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REPORT

PROMs risk adjustment methodology guide for general surgery and orthopaedic procedures

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In 2009, Northgate was awarded the contract to develop and apply routinely a risk adjustment methodology for the national PROMs (Patient Reported Outcome Measures) programme.

Northgate, with CHKS, have developed a series of risk-adjustment methodologies for the different outcome measures for two general surgery interventions, groin hernia and varicose vein surgery, and for two orthopaedic interventions, hip and knee replacements. These adjustments have been applied to monthly data extracts from the summer of 2010, to make raw and comparable risk adjusted data available to the NHS Information Centre for publication.

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Risk Adjustment models for Patient Reported Outcome Measures

Executive Summary

Introduction

The objective of the case-mix or risk adjustment process is to adjust the reported PROMs health status data to take account of factors that could influence it – such as patient characteristics, age, sex, presence of comorbidities, and the nature of the intervention itself – which are beyond the control of the provider, so that outcomes data can be compared across providers on a like-for-like basis.

This paper describes the risk adjustment models developed for the two general surgical procedures (groin hernia and varicose veins surgery) and two orthopaedic procedures (hip and knee replacements) that are currently within the scope of the PROMs programme. The models seek to risk adjust the reported 'raw' post-operative follow-up (referred to in this document as questionnaire 2 or "Q2") scores to reflect the outcomes that would have been achieved had the provider treated a national average case-mix of patients.

Development of a model

The risk-adjustment methodology proposed will use the relationship between an individual provider's actual post-operative (Q2) PROMs score and their predicted Q2 score, based on a statistical prediction model, to adjust the national average Q2 PROMs score. In this way, a risk-adjusted Q2 value is estimated for the provider which indicates the average Q2 score that would have been achieved had that provider treated a national average case-mix of patients. The ratio of average to predicted Q2 scores is taken as a measure of the extent to which the provider over- or under-performs relative to the level expected. A measure of the risk-adjusted change in health status for any given provider is calculated by subtracting the national average pre-operative baseline score (Q1) from the risk-adjusted Q2 score.

The main focus of this paper is on the development of a prediction model for Q2 scores as this is fundamental to the development and application of the risk-adjustment methodology.

Variation in the post-operative follow-up PROMs scores may be the result of variation in a range of demographic and other patient characteristics as well as clinical factors, and differences in the quality of healthcare delivered by the provider. While the prediction models seek to identify and understand all these sources of variation, once identified it will be desirable to separate the last effect (provider quality) from the others, so that case-mix adjustment does not adjust for variation which is of direct interest in drawing comparisons across providers.

The initial prediction models are developed using ordinary least squares (OLS) regression methods. OLS models were chosen as the methods are relatively well understood and the approach is fairly straightforward while, if applied appropriately, also produces unbiased estimates of model parameters. They were used to explore likely variables to include in

the basic modelling framework, as suggested by the literature review, and their relationships with the PROMs measures. It is anticipated that, as the volume of data increases from each provider unit, more sophisticated models, such as multi-level models (which should be better able to identify the differential effect of each provider on outcomes) will be developed.

One specific concern, which was recognised at an early stage, was whether the fact that the scores of each instrument are constrained within a limited range (e.g. -0.594 to 1.000 for the EQ5D Index and 0 to 100 for the EQ VAS), might produce bias within a standard OLS approach. Building on the initial OLS work, we have started to examine this using an approach called censored (tobit) regression which takes account of these constraints and we will continue to test the statistical properties of these models with a view to the adoption of such models during the annual review and refinement programme scheduled for winter 2010/11. Our initial work in this area suggested that such an approach did not materially improve the performance of the models beyond an OLS approach.

As well as the need for statistical robustness within the methodology, the models and the inclusion of the potential causes of variation need to be, as far as possible, evidence based. A literature and web-based search was undertaken to identify any consensus in the type of variables to be included in the risk adjustment of PROMs data. While there was relatively little that met these specific needs (other than some earlier work by the London School of Hygiene and Tropical Medicine (LSHTM)/ Royal College of Surgeons (RCS) as part of the pilot study which was the precursor to the PROMs programme), a number of general papers addressed the subject of risk adjusting outcomes while others identified risk factors associated with the underlying conditions requiring the surgical procedure.

This work led to the identification of categories of variables to be included in the models and to the inclusion of a range of patient comorbidities that would be derived both from the patient administrative database (HES) and from the PROMs patient questionnaires themselves. As well as these variables, a number of other important variables were included reflecting demographics and the way care was delivered locally.

Methods

The principles that we tried to follow in developing the models included (i) the need for the variables included to be clinically relevant, (ii) a consistency of structure and approach across all models (across all measures and procedures), and (iii) the models should be transparent and as simple and parsimonious as possible, while being clinically and academically acceptable.

The data used within the models were obtained from the patient's Hospital Episode Statistics (HES) record and from their replies to two separately administered questionnaires that patients were asked to complete prior to operation (the "Q1" questionnaire) and at a period approximately three or six months following discharge (Q2). Only the HES record for the spell containing the PROMs procedure has been included in the database at present, although consideration is also being given to whether it is possible to include past data about longstanding comorbidities that might not have been recorded in

the current HES spell. Work will be undertaken by another part of the PROMs programme to establish whether omitting unlinked data from the analysis could introduce any biases. Should any such biases be identified, we will reflect these results in subsequent versions of the model (see *Updating the models and future developments* below)

A progressive approach to model development was taken with each category of variables (e.g. demographics, other patient characteristics, HES based clinical risk factors etc) being introduced and evaluated sequentially. Multiple linear regression (OLS) was used to produce a full model across all variables that were still under consideration at each stage. A robust standard error calculation was used as it was considered that the usual assumption of an equal variance in the error terms across the range of each variable should not necessarily be accepted. Detailed diagnostics were considered to decide whether a variable should be excluded before moving on to the next stage. Once the 'final' model had been produced the face validity of the model, appropriateness of the scale, and direction and stability of the coefficients were all considered.

The developed models were tested on a separate subset of the PROMs data. The size of the samples used to test the models was about 17% (in the case of the orthopaedic models) and between 60% and 78% (for general surgery) of the size of the samples used to develop the original models. The reasons for the difference between the size of the test samples were the larger samples used to develop the orthopaedic models initially and the longer Q2 response period required by these procedures (6 months rather than 3 post-operatively). Comparisons of the models applied to the separate data sets were made with the results when they were applied to the combined data set for each procedure.

Results

An examination of the descriptive statistics showed that a few variables had been included in the original models that had a very low incidence in the database. Their inclusion presented a slight anomaly, which was expected to be highlighted (as indeed it was) when the models were tested on new data samples. Such variables have now been excluded from the models until such time as their incidence becomes important (Note: The sub-groups of such patients can continue to be reviewed individually to ensure that important patient care messages are not being overlooked).

The prediction models for the two general surgery interventions explained between 23% and 46% of the variation in Q2 follow-up scores with the EQ VAS models appearing to have more explanatory power than the models for the Aberdeen Varicose vein Score or for either of the EQ5D Index scores. This latter finding may be related to the ceiling effect of the Index instrument which (for these procedures at least) sees a large proportion of patients' Q2 scores at the upper limit of 1.0.

The testing of the models on the new data samples found that, in the case of the Groin hernia (Index and VAS) and the Aberdeen Varicose vein Score models, there was no significant difference in the estimated parameters in the different periods suggesting that these were fairly robust models. Some differences were found when applying the varicose vein (Index and VAS) models to the test data samples. Inspection suggested that these

models might be over specified, with the potential to remove some of the low incidence patient reported comorbidity variables e.g. kidney and liver disease from the original models.

Similarly, when testing the six Orthopaedic models only one (Knee VAS) showed a significantly different result between the development sample and the test sample. Again this was due, at least in part, to the low incidence of some variables.

