolation. Regression analyses that include each standard as a separate explanatory variable (that is, to isolate the contribution of that particular standard to the outcomes of interest) are feasible. In practice, it was not possible to run these models due to the data that were coded as "not applicable." The "non-applicable" category provides clinically informative data, but including this as a separate response for each standard, in addition to whether or not the standard was met, makes results difficult to interpret. Equally, making a simplifying assumption that if a standard was "not applicable" it could be defined as being "not met" is not an accurate reflection of the data.

We explored use of multivariate methods to try to group combinations of standards being met or otherwise, but again, interpretation was dependent on the "not applicable" coding and was not considered helpful for decision-making.

Discussion

The number and proportion of standards being met has increased since the SHFA recommenced, according to available data from 2016. The regression models show that this has led to reductions in length of stay and improvements in patient survival at 30 days.

The large dataset increases the likelihood of statistically significant findings that may not be clinically relevant. There is also the possibility that the effects on 30 day survival or length of stay may be dependent on one of the other explanatory variables. We were able to account for the latter issue by considering first order interaction effects, but because this complicates the interpretation of the coefficients, only the results of the simplified main effects models have been reported.

The number of standards being met was positively associated with increased odds of survival at 30 days, yet this is not likely to result in substantial increased survival gains in clinical practice given the proportion of patients who survive a hip fracture in Scotland is already over 90%. Marginal gains from the audit are expected to diminish over time, but the results show that increased compliance with audit standards maximises patients' chances of survival.

With regard to length of stay costs, as the audit already truncates length of stays beyond 60 days, so the associated costs (and subsequent savings in terms of costs avoided through reduced lengths of stay) may be underestimated compared to the costs experienced by NHS Boards. The model confirms a strong relationship between higher proportions of standards being met and reduced length of stay costs. The findings suggest that for every £1 spent on the SHFA since 2016, approximate length of stay savings of £6.61 and £10.17 can be expected, depending on additional Local Audit Co-ordination costs.

The analysis has only been able to explore changes during the time the audit has been in place. We have not been able to compare audited years with years without audit (that is, between 2008 and 2016). It remains unclear what effect the general presence of the audit has upon compliance with standards.

The impact of COVID-19 and other socio-economic events may have contributed to a lack of accuracy in the calculations that potentially underestimate the effect of the SHFA. Bed day cost data from the PHS cost book has not been updated in recent years, so we had to inflate the last available year's data, and this may not fully account for the recent cost increases experienced across NHS Boards.

With regard to length of stay reductions in recent years, it is possible that these could be driven by other factors beyond improved compliance with the hip fracture audit, including hospital-specific policies on discharge, and improvement initiatives that change, for example, protocols for dealing with patient falls. In our analysis it has only been possible to account for confounding variables that are captured by the PHS audit.

The limitation of the analysis was not being able to account for the effect of individual standards, and common combinations of standards that are observed in clinical practice, given the use of "not applicable" as a relevant response that is not equivalent to either data being either missing or the standard not being met.

For future research, the SHFA and Local Audit Co-ordinators could agree a common approach to using "not applicable" responses, as changes to how these data are collected could improve the interpretability of research findings. In addition, it may be pertinent to collect additional information on any external policy changes that may be impacting on patient outcomes that are collected as part of the audit, as other factors could influence, for example, length of stay.

Conclusions

Improved compliance with SHFA standards was shown to increase the odds of patient survival. Given that survival rates are already above 90%, the survival gains expected from increased compliance diminish as the number and/or proportion of standards being met increases. That is, at the observed levels of compliance seen in clinical practice in Scotland, additional lives saved cannot be explicitly shown to be attributed to increased compliance with the SHFA. Nevertheless, because the odds of survival are significantly associated with meeting the standards, this does suggest that odds of survival could be adversely affected if standards were not in place and being audited. However, testing this hypothesis would hypothetically require years where audit data were still being collected but there were no consequences associated with non-compliance, which is unrealistic for both ethical (clinical governance) and efficiency (data collection) reasons.

We estimate approximately £30 million of resource has been saved due to the audit since 2016 through reduced length of stay costs, which were significantly associated with higher proportions of standards being met. For every £1 that has been invested in the SHFA, a saving of approximately between £6 and £10 can be expected.