The results of testing and of the early censored regression analysis both suggested that there was scope to remove a further, small number of variables from the models developed previously, either because of their low incidence or their volatility when applied to a new data extract.

The main results for the individual models for each procedure are described in section 4.3 of the paper with a detailed example of the way the OLS results were constructed being provided in Appendix 4. These results have been obtained following the testing procedure described above and using the full dataset available. This Appendix also provides full details of all eleven models.

Risk adjusting the 'raw' PROMs scores

The prediction models described in this paper identify all the variables that make a significant contribution to explaining the differences between individual patient responses. However, when risk adjusting the 'raw' PROMs scores, those variables relating to the local health service or to the provider itself should not be included so as not to advantage or disadvantage provider organisations which have either already made substantial efforts to improve their performance in treating these particular clinical conditions, or conversely, which are lagging behind others in this respect. In essence, the variation in outcomes attributable to the provider is of direct interest and should not be controlled for.

Applying the models to new data extracts provides predicted Q2 scores (Q2 pred) for each patient record in the specified period. Dividing the actual Q2 score obtained by that predicted by the model (Q2 pred) provides an index of the extent to which a provider is performing above or below what would have been expected if they performing with national average quality. Multiplying this ratio by the national average Q2 would provide a measure of the Q2 score that would have been achieved by an individual provider had they treated a national average case-mix of patients. This principle underpins the risk adjustment methodology developed and reported here. Further details are provided in section 5.3.

Updating the models and future developments

The PROMs programme recognises that due, in part, to the innovative nature of this work and the relatively small volume of data feeding the models developed to date, they are 'fit for purpose', but can be improved upon over time.

Firstly, the models will be updated annually with the expectation that they will become more robust and that some of the coefficients will be less susceptible to the impact of small numbers of patients.

Additionally, this paper describes some of the developments to the current models that we consider it would be useful to examine, such as further consideration of a more detailed consideration of diagnoses and procedures, including comorbidities reflected by secondary diagnoses, and an analysis of interactions between the variables that are already included in the models.

The timetable for this process is that between the publication of this version of the models in September 2010 and the end of November the team will collect and catalogue proposals for model development and will present these back to the PROMs Stakeholder Reference Group and its Technical Working Group to agree the work to be undertaken. The period from December to early February will see the updating and refinement of the models themselves, with the results being reviewed subsequently by the Groups and agreed by the PROMs Stakeholder Reference Group for publication and implementation from 1st April 2011.

Risk Adjustment models for Patient Reported Outcome Measures

1. Introduction

1.1 The National PROMs programme is initially focusing on four elective surgery interventions: groin hernias, varicose veins; and hip and knee replacements. Patients are being surveyed as to their health status and the impact of the condition on their lifestyle at a pre-operative baseline (Q1) and post-operatively (Q2). Initial 'Version 1' risk adjustment models were developed for Groin Hernias and Varicose veins with five separate models being constructed for each of the required instruments. The instruments for these conditions are:

- EQ5D Index, applied to groin hernia patients
- EQ Visual Analogue Scale (EQ VAS), applied to groin hernia patients
- EQ5D Index, applied to varicose vein patients
- EQ Visual Analogue Scale, applied to varicose vein patients
- Aberdeen Varicose vein Score, applied to varicose vein patients

1.2 The objective of the case-mix or risk adjustment process is to provide a method for adjusting the variable in which we are interested (the reported health status as obtained from a post-operative questionnaires) to take account of the different factors that influence it, such as patient characteristics e.g. age, sex, comorbidities, general health etc of patients treated by different providers, and other factors, which are beyond the control of the provider. For comparative information presented back to a range of audiences to be clear, such effects should be controlled for as far as possible to ensure that comparisons are on a like-for-like basis.

1.3 The models seek to risk-adjust the reported 'raw' follow-up (Q2) scores for specific patient and other variables, including the baseline Q1 score, that are mostly outside of the control of providers[1,2]. Modelling of the Q2 score is useful since it can be used in a variety of case-mix adjustment approaches.

1.4 The purpose of this paper is to describe the theoretical basis for the General Surgical and Orthopaedic models, the methodological development of these 'Version 2' models and the current results. The instruments being used for the Orthopaedic conditions are:

- EQ5D Index, applied to hip replacement patients
- EQ Visual Analogue Scale (EQ VAS), applied to hip replacement patients
- Oxford Hip Score, applied to hip replacement patients
- EQ5D Index, applied to knee replacement patients

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[1] Browne J, Jamieson L, Lamping D et al. *Minimally Important difference values have a weak association with baseline severity when mathematical coupling and regression to the mean are controlled for*. (to be published) 2009.
[2] Tu YK, Gilthorpe MS. Revisiting the relation between change and initial value: a review and evaluation. *Statist Med* 2007;26:443-457

- EQ Visual Analogue Scale, applied to knee replacement patients
- Oxford Knee Score, applied to knee replacement patients

2. Development of a theoretical model

2.1 The models to be developed attempt to explain variation in the outcomes of patients undergoing similar surgical procedures e.g. groin hernia operations, as assessed by a number of patient reported outcome measures (PROMS). As mentioned in section 1, such variation (in PROMs) may be caused by a range of demographic and other patient characteristics as well as clinical factors and differences in the quality of healthcare delivered by the provider. While the models seek to examine all these sources of variation, once identified, it would be desirable to separate the last effect (provider quality) from that of the others, so that case-mix adjustment does not adjust for this effect which is in the control of the providers and of direct interest in making comparisons.

2.2 Current single level models:

The initial models are based on simple ordinary least squares (OLS) regression models, with which most clinicians and senior managers will be familiar:

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \beta_3 x_{i3} \ldots + e_i \qquad i = 1,\ldots,N \text{ where } N = \Sigma n_j, \qquad j = 1,\ldots..,J,$$
$$e_i \sim N(0,\sigma_e^2)$$

where y_i is the follow-up (Q2) value of the various instruments e.g. EQ5D index, EQ visual analogue scale (EQ VAS), Aberdeen Varicose vein score, Oxford Hip and Knee Scores for the *i*th patient across j provider units (NHS or independent hospital or treatment centre);

$x_{i.}$ are independent predictor variables (including relevant baseline (Q1) value), and e_i are the error terms

e_i is assumed normally distributed and independent of any predictor variables.

2.2.1 The choice of OLS as an exploratory tool for model development reflects one of the principles of our initial approach (described in section 3.2) of simplicity, while also providing the best linear unbiased estimator having uncorrelated errors with constant variance. Movement away from such an approach would require evidence based justification that these conditions are not met, but may be necessary to ensure unbiased estimates. However, there are some concerns with such a simple approach, which will be addressed over time.

2.3 Multilevel models

2.3.1 The first lies in the possibility that such an approach does not adequately identify the impact of provider specific differences on outcomes. While one might suspect that demographic and other patient related effects should be consistent across all providers, variables that relate to provider quality and treatment choices may have a differential effect. To deal with this, it is usual to consider a multi-level model but this requires there to be sufficient data from **each** provider unit. To date, this has

not been possible, due to the volume of data available, and therefore the single level least squares models have been developed.

Multi-level models are expressed as:

$$y_{ij} = \beta_0 + \beta_1 x_{ij1} + \beta_2 x_{ij2} + u\ \beta_3 x_{ij3} \ldots + u_j + e_{ij} \qquad i = 1,\ldots,n_j, \qquad j = 1,\ldots,J$$
$$u_j \sim N(0,\sigma_u^2),$$
$$e_{ij} \sim N(0,\sigma_e^2)$$

where yij is the follow-up (Q2) value of the various instruments e.g. EQ5D index, EQ visual analogue scale (EQ VAS), Aberdeen Varicose vein score, Oxford Hip and Knee Scores for the *i*th patient from the *j*th provider unit (NHS or independent hospital or treatment centre

$x_{ij.}$ are independent predictor variables (including relevant baseline (Q1) value),

u_j are the provider unit level random effects, and

e_{ij} are the patient level error terms

u_j and e_{ij} are assumed normally distributed, independent of one another and of any predictor variables.

2.4 Censored (or tobit) regression

2.4.1 The second concern lies in the fact that each of the instruments has an upper limit (e.g. the EQ5D index is limited at 1.0), the visual analogue scale at 100, and less importantly, a lower limit (generally zero, although the EQ5D Index can take a negative value). There is concern that the 'floor' and 'ceiling' effects may result in the calculation of biased estimates (particularly at the end of the data ranges)[3]. Initially this effect was examined by the introduction of transformed variables (e.g. squaring the value of each of the instruments in their respective models). However, censored regression models are being examined in each case and will continue to do so with a view to introducing such an adjustment (if it proves necessary) in the next revision of the models that are scheduled for winter 2010/11.

2.5 The selection of variables for inclusion in the model

2.5.1 As well as the need for statistical robustness within the methodology, the models and the inclusion of the potential causes of variation need to be evidence based. Appendix 1 lists the variables that are available from the patient questionnaires (Q1 and Q2) and Hospital Episode Statistics (HES). In the case of Hip and Knee replacements, the long list is potentially further supplemented by a large number of variables that are available from the National Joint Registry (NJR) database. With so many variables available the process of model development faces a number of challenges. Firstly there is the problem of multi-collinearity – with so many variables, there is an increased likelihood of a relationship existing between some

[3] Brazier J, Roberts J, Tsuchiya A, Busschbach J: A comparison of the EQ-5D and SF-6D across seven patient groups. Health Econ 2004, 13(9):873-884.

of them (e.g. between the various Strategic Health Authority variables within HES) or between the individual component responses or linear combinations thereof (that contribute to the overall outcome score) with the score itself. The model builder needs to identify whether the relationships are sufficiently strong that only one variable should be used within the model from the start, or whether a case can be made for including more than one at the outset (perhaps on the basis that each variable, although correlated, has some conceptual strengths of its own) while keeping a close watch for multi-collinearity. Secondly, the choice from a large number of variables can lead to an unstructured approach to model development where the apparent power of a model overrides any logical consideration of its composition. This has been avoided by including only variables where others have previously reported a connection with outcomes for the condition, or where the variable was considered sufficiently important from *a priori* theoretical grounds to include in the initial consideration e.g. ethnicity.

2.6 *Literature and web-based review*

2.6.1 To avoid, or at least reduce, these possibilities a literature and web-based search has been undertaken to identify any consensus in the type of variables to be included in patient reported outcome models. The results of these searches are summarised in Appendix 2. Iezzoni in her generic book on risk adjustment for health outcomes proposes a range of risk factors within the following overall categorisation:

- demographic and other patient characteristics
- prior health related factors
- clinical factors
- patients' attitudes and perceptions
- socio-economic factors and
- differences in the quality of healthcare delivered by the provider unit.

2.6.2 A number of these factors (including general health status, comorbidities and previous similar surgery) were found to be useful in adjusting post-operative scores by the LSHTM and RCS Research Team (Browne, Black et al[4]) that undertook the pilot study for the current work. The selected comorbidities were based on previous work by Bayliss et al[5].

2.6.3 Browne and Black's work recommended that post-operative PROMs scores should be adjusted for age, sex, general health status, comorbidity (eight systemic conditions) and previous similar surgery, but found little requirement to include duration of symptoms or the Index of Multiple Deprivation within the General Surgical conditions.

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[4] Browne J, Black N et al. *Patient Reported Outcome Measures (PROMs) in Elective Surgery*. Report to the Department of Health. London, December 2007.
[5] Bayliss EA. Ellis JL, Steiner JF. Subjective assessments of comorbidity correlate with quality of life health outcomes: Initial validation of a comorbidity assessment instrument. *Health and Quality of Life Outcomes* 3:51-58. 2007

2.6.4 As well as patient reported comorbidities, the Charlson Index[6] has been included together with variables indicating the presence or absence of each of the seventeen comorbidities included within the Index. The Index (or variations of it) has been extensively used within clinical studies and has found general clinical acceptance; however, its dependent variable is mortality rather than the broader reporting of PROMs outcome measures. For this reason, we included the additional variables using definitions derived by Quan et al[7].

2.6.5 The above findings provided the majority of the variables included in the development of the models. However, due to the relatively limited literature related to risk factors in the prediction of PROMs following surgery, it was decided to add a number of other factors that were considered likely on theoretical grounds to explain outcomes (many of which have been found important in other areas of risk adjustment). These included:

- additional patient characteristics such as ethnicity, patient reported disability, living arrangements e.g. in hospital or long term care;
- whether the patient received assistance in completing either questionnaire; and
- the specific type of procedure undertaken.

2.6.6 Additional variables reflecting the area of the country in which the patient was treated and certain provider related variables were drawn from HES for inclusion, to be able to examine specific questions. These included:

- the Strategic Health Authority of Treatment (in due course, when volumes permit, this may be replaced by the commissioning authority)
- the Index of Multiple Deprivation
- admission category, method and source
- discharge destination
- pre and post operative length of stay
- the nature of the provider organisation, and
- times between the completion of the two questionnaires and the procedures.

While including these variables within the development of the models (to explain as much variation as possible), it was recognised that the impact of provider related variables should be removed from any calculation of a comparative case-mix adjusted figure. This is discussed further in section 5.1.

[6] Charlson M, Pompei P, Ales K, MacKenzie C. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis.* 1987;40(5):373-83
[7] Quan H, Sundararajan V et al. Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. *Medical Care*. 2005;43(11):1130-9

3. Methods

3.1 Variables available to the models

3.1.1 Results of the literature survey and initial correlation and other exploratory analysis (on complete and linked records received before the end of November 2009) led to the proposal of a 'long list' of variables for inclusion in the modelling process. These are identified in the right hand column of the table in Appendix 1. At present these do not include the 200+ variables available in the NJR dataset, as these have not yet been included in model development due to time constraints and will be added in for the next iteration of development.

3.2 Principles

3.2.1 In developing the models, a number of principles were established at the outset. These included that:

- the variables for inclusion should be considered clinically appropriate (by reference to literature and PROMs stakeholders)
- while the coefficients and variables in each model may differ, there should be consistency of structure and approach across all models (e.g. they would be of the same order – linear (or polynomial) and be produced using the same regression approach)
- the models would be transparent, as simple as possible and parsimonious in the use of variables.

3.3 Further rules for selecting variables for consideration

3.3.1 In addition to the principles described in the previous section, it was felt appropriate to apply the following rules when considering variables for inclusion:

- the only independent variables from the follow-up questionnaire (Q2) to be considered for inclusion in the model were (i) those describing whether the patient had received assistance in completing the Q2, and (ii) the time between date of procedure and date of Q2 completion;
- in constructing the models for each instrument, variables related to the other instruments were not included (e.g. the Aberdeen Varicose vein score (Q1) was not included in the EQ5D Index or VAS models);
- at this stage, responses to individual component questions that lead to the construction of the value for each instrument was not included. (It is recognised that such responses to specific questions may provide additional explanatory power, which could be examined at a later date);
- the principal procedure code for each patient was included in the statistical analysis to develop each model but, to date, secondary procedures have not. (Also, it is recognised that the order of coding procedures is not an exact science and that the introduction of an algorithm that encompasses secondary procedures is worth consideration). The diversity of primary diagnoses across the records within each database has also meant that this variable has not yet been included in the models.