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Healthcare Improvement Scotland development team

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- Ms Jenni Hislop, Senior Health Economist, Healthcare Improvement Scotland
- Mr James Stewart, Public Involvement Advisor, Healthcare Improvement Scotland

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- Ms Karen Adam, National Trauma & Orthopaedic Performance Manager, Scottish Government
- Mr Luke Farrow, Clinical Research Fellow, Out of Programme Research Trauma & Orthopaedics North of Scotland 2021 – 2024, University of Aberdeen
- Ms Caroline Martin, Senior Information Analyst, Scottish National Audit Programme, Clinical and Protecting Health, Public Health Scotland
- Ms Kirsty Ward, National Clinical Co-ordinator, Scottish National Audit Programme, Clinical and Protecting Health, Public Health Scotland

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- Mr Neil Craig, Interim Head of Evaluation, Public Health Scotland
- Ms Lorraine Donaldson, Senior Information Analyst, Public Health Scotland
- Dr Ali Mehdi, Medical Director, East Kent Hospitals University NHS Foundation Trust

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Appendix 1: Abbreviations

A&E	accident and emergency
CI	confidence interval
EWS	Early warning score
GDP	Gross Domestic Product
GLM	Generalised Linear Model
ICER	Incremental cost-effectiveness ratio
IQR	Interquartile range
ONS	Office for National Statistics
PHS	Public Health Scotland
SD	Standard deviation
SHTG	Scottish Health Technologies Group
SHFA	Scottish Hip Fracture Audit
WTE	Whole time equivalent

Appendix 2: Additional Information

Correlation coefficients for the main effects logistic regression testing the association between survival at 30 days and the proportion of standards being met are shown in *Table A1* below. The results indicate that survival is significantly associated with the proportion of standards being met. The coefficient for the proportion of standards met in the survival model was 0.0696 (95%CI: 0.0671 to 0.0722). As the model is a logistic regression (survival at 30 days is a binary variable) this is the coefficient for the *log* odds of survival, so the exponential of 0.0696 is required. The result was 1.072 (95%CI: 1.069 to 1.075), indicating a 1% improvement in the proportion of standards being met increases the odds of survival by 7.2% (95%CI: 6.9 to 7.5%), adjusting for other factors.

Table A1: Main effects model for survival at 30 days

Explanatory variable	Estimate	95% CI	Exponent of Estimate	95% CI of exponent of estimate	p-value
(Intercept)	5.062	4.57 to 5.56	157.985	96.09 to 259.76	<0.001*
PropStandardsMet	0.07	0.067 to 0.072	1.072	1.069 to 1.075	<0.001*
Age	-0.086	-0.09 to -0.08	0.917	0.91 to 0.92	<0.001*
Sex (male=1) as base level is female	-0.744	-0.84 to -0.65	0.475	0.43 to 0.52	<0.001*
Year2017 (base=2016)	-0.485	-0.67 to -0.3	0.616	0.51 to 0.74	<0.001*
Year2018	-0.553	-0.74 to -0.36	0.575	0.48 to 0.7	<0.001*
Year2019	-0.876	-1.06 to -0.69	0.417	0.35 to 0.5	<0.001*
Year2020	-1.001	-1.19 to -0.81	0.368	0.31 to 0.44	<0.001*
Year2021	-0.78	-0.96 to -0.6	0.458	0.38 to 0.55	<0.001*
hospital_codeA210H	0.364	-0.02 to 0.75	1.438	0.98 to 2.12	0.066

(base=A111H)					
hospital_codeB120H	-0.912	-1.27 to -0.55	0.402	0.28 to 0.58	<0.001*
hospital_codeC313H	-0.079	-0.44 to 0.28	0.924	0.65 to 1.32	0.666
hospital_codeC418H	-0.912	-1.2 to -0.62	0.402	0.3 to 0.54	<0.001*
hospital_codeF704H	-0.375	-0.66 to -0.09	0.688	0.52 to 0.91	0.01*
hospital_codeG107H	-0.178	-0.46 to 0.11	0.837	0.63 to 1.11	0.222
hospital_codeG405H	-0.667	-0.93 to -0.4	0.513	0.39 to 0.67	<0.001*
hospital_codeH202H	-0.297	-0.61 to 0.02	0.743	0.54 to 1.02	0.063
hospital_codeL106H	0.063	-0.75 to 0.88	1.065	0.47 to 2.4	0.878
hospital_codeL302H	-0.125	-0.45 to 0.2	0.882	0.64 to 1.22	0.444
hospital_codeL308H	-0.186	-0.45 to 0.08	0.83	0.64 to 1.08	0.17
hospital_codeN101H	-0.421	-0.7 to -0.14	0.656	0.5 to 0.87	0.003*
hospital_codeN411H	-0.431	-0.79 to -0.07	0.65	0.45 to 0.93	0.02*
hospital_codeR103H	0.169	-1.5 to 1.83	1.184	0.22 to 6.26	0.843
hospital_codeS314H	0.272	0.02 to 0.52	1.312	1.02 to 1.69	0.034*
hospital_codeT101H	-0.07	-0.34 to 0.2	0.932	0.71 to 1.22	0.608
hospital_codeT202H	0.2	-0.3 to 0.7	1.221	0.74 to 2.01	0.43
hospital_codeV217H	-0.334	-0.62 to -0.04	0.716	0.54 to 0.96	0.024*
hospital_codeW107H	0.958	0.29 to 1.63	2.606	1.34 to 5.08	0.005*
hospital_codeY104H	-0.384	-0.9 to 0.13	0.681	0.41 to 1.14	0.146

hospital_codeY146H	-0.468	-0.81 to -0.12	0.626	0.44 to 0.88	0.008*
Readmission within 14days = Yes (base=No)	2.249	1.84 to 2.65	9.474	6.32 to 14.2	<0.001*
Acute_LOS_days	0.072	0.07 to 0.08	1.075	1.07 to 1.08	<0.001*
nonacutestay	0.089	0.08 to 0.1	1.094	1.09 to 1.1	<0.001*

The main effects analysis in *Table A1* above adjusts for age, gender, hospital site, year, readmissions at 14 days and length of stay (acute and non-acute). Main effects variables in the model were included if they had a statistically significant effect on the results (for example, in the survival model lockdown was not statistically significant and so was not included as an explanatory variable). Additional models provided in *Table A2* accounted for first order interactions between a) all variables and b) all statistically significant interactions. Fit statistics suggest the interaction models provide a better fit than the main effects model, which is to be expected, but they also potentially over-complicate the interpretation, given the small differences seen in the pseudo R^2 values that indicate how much variation in the data is explained by each model. For the main effects only model was 0.313, whereas for the interactions (statistically significant at the 0.05 level only) model it was 0.341 and for all interactions it was 0.348.

The interaction models are useful because they show that, compared with the main effects model results where survival at 30 days was influenced by the proportion of standards met, age, sex, year, hospital attended, readmissions, acute and non-acute length of stay:

- only the intercept (the log odds of survival when the number of standards is estimated as zero), the proportion of standards being met and patient age remained significant in the best fitting interaction model
- sex no longer had a statistically significant effect on survival at 30 days, even though the interaction between sex and the proportion of standards being met, and sex and age were both significant at the 0.05 level
- compared to the base year of 2016 (re-start of the SHFA), only 2020 had a statistically significant effect on survival at 30 days, once the relationship between year and each of the other explanatory variables was taken into account
- in the best fitting interaction model none of the hospitals had significantly different odds of survival from the base hospital (alphabetically listed so the Ayr Hospital was used), but there were interaction effects, most notably between survival and hospital varying depending on the year (2020 in four out of five cases), and as noted

above, 2020 was the only year compared to 2016 to remain statistically significant in the model once interaction effects has been taken into account.

Additional main effects analyses were conducted, one using survival at 60 days as the dependent variable but the pseudo R^2 value (0.199) indicated survival at 30 days is better explained by the available data. Using the number of standards met, rather than the proportion of all standards met, results in an equivalent pseudo R^2 value (0.313) but the interpretation may be misleading owing to the creation of a new standard in 2021 (Standard 4); using the proportion of standards met is likely the more appropriate, and the more conservative choice.

Table A2: Coefficients for (a) all first order interactions (b) all first order interactions retained for statistical significance and (c) main effects only models for survival at 30 days