3.4 Data quality and other data considerations

3.4.1 The data used within the models were obtained from the patient's Hospital Episode Statistics (HES) record and from their replies to two separately administered questionnaires (Q1 and Q2) that patients were asked to complete prior to operation and at a period approximately three months following discharge.

3.4.2 Only the HES record for the spell containing the PROMs procedure has been included in the database at present, although consideration is also being given to whether it is possible to include past data about longstanding comorbidities that might not have been recorded in the current HES spell.

In order for a record to be entered into the PROMs database the separate elements (HES, Q1 and Q2) all had to be present and linked to form a single record. This implies that the patient had to return both Q1 and Q2 questionnaires and that the patient / questionnaire identifiers had to be attributable to an identified HES record. Where this linkage cannot be made the record has to be considered incomplete. The characteristics of patients undergoing these surgeries, who either choose not to respond to the questionnaires or who do not have a complete HES / Q1 / Q2 profile will be examined in the analytical part of the PROMs programme, to address issues of potential response bias in the results.

3.4.3 Even within the linked database, not all patients had completed each instrument related to the condition e.g. the EQ5D Index questions may have been completed but not the Visual Analogue Scale or the Aberdeen Varicose vein (or Oxford Hip or Knee score) questions, hence the number of records used in building each model varied. In the same way, levels of HES recording and response levels to other questions (that contribute to some of the independent variables in the models) vary, although this is not thought to have been significant.

3.4.4 Finally, as implied by comments in section 2, the number of usable records received to date from provider organisations varies considerably, with more than half so far contributing less than 50 linked records to the analysis of hernia and knee replacement PROMs and fewer in respect of varicose veins and hip replacements. When considerably more data are available for each provider, consideration will be given to producing relevant multi-level models.

No of responses received per provider	Groin Hernias (no of providers)	Varicose veins (no of providers)
<10	42	50
>=10 and <25	46	41
>=25 and <50	52	38
>=50 and <75	49	26
>=75 and <100	23	5
>=100	30	9
Total no of providers	242	169

No of responses received per provider	Hip replacements (no of providers)	Knee replacements (no of providers)
<10	72	56
>=10 and <25	62	43
>=25 and <50	26	44
>=50 and <75	30	28
>=75 and <100	17	14
>=100	33	51
Total no of providers	240	236

3.5 Development of models

3.5.1 The general approach and initial models, based on very small amounts of data obtained in the first three months of the programme, were presented to the PROMs Stakeholder Reference Group and its Technical Sub-Group in December 2009 and January 2010. These groups agreed with the general approach being adopted and made useful comments and suggestions in respect of its detail. These comments have been considered and, where appropriate, included in the current approach described here.

3.5.2 As mentioned previously, for each model, a broad-based exploratory analysis of 'candidate' variables was carried out to identify a potential shorter list for consideration within the model development process. This included an examination of completion levels, variation in the variable across records and correlation with the various dependent variables. These shorter lists were also influenced by the earlier literature and web searches.

3.5.3 Once the shorter lists had been proposed, they were defined as belonging to one or other of the following sub-groups:

- patient demographics (age, sex, ethnicity)
- other patient characteristics (such as whether the patient lived at home etc, whether they considered themselves disabled etc)
- clinical risk variables derived from HES (mainly diagnosis and procedure type and comorbidities)
- clinical risk variables from the patient questionnaires (e.g. the baseline score of the instrument, patient perceived comorbidities)

- other risk factors from the patient questionnaires (the patient's view of their general health)
- local area related variables (Strategic Health Authority of treatment, level of deprivation)
- provider related variables (such as pre- and post-operative length of stay, discharge destination and type of provider e.g. NHS/independent, foundation or other trust, treatment centre or hospital).

3.5.4 This categorisation was important to the model building process, as the models were developed sequentially starting with the single patient demographics category and then adding each following category individually in order to examine what impact its introduction had on the model. Multiple linear regression was used (to obtain a full model across all included variables). Detailed diagnostics were obtained for consideration at each stage. Records without a value for the dependent variable were excluded at the outset. This approach allowed us to explore the stability of coefficients to the sequential addition of explanatory variables and to understand potential relationships between them.

3.5.5 At each stage, the explanatory power of the model was examined to identify the additional benefit of adding further variables, but more importantly each variable was considered in its own right. At each stage, a variable might be:

- excluded purposefully (in the case of categorical variables, one acts as a 'null variable' against which other levels are compared or because there was no variation in the variable across all the records under consideration);
- removed by the developers of the model, because the coefficient of the variable was not significant (as shown by its t-statistic or because there were concerns about collinearity as shown by a variance inflation factor > 10).

The remaining variables were then taken forward and those within the next category added and the process repeated.

3.5.6 Once the computation aspect of the model building process had been completed, the results were inspected further. The first issue to be considered was the face validity of the results: were the variables that remained in the 'final' model considered appropriate; did the scale and the direction of the coefficients seem right, and did the explanatory power of the model seem adequate?

3.5.7 Other aspects considered included whether the coefficients appeared relatively stable as the model developed – a lack of stability might suggest a continuing and changing inter-relationship between independent variables - and, in a similar vein, the size of the variance inflation factor in the remaining variables.

3.5.8 Once the OLS models had been completed, further consideration was given to addressing the potential 'floor' and 'ceiling' affects. As mentioned earlier, there

was some concern that the upper and lower bounds of the various instruments might lead to the production of biased estimates when using a linear regression approach. It was agreed that the analysis should be extended to include an examination of a censored regression approach and while an initial analysis has been undertaken on some of the models – and shown no evidence of an improvement in model performance at the national or provider levels – time constraints have meant that a full implementation of such an approach (should it prove necessary) has been delayed until the implementation of the revised version 3 of the models in April 2011.

3.5.9 A robust standard error calculation was used as it was considered that the usual assumption of an equal variance in the error terms across the range of each variable should not necessarily be accepted.

3.6 Testing of the models

3.6.1 The OLS models that had been developed were tested on a separate and independent set of PROMs data containing linked records that had been received in the subsequent two months (December 2009 and January 2010 for the general surgical models and March and April 2010 for the orthopaedic models). Testing was undertaken using an application of the Chow test, which uses as its null hypothesis that there is no difference between the estimated parameters of the models for the two datasets. This test explores whether the parameter estimates are stable over time.

3.6.2 The approach requires the calculation of the residual sum of squares of the model when run on the combined data set RSS_a and degrees of freedom DF_a, and also of the same statistics when run on the two sets of data separately RSS_b and RSS_c with degrees of freedom DF_b and DF_c respectively. These latter statistics are then added together to produce 'pooled' figures RSS_g and DF_g.

A test statistic is then produced using the following formulae:

$$W = (RSS_a - RSS_g) / (DF_a - DF_g)$$

$$V = W / (RSS_g / DF_g)$$

with V being tested against $F_{(DFa-DFg,DFg)}$

Disaggregation of the residual sums of squares and examination of each variable's contribution together with the relative significance of the coefficients across the two datasets provide an indication of where any major differences lie.

3.6.3 Following a review of the results of testing of the models and early consideration of some of the censored regression results, a further rationalisation of the variables within the models took place. For example, a number of variables that had a low incidence but appeared significant in the initial data sample were no longer

significant in the larger dataset and were therefore dropped. The full models were then applied again to the complete dataset (of linked records received up to the end of January 2010 in the case of the general surgical models, with the orthopaedic models being developed somewhat later using linked records received up to the end of April 2010) and it is these results that are now reported.

4. Results

4.1 Results of Testing

4.1.1 As mentioned above, the original general surgery 'prototype' models based on the first seven months of the programme were tested using new samples of data received and successfully linked during the a two month period up to the end of January 2010. The size of these samples were groin hernia (4281 records) and varicose veins (2093 records) although, as with the data used in model construction, not all variables were complete and therefore a small number of records were excluded when testing any particular model.