Explanatory variable	a) All interactions		b) Retained statistically significant interactions		c) main effects only	
	Coefficient estimate	Statistically significant at 0.05 level	Coefficient estimate	Statistically significant at 0.05 level	Coefficient estimate	Statistically significant at 0.05 level
(Intercept)	5.9651	*	5.0746	*	5.0625	*
PropStandardsMet	0.0881	*	0.1008	*	0.0696	*
Age	-0.1156	*	-0.1033	*	-0.0863	*
sexMALE	0.4956		0.3926		-0.7441	*
Year2017	0.2953		-0.7882		-0.4853	*
Year2018	0.3316		-0.4241		-0.5535	*
Year2019	0.0378		-0.4846		-0.8756	*
Year2020	-2.6960	*	-2.1185	*	-1.0008	*
Year2021	-0.9829		-1.1339		-0.7804	*
hospital_codeA210H	3.6422		0.5694		0.3635	
hospital_codeB120H	0.4759		-0.8405		-0.9122	*
hospital_codeC313H	0.0761		0.2820		-0.0786	
hospital_codeC418H	-1.0571		-1.7628	*	-0.9122	*
hospital_codeF704H	-1.2092		-0.8859		-0.3746	*
hospital_codeG107H	-0.4882		-0.5442		-0.1780	
hospital_codeG405H	-2.3327		-1.5218	*	-0.6672	*
hospital_codeH202H	-1.8136		-0.1629		-0.2966	
hospital_codeL106H	-2.6625		-0.1127		0.0634	
hospital_codeL302H	0.3960		-1.1511		-0.1254	
hospital_codeL308H	-1.3914		-0.3027		-0.1860	
hospital_codeN101H	-0.1341		-0.3670		-0.4212	*
hospital_codeN411H	-1.9189		-0.6154		-0.4310	*
hospital_codeR103H	483.2008		0.7269		0.1686	
hospital_codeS314H	-0.4717		0.3994		0.2719	*
hospital_codeT101H	-0.3367		0.1489		-0.0705	
hospital_codeT202H	0.1123		0.2253		0.1997	

hospital_codeV217H	-0.2970		0.5557		-0.3338	*
hospital_codeW107 H	-0.7625		-0.8301		0.9577	*
hospital_codeY104H	-1.9146		-0.5117		-0.3841	
hospital_codeY146H	-2.4916		-0.8825		-0.4679	*
readmission_14days 1	-1.9270		-1.3880		2.2486	*
Acute_LOS_days	0.0532		0.0463		0.0724	*
Nonacutestay	-0.0759		-0.0542		0.0894	*
PropStandardsMet: sexMALE	-0.0065	*	-0.0075	*	NA	NA
PropStandardsMet: readmission_14days 1	-0.0615	*	-0.0574	*	NA	NA
PropStandardsMet: Acute_LOS_days	-0.0021	*	-0.0019	*	NA	NA
PropStandardsMet: nonacutestay	-0.0018	*	-0.0017	*	NA	NA
age: sexMALE	-0.0175	*	-0.0165	*	NA	NA
age: readmission_14days 1	0.0601	*	0.0631	*	NA	NA
age: Acute_LOS_days	0.0017	*	0.0017	*	NA	NA
age: nonacutestay	0.0021	*	0.0020	*	NA	NA
sexMALE: Year2019	0.4875	*	0.5489	*	NA	NA
sexMALE: Year2021	0.4150	*	0.4364	*	NA	NA
sexMALE: hospital_codeC418H	0.8524	*	0.8951	*	NA	NA
sexMALE: hospital_codeG405H	0.5241		0.5673	*	NA	NA
sexMALE: hospital_codeT202H	1.3644	*	1.3796	*	NA	NA
sexMALE: readmission_14days 1	0.9704	*	0.8969		NA	NA
Year2020: hospital_codeG405H	1.8711	*	1.8769	*	NA	NA
Year2020: hospital_codeL302H	1.6579	*	1.4761		NA	NA
Year2020: hospital_codeN101H	1.3028	*	1.2562	*	NA	NA
Year2019: hospital_codeV217H	-1.6667	*	-1.5649	*	NA	NA
Year2020: hospital_codeY146H	1.3879	*	1.3903	*	NA	NA
hospital_codeA210H : Acute_LOS_days	-0.0593	*	-0.0568	*	NA	NA
hospital_codeH202H : Acute_LOS_days	-0.0365		-0.0423	*	NA	NA

hospital_codeL308H: Acute_LOS_days	-0.0374	*	-0.0361	*	NA	NA
hospital_codeT101H: Acute_LOS_days	-0.0375		-0.0404	*	NA	NA
hospital_codeV217H : Acute_LOS_days	-0.0746	*	-0.0788	*	NA	NA
hospital_codeC418H: nonacutestay	0.0980	*	0.1013	*	NA	NA
hospital_codeG405H : nonacutestay	0.0624	*	0.0644	*	NA	NA
hospital_codeH202H : nonacutestay	0.0891	*	0.0879	*	NA	NA
hospital_codeL308H: nonacutestay	0.0674	*	0.0675	*	NA	NA
hospital_codeN101H : nonacutestay	0.0486		0.0514	*	NA	NA
hospital_codeS314H: nonacutestay	0.0435		0.0517	*	NA	NA
hospital_codeV217H : nonacutestay	0.0482		0.0519	*	NA	NA
hospital_codeY146H: nonacutestay	0.0787	*	0.0785	*	NA	NA
readmission_14days 1: Acute_LOS_days	0.2304	*	0.1900	*	NA	NA
Acute_LOS_days: nonacutestay	0.0027	*	0.0024	*	NA	NA