4.1.2 The scale of the new data for varicose veins in particular, (approximately 2100 records compared to the 2700 used in the development of the original model) was always likely to result in the identification of greater differences between the 'development' and 'test' samples than with the hernia data and this was found to be the case.

The results of applying the test method described in section 3.6 above can be summarised as follows:

Model	Value of V statistic (see 3.6.2)	F degrees of freedom	Significance
Groin hernia EQ5D Index	1.700	(21,11193)	Not Sig.
Groin hernia EQ VAS	1.692	(18,10609)	Not Sig.
Varicose veins EQ5D Index	2.093	(15,4419)	0.008
Varicose veins EQ VAS	2.014	(14,4216)	0.014
Aberdeen Varicose veins Score	1.574	(13,4645)	Not Sig.

4.1.3 From the above table it can be seen that in three of the models, there was no significant difference when applying the parameters to the 'development' and 'test' data samples. In the case of the groin hernia models, when admission source and discharge destination (variables that did not appear in the 'test' sample) were removed from the 'development' model and the test methodology repeated, the results were even less significant.

4.1.4 Inspecting the application of the original varicose vein Index and VAS models to the 'test' data samples would suggest that these models might be over specified, particularly when the results are compared to those of the Aberdeen Score. The inclusion in the Index model of both variables that identify patients that had and had not received assistance in completing the follow-up questionnaire is unnecessary and one of the variables will now be removed. Additionally, the inclusion of some of the low volume patient reported comorbidities in the original models (e.g. kidney and liver disease) needed to be reviewed.

4.1.5 As the data available to the varicose vein models have now almost doubled in size from that available when the 'prototype' models were constructed, it is not surprising that differences between the 'development' and 'test' samples have been noted.

4.1.6 The method described above was replicated for the orthopaedic models (using records received and successfully linked during March and April 2010). The test results obtained being shown in the table below.

Model	Value of V statistic (see 3.6.2)	F degrees of freedom	Significance
Hip Replacement EQ5D Index	1.180	(21,12693)	Not Sig.
Hip Replacement EQ VAS	1.133	(21,11728)	Not Sig.
Oxford Hip Score	1.113	(19,13974)	Not Sig.
Knee Replacement EQ5D Index	0.963	(19,14004)	Not Sig.
Knee Replacement EQ VAS	1.793	(21,13258)	0.014
Oxford Knee Score	1.164	(24,15669)	Not Sig.

The only significant difference between samples occurred in the knee EQ VAS. On inspection, this appeared to have been caused by the low incidence of some of the patient reported comorbidities in the two month sample, as well as the lack of any records with specific admission sources or discharge methods. These areas were reviewed before the finalisation of this version of the model.

4.2 Descriptive statistics

4.2.1 Descriptive statistics for the variables included in the eleven models are shown in Appendix 3. This identifies that a number of the variables e.g. varicose vein patients living in nursing homes, hospital or long-term care; HES based comorbidity of metastatic tumour in varicose vein patients, still have a very low incidence in the database. They have, however, been included into the models because, for those patients, they do explain a significant part of the variation in their scores i.e. these patients have reported a Q2 index or VAS score that is significantly different from otherwise similar patients who have not been admitted from these sources.

4.2.2 Such variations, if an artefact of the small number of individual responses, rather than a 'real' effect, would be expected to become apparent when the volume of data increases.

4.3 General Surgical Models

4.3.1 Appendix 4 shows an example of the results obtained from applying the OLS developmental process described in section 3.5 in respect of the groin hernia data.

Summaries of all five models are also included within Appendix 4. The number of variables included in the models varies from twelve (for the Aberdeen Varicose vein Score model) to 19 (for the Groin hernia EQ VAS model). The number of variables, the number of records used to develop the model and the R-squared for each of the five models are shown in the table below.

Model	No of variables	No of records	R-squared
Groin hernia EQ5D Index	18	10674	0.329
Groin hernia EQ VAS	19	10012	0.459
Varicose veins EQ5D Index	12	4412	0.361
Varicose veins EQ VAS	15	4180	0.412
Aberdeen Varicose veins Score	12	4664	0.341

4.3.2 From the above, the models can be seen to explain between 33% and 46% of the variation in the Q2 follow-up scores, and that the varicose vein models require fewer variables to achieve this than the groin hernia models. It is also clear that fewer patients completed the two Visual Analogue Scales than the other instruments but that these models appear to have greater explanatory power.

4.3.3 With respect to face validity, all of the models contain variables that appear to be appropriate and have coefficients that are directionally correct (e.g. the inclusion of a comorbidity or a patient considering themselves disabled) generally has a negative effect on the Q2 score.

4.3.4 Two comments need to be made in this respect:

i) in most cases, the effect of HES defined comorbidities is limited with few being included in the final models. This contrasts with the position in respect of patient reported comorbidities, where a number of these are included in the final models of each instrument. (In an additional study, we examined whether inclusion of HES based comorbidities corresponding to the already included patient comorbidities would produce improved models. However, the results of doing so were consistently poorer models with the HES based comorbidities remaining non-significant);

ii) a few of the variables (e.g. patient reported liver disease comorbidity in the varicose veins EQ5D Index model) exhibit positive coefficients which appear intuitively inappropriate. A special investigation of these data showed that these patients had a worse baseline position (Q1) than the general cohort of patients but achieved similar outcomes at Q2, hence achieving a positive coefficient on the comorbidity. This contrasted to other comorbidities where the patients with the comorbidity tended to have a similar starting position (Q1) to the general cohort but did not report as much benefit from

the procedure (Q2) because of the comorbidity. These effects will be kept under review as additional data are obtained.

4.4 Orthopaedic Models

4.4.1 The following results describe the six orthopaedic models. Full summaries of all six orthopaedic models are provided within Appendix 4. The number of variables included in the models varies from 16 to 20. It is somewhat surprising that the models for the Oxford Hip and Knee scores require quite different numbers of variables. The number of variables, the number of records used to develop the model and the R-squared for each of the six models are shown in the table below.

Model	No of variables	No of records	R-squared
Hip Replacement EQ5D Index	18	12743	0.230
Hip Replacement EQ VAS	18	12084	0.265
Oxford Hip Score	16	14019	0.241
Knee Replacement EQ5D Index	17	14041	0.252
Knee Replacement EQ VAS	18	13303	0.299
Oxford Knee Score	20	15718	0.262

4.4.2 From the above table, the models can be seen to explain between 23% and 30% of the variation in the Q2 follow-up scores, a rather lower percentage than that explained by the general surgical models. This would suggest that there is greater heterogeneity amongst these patient populations. It is also noticeable that the knee replacement models explain slightly more of the variation than those for hip replacement. Again, fewer patients completed the two Visual Analogue Scales than the other instruments but those models appear to have greater explanatory power.

4.4.3 As in the general surgical models, all of the orthopaedic models showed face validity in terms of the scale, direction and appropriateness of the variables included. The nature and type of the procedure (e.g. primary, revision, hybrid) were included in the analysis and, perhaps not surprisingly, some of these variables are included in the models. Again, the limited inclusion of HES defined comorbidities contrasts with the number of patient reported comorbidities included in the final models of each instrument.

4.5 Summary of results for individual models

4.5.1 Appendix 4 provides full results showing the build up of each of the individual models. A summary of the variables included in each model is provided overleaf for comparison across the models. The following sections describe some of the more important aspects of these models for each instrument.