We initially sought to conduct a generalised linear model (GLM) on length of stay as measured in bed days, to estimate an incremental cost-effectiveness ratio (ICER) for the cost per additional acute and/or non-acute bed day avoided. However, the skewed nature of length of stay data, plus the truncation of audit follow-up of length of stay after 59 days created considerable difficulties in specifying a model that did not violate the required regression assumptions.

There were three key problems:

- the relationship between the standards and length of stay is not linear for all patients. Deceased patients may have both a truncated length of stay owing to their death and a lower number of standards being achieved for them if their death occurred before further care (and subsequently additional SHFA standards) could be provided. It was therefore necessary to remove deceased patients from the dataset after previously establishing the association between improvements in the number and proportion of standards met and survival at 30 days (see “Survival” section above)
- use of the relevant GLM for bed day data (count data i.e. Poisson regression) continued to produce considerable over-dispersion in the results, so a decision was

made to transform the length of stay data prior to modelling, in order to use multiple linear regression instead

- despite transformation of the length of stay data, there was still relatively poor variability in available length of stay values, making it difficult to verify the required model fitting assumptions for multiple linear regression.

The regression was conducted using a dependent variable of length of stay costs rather than length of stay in days. This was because greater variability was expected from using data where unit costs had already been applied to bed days, based on hospital and/or national averages (see Methods section above). Two transformations of the cost data were considered, a log transformation of length of stay costs and a cube root transformation.

As shown in *Table A3* the log transformation of the data showed that the proportion of standards being met resulted in a statistically significant reduction in overall (acute and non-acute) length of stay costs. For every unit increase in the proportion of standards being met log length of stay costs were reduced by exp(0.007), that is, 1.007 or 0.7%.

Table A3: Main effects model of log transformation of length of stay costs

Coefficient_Name	Estimate	Std..Error	CI95_estimate	T	p_value
(Intercept)	9.499	0.035	9.43 to 9.568	269.757	<0.001*
PropStandardsMet	-0.007	0	-0.007 to -0.006	-31	<0.001*
Age	0.011	0	0.01 to 0.012	34.123	<0.001*
sexMALE	0.043	0.007	0.029 to 0.057	6.077	<0.001*
Year2017	-0.018	0.013	-0.044 to 0.007	-1.406	0.16
Year2018	-0.052	0.013	-0.077 to -0.027	-3.996	<0.001*
Year2019	-0.033	0.013	-0.059 to -0.008	-2.547	0.011*
Year2020	0.062	0.015	0.032 to 0.091	4.105	<0.001*
Year2021	0.09	0.014	0.062 to 0.119	6.27	<0.001*
Lockdown_Months2	-0.087	0.013	-0.112 to -0.062	-6.754	<0.001*

AcutePropTotalLOS	-0.624	0.01	-0.643 to -0.604	-62.222	<0.001*
hospital_codeA210H	0.029	0.026	-0.022 to 0.08	1.103	0.27
hospital_codeB120H	0.032	0.027	-0.021 to 0.086	1.188	0.235
hospital_codeC313H	-0.168	0.025	-0.218 to -0.119	-6.642	<0.001*
hospital_codeC418H	-0.192	0.021	-0.232 to -0.151	-9.263	<0.001*
hospital_codeF704H	0.169	0.021	0.129 to 0.21	8.214	<0.001*
hospital_codeG107H	0.031	0.02	-0.008 to 0.069	1.551	0.121
hospital_codeG405H	-0.048	0.019	-0.085 to -0.01	-2.48	0.013*
hospital_codeH202H	0.086	0.021	0.044 to 0.128	4.024	<0.001*
hospital_codeL106H	-0.384	0.059	-0.5 to -0.267	-6.483	<0.001*
hospital_codeL302H	-0.234	0.024	-0.28 to -0.187	-9.856	<0.001*
hospital_codeL308H	-0.331	0.02	-0.37 to -0.292	-16.783	<0.001*
hospital_codeN101H	-0.108	0.02	-0.148 to -0.068	-5.328	<0.001*
hospital_codeN411H	-0.105	0.028	-0.159 to -0.05	-3.758	<0.001*
hospital_codeR103H	0.397	0.169	0.066 to 0.728	2.352	0.019*
hospital_codeS314H	-0.29	0.018	-0.326 to -0.255	-16.059	<0.001*
hospital_codeT101H	-0.066	0.019	-0.104 to -0.028	-3.389	0.001*
hospital_codeT202H	0.088	0.033	0.024 to 0.152	2.673	0.007*
hospital_codeV217H	-0.4	0.021	-0.44 to -0.359	-19.174	<0.001*
hospital_codeW107H	0.015	0.04	-0.064 to 0.094	0.376	0.707