4.5.2 *Groin Hernias EQ5D Index*

Patient demographics – The age and sex of the patient is included in this model. No ethnic group was found to have a significant effect.
Other patient characteristics – Patients who considered themselves disabled had a highly significant negative effect. In this model, patients who had had assistance in completing the Q2 questionnaire were also found to have a negative effect.
Clinical risk variables derived from HES - No HES based comorbidity was found to have a significant effect. The specific principal procedure within the overall Groin hernia definition was not found to have an effect.
Clinical risk variables from the patient questionnaires - Patient reported circulation, nervous system, depression and arthritis comorbidities all had a negative effect on the predicted Q2 score while the baseline EQ5D Index had a highly significant positive effect.
Other risk factors from the patient questionnaires - A General Health question produced results that were highly significant with the coefficients having strong face validity in their hierarchical differential.
Local area related variables -The IMD04 measure of deprivation has a negative effect in the model. One Strategic Health Authority had a significant positive effect.
Provider related variables - Admission from the patient's usual place of residence, post-operative length of stay and time between procedure and completion of the follow-up questionnaire are explanatory variables included in the model.

4.5.3 *Groin Hernias EQ VAS*

Patient demographics - No demographic variables are included in this model.
Other patient characteristics - Patients who considered themselves disabled had a highly significant negative effect. In this model, patients who had had assistance in completing the Q2 questionnaire were also found to have a negative effect.

Variables included in each final OLS regression model

	Groin Hernias		Varicose Veins		
Variable	EQ5d Index	EQ VAS	EQ5d Index	EQ VAS	Aberdeen VV Score
Number of variables in model	18	19	12	15	12
Constant term					
Q1 EQ5d Index score	Yes	-	Yes	-	-
Q1 EQ5d VAS Scale score	-	Yes	-	Yes	-
Q1 Aberdeen Varicose Vein score	-	-	-	-	Yes
Age at start of PROMs procedure spell	Yes	-	-	-	-
Sex (Female patients)	Yes	-	-	-	Yes
Patients who responded who were of Asian origin	-	-	-	-	Yes
Patients who had assistance in completing the Q2 questionnaire	Yes	Yes	-	-	-
Patients who were living in a nursing home, an NHS hospital or long-term care	-	-	-	Yes	Yes
Patients who considered themselves disabled	Yes	Yes	Yes	Yes	Yes
Charlson Index (calculated from HES data)	-	-	-	Yes	-
Patients with a comorbidity of COPD according to HES	-	Yes	-	-	-
Patients with a comorbidity of metastatic tumour according to HES	-	-	Yes	-	-
Patients who reported having had previous treatment (injections / surgery) for this condition	-	Yes	Yes	Yes	Yes
Patients reporting a comorbidity of heart disease	-	Yes	-	-	-
Patients reporting a comorbidity of circulatory problems	Yes	Yes	-	Yes	Yes
Patients reporting a comorbidity affecting the nervous system	Yes	Yes	-	-	-
Patients reporting a comorbidity of liver disease	-	-	Yes	-	-
Patients reporting a comorbidity of cancer	-	Yes	-	-	-
Patients reporting a comorbidity of anxiety or depression	Yes	Yes	Yes	Yes	Yes
Patients reporting a comorbidity of arthritis	Yes	Yes	Yes	Yes	-
Patients reporting general health as being Excellent	Yes	Yes	Yes	Yes	-
Patients reporting general health as being Very Good	Yes	Yes	-	Yes	-
Patients reporting general health as being Fair	Yes	Yes	Yes	Yes	-
Patients reporting general health as being Poor	Yes	Yes	Yes	Yes	Yes
Patients from Strategic Health Authority Q31	-	-	-	Yes	Yes
Patients from Strategic Health Authority Q36	-	-	-	Yes	Yes
Patients from Strategic Health Authority Q39	Yes	-	-	-	-
Index of Multiple Deprivation Score, IMD04	Yes	Yes	Yes	-	-
Admission source = 19	Yes	-	-	-	-
Post operative length of stay following PROMs procedure	Yes	Yes	-	-	Yes
Patients whose provider organisation was an Independent Treatment Centre	-	Yes	-	-	-
Patients whose provider organisation was a PCT	-	-	Yes	-	-
Time from completion of Q1 to PROMs procedure	-	-	-	Yes	-
Time from PROMs procedure to completion of Q2	Yes	Yes	-	-	-

Variables included in each final OLS regression model

	Hip Replacements			Knee Replacements		
Variable	EQ5d Index	EQ VAS	Oxford Hip Score	EQ5d Index	EQ VAS	Oxford Knee Score
Number of variables in model	18	18	16	17	18	20
Constant term						
Q1 EQ5d Index score	Yes	-	-	Yes	-	-
Q1 EQ5d VAS Scale score	-	Yes	-	-	Yes	-
Q1 Oxford Hip / Oxford Knee Score	-	-	Yes	-	-	Yes
Age at start of PROMs procedure spell	-	-	-	Yes	Yes	Yes
Sex (Female patients)	Yes	Yes	Yes			
Patients who responded who were of Asian origin	-	-	-	-	-	Yes
Patients who did not give their ethnicity	-	-	-	Yes	Yes	Yes
Patients who had assistance in completing the Q2 questionnaire	Yes	Yes	Yes	Yes	-	-
Patients who were living alone	-	-	-	-	Yes	-
Patients who considered themselves disabled	-	-	Yes	-	-	-
Patients who did not consider themselves disabled	Yes	Yes	-	Yes	Yes	Yes
Patients with principal procedure of THR / TKR revision	Yes	-	-	Yes	-	-
Patients with principal procedure of hybrid prosthetic hip revision	Yes	-	-	-	-	-
Patients with a comorbidity of dementia according to HES	-	-	-	Yes	-	-
Patients with a comorbidity of COPD according to HES	Yes	Yes	Yes	-	Yes	-
Patients with a comorbidity of rheumatoid arthritis according to HES	Yes	Yes	-	-	-	-
Patients with a comorbidity of diabetes according to HES	-	Yes	-	-	-	-
Patients reporting that they had problems with their knee for less than 1 year	-	-	-	-	-	Yes
Patients reporting that they had problems with their knee for between 1 and 5 years	-	-	-	-	-	Yes
Patients reporting that they had problems with their knee for between 6 and 10 years	-	-	-	-	-	Yes
Patients reporting that they had problems with their knee for more than 10 years	-	-	-	-	-	Yes
Patients who reported having had previous treatment (injections / surgery) for this condition	-	-	Yes	-	-	-
Patients who reported not having had previous treatment (injections / surgery) for this condition	-	-	-	-	-	Yes
Patients reporting a comorbidity of heart disease	-	Yes	-	-	Yes	-
Patients reporting a comorbidity of stroke	-	-	-	-	Yes	-
Patients reporting a comorbidity of circulatory problems	Yes	Yes	Yes	Yes	Yes	Yes
Patients reporting a comorbidity affecting the nervous system	-	-	-	-	Yes	-
Patients reporting a comorbidity of anxiety or depression	Yes	Yes	Yes	Yes	Yes	Yes
Patients reporting a comorbidity of arthritis	Yes	Yes	-	-	-	-
Patients reporting general health as being Excellent	Yes	Yes	Yes	Yes	Yes	Yes
Patients reporting general health as being Very Good	Yes	Yes	Yes	Yes	Yes	Yes
Patients reporting general health as being Good	-	-	Yes	-	-	-
Patients reporting general health as being Fair	Yes	Yes	-	Yes	Yes	Yes
Patients reporting general health as being Poor	Yes	Yes	Yes	Yes	Yes	Yes
Index of Multiple Deprivation Score, IMD04	Yes	Yes	Yes	Yes	Yes	Yes
Discharge destination = 19	-	-	Yes	-	-	Yes
Operating status = 8	-	-	-	Yes	-	Yes
Post operative length of stay following PROMs procedure	Yes	Yes	Yes	Yes	Yes	Yes
Time from completion of Q1 to PROMs procedure	-	Yes	-	-	-	-
Time from PROMs procedure to completion of Q2	Yes	-	Yes	Yes	Yes	-

Clinical risk variables derived from HES - The only HES based comorbidity found to have an effect was a COPD comorbidity. The specific principal procedure within the overall groin hernia definition was not found to have an effect.
Clinical risk variables from the patient questionnaires - Patient reported heart disease, circulation, nervous system, cancer, anxiety and depression and arthritis comorbidities all had a negative effect on the predicted Q2 score. Whether the patient had had previous treatment or surgery for their condition also had a significant effect. The baseline EQ VAS had a highly significant positive effect.
Other risk factors from the patient questionnaires - A general health question produced results that were highly significant with the coefficients having strong face validity in their hierarchical differential.
Local area related variables - The IMD04 measure of deprivation has a negative effect in the model.
Provider related variables - Post-operative length of stay and time between procedure and completion of the follow-up questionnaire are explanatory variables included in the model with negative effect, while independent treatment centres as a provider type had a positive effect.

4.5.4 *Varicose vein EQ5D Index*

Patient demographics – No demographic variables are included in this model.
Other patient characteristics - Patients who considered themselves disabled had a highly significant negative effect.
Clinical risk variables derived from HES - The only HES based comorbidity found to have an effect was that of metastatic tumours. The specific principal procedure within the overall varicose vein definition was not found to have an effect.
Clinical risk variables from the patient questionnaires - Patient reported anxiety and depression and arthritis comorbidities had a negative effect on the predicted Q2 score while liver disease showed a positive effect (see earlier comment in section 4.2 about positive effects). Whether the patient had had previous treatment or surgery for their condition also had a significant effect. The baseline EQ5D Index had a highly significant positive effect.
Other risk factors from the patient questionnaires - A general health question produced results that were significant with the coefficients having strong face validity in their hierarchical differential.
Local area related variables - The IMD04 measure of deprivation has a negative effect in the model.
Provider related variables – PCTs as a provider type had a positive effect in this model.

4.5.5 *Varicose vein EQ VAS*

Patient demographics - No demographic variables are included in this model.
Other patient characteristics - Patients who were living in a nursing home, hospital or long-term care were, unexpectedly, found to have a highly significant positive effect (but see note in 4.3.4 above) while patients who considered themselves disabled had a highly significant negative effect.

Clinical risk variables derived from HES - The Charlson Index is included in the model with a significant negative effect. The specific principal procedure within the overall varicose vein definition was not found to have an effect.
Clinical risk variables from the patient questionnaires - Patient reported circulation, anxiety and depression and arthritis comorbidities all had a negative effect on the predicted Q2 score. Whether the patient had had previous treatment or surgery for their condition also had a significant effect. The baseline EQ5D Scale had a highly significant positive effect.
Other risk factors from the patient questionnaires - A general health question produced results that were highly significant with the coefficients having strong face validity in their hierarchical differential.
Local area related variables - Two Strategic Health Authorities had a significantly negative effect and is included in the model.
Provider related variables - The time between completion of the baseline questionnaire and the procedure is included in the model with a positive effect.

4.5.6 *Aberdeen Varicose vein Score (Note: In this instrument, it is a reduction in score which represents improved health)*

Patient demographics - The Asian ethnic group was included in the model, as was the sex of the patient.
Other patient characteristics - Patients who were living in a nursing home, hospital or long-term care were found to have a highly significant positive effect while patients who considered themselves disabled also had a significant positive effect.
Clinical risk variables derived from HES - None included. The specific principal procedure within the overall varicose vein definition was not found to have an effect.
Clinical risk variables from the patient questionnaires - Patient reported circulation and anxiety and depression comorbidities had a positive effect on the predicted Q2 score. Whether the patient had had previous treatment or surgery for their condition also had a significant effect. The baseline score had a highly significant positive effect.
Other risk factors from the patient questionnaires – Patients reporting that their general health question was 'poor' produced a significant result with a positive coefficient. Unlike the other models, this was the only general health variable included in the model.
Local area related variables - Two Strategic Health Authorities had a significantly positive effect and are included in the model.
Provider related variables - Post-operative length of stay is included in the model with a negative effect.

4.5.7 *Hip replacement EQ5D Index*

Patient demographics - The sex of the patient was the only demographic variable included in the model.

Other patient characteristics - Patients who did not consider themselves disabled had a significant positive effect. Patients who had had assistance in completing the Q2 questionnaire were also found to have a negative effect.
Clinical risk variables derived from HES - Patients undergoing total knee replacement or hybrid prosthetic hip revisions had a significant negative effect, as were those with COPD and rheumatoid arthritis comorbidities (as recorded by HES).
Clinical risk variables from the patient questionnaires - Patient who reported circulatory, arthritis or anxiety and depression comorbidities had a negative effect on the predicted Q2 score. The baseline Index had a significant positive effect.
Other risk factors from the patient questionnaires – A general health question produced results that were highly significant with the coefficients having strong face validity in their hierarchical differential.
Local area related variables – The Index of Multiple Deprivation had a significant negative effect within the model.
Provider related variables - Post-operative length of stay and time from procedure to completion of Q2 were included in the model with a negative effect.

4.5.8 Hip replacement EQ VAS

Patient demographics - The sex of the patient was the only demographic variable included in the model.
Other patient characteristics - Patients who did not consider themselves disabled had a significant positive effect. Patients who had had assistance in completing the Q2 questionnaire were also found to have a negative effect.
Clinical risk variables derived from HES - Patients with COPD, rheumatoid arthritis or diabetes comorbidities (as recorded by HES) were found to have a significant negative effect.
Clinical risk variables from the patient questionnaires - Patients who reported circulatory, heart disease, arthritis or anxiety and depression comorbidities all had a negative effect on the predicted Q2 score. The baseline VAS had a significant positive effect.
Other risk factors from the patient questionnaires – A general health question produced results that were highly significant with the coefficients having strong face validity in their hierarchical differential.
Local area related variables – The Index of Multiple Deprivation had a significant negative effect within the model.
Provider related variables - Post-operative length of stay and time from completion of Q1 to the PROMs procedure were included in the model with a negative effect.

4.5.9 Hip replacement Oxford Hip Score

Patient demographics - The sex of the patient was the only demographic variable included in the model.

Other patient characteristics - Patients who consider themselves disabled had a significant negative effect on this model. Patients who had had assistance in completing the Q2 questionnaire were also found to have a negative effect.

Clinical risk variables derived from HES – Patients with a COPD comorbidity (as recorded by HES) were found to have a significant negative effect.
Clinical risk variables from the patient questionnaires - Patient who reported circulatory or anxiety and depression comorbidities had a negative effect on the predicted Q2 score, as did those who reported having had previous treatment for this condition. The baseline Score had a significant positive effect.
Other risk factors from the patient questionnaires – Again the General Health question produced results that were highly significant with the coefficients having strong face validity in their hierarchical differential.
Local area related variables – The Index of Multiple Deprivation had a significant negative effect within the model.
Provider related variables - Post-operative length of stay and time from procedure to completion of Q2 were included in the model with a negative effect. Discharge destination 19 was found to have a significant positive effect.

4.5.10 Knee replacement EQ5D Index

Patient demographics - The age of the patient and patients who did not give their ethnic origin were variables included in the model. Both showed a positive effect.
Other patient characteristics - Patients who did not consider themselves disabled had a significant positive effect on this model. In this model, patients who had had assistance in completing the Q2 questionnaire were also found to have a negative effect.
Clinical risk variables derived from HES - Patients who were undergoing a total knee replacement revision had a significant negative effect as did those with a dementia comorbidity (as recorded by HES).
Clinical risk variables from the patient questionnaires - Patient who reported circulatory or anxiety and depression comorbidities had a negative effect on the predicted Q2 score. The baseline Index had a significant positive effect.
Other risk factors from the patient questionnaires – The general health question produced results that were highly significant with the coefficients having strong face validity in their hierarchical differential.
Local area related variables – The Index of Multiple Deprivation had a significant negative effect within the model.
Provider related variables - Post-operative length of stay and time from procedure to completion of Q2 were included in the model with a negative effect. Operating status 8 was found to have a significant positive effect.