hospital_codeY104H	-0.082	0.039	-0.158 to -0.006	-2.11	0.035*
hospital_codeY146H	-0.05	0.026	-0.101 to 0	-1.962	0.05*

The cube root transformation shown in Table A4 requires the Chain Rule to interpret. Three times the cube root coefficient of -0.056 is -0.168. The effect of a unit change in the proportion of standards met is associated with a reduction in costs that is 0.168 times the cube root costs squared.

Table A4: Main effects model of cube root transformation of length of stay costs

Coefficient_Name	Estimate	Std..Error	CI95_estimate	t	p_value
(Intercept)	24.524	0.266	24.004 to 25.045	92.287	<0.001*
PropStandardsMet	-0.056	0.002	-0.059 to -0.053	-34.785	<0.001*
Age	0.08	0.002	0.075 to 0.085	32.879	<0.001*
sexMALE	0.376	0.054	0.271 to 0.481	7.004	<0.001*
Year2017	-0.105	0.099	-0.299 to 0.089	-1.063	0.288
Year2018	-0.32	0.098	-0.512 to -0.127	-3.252	0.001*
Year2019	-0.172	0.099	-0.366 to 0.022	-1.733	0.083
Year2020	0.579	0.113	0.357 to 0.8	5.114	<0.001*
Year2021	0.791	0.109	0.578 to 1.004	7.279	<0.001*
Lockdown_Months2	-0.665	0.097	-0.856 to -0.474	-6.829	<0.001*
AcutePropTotalLOS	-4.455	0.076	-4.603 to -4.306	-58.884	<0.001*
hospital_codeA210H	0.271	0.197	-0.115 to 0.656	1.378	0.168
hospital_codeB120H	0.217	0.205	-0.185 to 0.619	1.059	0.29

hospital_codeC313H	-1.287	0.191	-1.661 to -0.912	-6.73	<0.001*
hospital_codeC418H	-1.443	0.156	-1.749 to -1.136	-9.232	<0.001*
hospital_codeF704H	1.292	0.156	0.987 to 1.596	8.308	<0.001*
hospital_codeG107H	0.246	0.149	-0.046 to 0.538	1.654	0.098
hospital_codeG405H	-0.372	0.145	-0.656 to -0.088	-2.568	0.01*
hospital_codeH202H	0.633	0.162	0.317 to 0.95	3.918	<0.001*
hospital_codeL106H	-2.952	0.446	-3.827 to -2.077	-6.613	<0.001*
hospital_codeL302H	-1.692	0.179	-2.042 to -1.341	-9.459	<0.001*
hospital_codeL308H	-2.43	0.149	-2.721 to -2.138	-16.327	<0.001*
hospital_codeN101H	-0.844	0.153	-1.144 to -0.545	-5.522	<0.001*
hospital_codeN411H	-0.712	0.21	-1.123 to -0.3	-3.385	0.001*
hospital_codeR103H	3.482	1.274	0.985 to 5.978	2.733	0.006*
hospital_codeS314H	-2.164	0.136	-2.432 to -1.897	-15.862	<0.001*
hospital_codeT101H	-0.396	0.146	-0.683 to -0.11	-2.714	0.007*
hospital_codeT202H	0.735	0.248	0.25 to 1.221	2.967	0.003*
hospital_codeV217H	-3.069	0.157	-3.378 to -2.761	-19.515	<0.001*
hospital_codeW107H	0.143	0.304	-0.453 to 0.739	0.47	0.638
hospital_codeY104H	-0.605	0.292	-1.177 to -0.032	-2.071	0.038*
hospital_codeY146H	-0.416	0.194	-0.796 to -0.037	-2.151	0.032*