4.5.11 Knee replacement EQ VAS

Patient demographics - The age of the patient and patients who did not give their ethnic origin were variables included in the model. Both showed a positive effect.

Other patient characteristics - Patients who did not consider themselves disabled had a significant positive effect on this model. Patients living alone showed a significant negative effect.
Clinical risk variables derived from HES - Patients with a COPD comorbidity (as recorded by HES) showed a significant negative effect.
Clinical risk variables from the patient questionnaires - Patient who reported heart disease, stroke, circulatory, nervous system or anxiety and depression comorbidities all had a significant negative effect on the predicted Q2 score. The baseline VAS had a significant positive effect.
Other risk factors from the patient questionnaires – A general health question produced results that were highly significant with the coefficients having strong face validity in their hierarchical differential.
Local area related variables – The Index of Multiple Deprivation had a significant negative effect within the model.
Provider related variables - Post-operative length of stay and time from procedure to completion of Q2 were included in the model with a negative effect.

4.5.12 Knee replacement Oxford Knee Score

Patient demographics - The age of the patient and patients of Asian origin, or who did not give their ethnic origin were variables included in the model. Asian ethnicity showed a negative effect while the other two variables showed a positive effect.
Other patient characteristics - Patients who did not consider themselves disabled had a significant positive effect on this model.
Clinical risk variables derived from HES - The duration of symptoms prior to current treatment was found to have a significant negative effect. Patient who reported that they had not had previous treatment for this condition showed a positive effect.
Clinical risk variables from the patient questionnaires - Patient who reported circulatory or anxiety and depression comorbidities had a negative effect on the predicted Q2 score. The baseline Score had a significant positive effect.
Other risk factors from the patient questionnaires – The general health question produced results that were highly significant with the coefficients having strong face validity in their hierarchical differential.
Local area related variables – The Index of Multiple Deprivation had a significant negative effect within the model.
Provider related variables - Post-operative length of stay was included in the model with a negative effect. Discharge destination 19 and operating status 8 were both found to have a significant positive effect.

4.6 The impact of increasing data volumes can be seen in Appendix 5. This Appendix provides two graphs comparing the average predicted Q2 value for the varicose vein EQ5D Index plotted against the actual Q2 value at provider level. The first graph shows all providers, irrespective of the number of replies received, while the second graph contains only those providers for which more than 30 responses have

been received to date. From graph (b), it can be seen that some of the potential volatility is removed as providers increase the number of their responses, while the overall correlation increases from 0.56 to 0.66 when this constraint is introduced.

4.7 The models have subsequently been applied to the latest data extract available at the time of writing and the results are being published on the Information Centre's website from September 2010.

5. Risk adjusting the 'raw' PROMs scores

5.1 Local Area and Provider related variables

5.1.1 While the methods described in section 3 and the models presented in Appendix 4 identify all the variables that make a significant contribution to explaining the differences between individual patient responses, it was decided that not all of them should be included when risk adjusting the 'raw' PROMs scores. This decision affects Local Area and Provider related variables, to remove pre-existing effects such as those that might be attributable to particular initiatives of a Strategic Health Authority, NHS trust (or other provider) which have been identified by the model as impacting on the PROMs Q2 scores. Leaving these variables in the model when adjusting the scores would in effect be discounting existing performance (requiring high performing providers to start from a higher base or adjusting out existing low performance).

The variables affected and removed from the model by this decision are those shaded in the tables in Appendix 4. Their effect has been removed from the individual records and 'shared' across the whole dataset by amending the constant term in the models, as follows:

The adjustment to the constant was made by adding to it, for variable y,

mean value of y * coefficient of y

5.1.2 In this way, the results presented will neither advantage nor disadvantage provider organisations which have either already made substantial efforts to improve their performance in treating these particular clinical conditions, or conversely, who are lagging behind others in this respect.

5.2 Deriving a risk adjusted index for each provider organisation

5.2.1 The aim of the risk adjustment process is to make the results for any given provider directly comparable across providers. Risk adjustment has been applied to each individual provider's average post-operative PROMs score. While the variable of interest is the average health gain achieved by the provider (Q2 – Q1 for each individual patient, or Mean $(Q2\text{-}Q1)_j$ for provider j), it is assumed that only the post-operative score is impacted upon by providers. The pre-operative PROMs scores of individual patients are assumed to be determined by the referral practices of individual GP practices and outside of the provider's influence.

5.2.2 Applying the models (without including Local Area and Provider related variables, with the exception of Admission source where the provider has little or no scope of influence) produces a predicted Q2 value (Q2 pred.) for each patient record. The Q2 pred. figure has been constrained to lie within the limits of the particular instrument under consideration e.g. between -0.596 and 1.0 for the EQ5D Index

and between 0 and 100 for the EQ VAS. (In practice, this constraint is needed in only very few, atypical cases).

5.2.3 Individual provider's post-operative PROMs scores are risk adjusted using a provider-specific variable, which reflects how the provider performs on post-operative PROMs scores relative to the national average. This relative performance variable is calculated as the ratio of actual Q2 to predicted Q2 and would take a value in excess of 1 if the provider achieves, on average, post-operative PROMs scores greater than those predicted using the statistical models developed earlier. The relative performance variable will take a value less than 1 if, on average, the provider performs worse than predicted and 1 if, on average, it delivers post-operative PROMs scores as predicted.

5.2.4 To ensure a comparable case-mix of patients, an individual provider's relative performance variable is applied to (multiplied by) the national average post-operative PROMs score to produce a provider-specific post-operative PROMs score based on a standard, national average, case-mix. The risk adjusted post-operative PROMs score for provider *j*, is then calculated as the provider-specific relative performance multiplied by the national average observed post-operative PROMs score.

A further adjustment is applied to rescale the risk adjusted post-operative PROMs score such that the mean across providers equals the national average mean post-operative PROMs score to aid interpretation and for presentational purposes.

5.2.5 The average health gain achieved by any provider *j* (Q2-Q1) is defined as the difference between the average post-operative PROMs score it achieves and the average pre-operative score. To calculate the risk adjusted average health gain for any provider *j* we subtract the national average pre-operative PROMs score from the provider-specific risk adjusted post-operative PROMs score.

risk-adjusted change in health status = risk adjusted mean Q2 - Nat. Mean Q1

5.2.6 To operationalise the risk adjustment model, the relative performance parameter is estimated using observed post-operative PROMs values for individual patients and the corresponding values predicted by the statistical models.

5.2.7 The estimator for the relative performance parameter is an unbiased point estimator. As the sample size increases – i.e. the number of patients treated by the provider and therefore the number of observations on the ratio of observed to predicted post-operative PROMs scores increases – the closer the estimator will be to its true value. Using Central Limit Theorem we can derive confidence limits around the estimator:

$$r_j \pm z\frac{s_j}{\sqrt{n_j}}$$

where s_j is the standard error of the estimator for the relative performance parameter, r_j, and n_j is the number of patients at provider j.

we can then derive expressions for the *upper* and *lower* confidence limits of the risk adjusted health gain, at the 95% level:

Upper confidence limit:

Risk-adjusted health gain = [r_j + 1.96s_j /SQRT(n_j)]* nat mean Q2 –nat mean Q1

Lower confidence limit:

Risk-adjusted health gain = [r_j - 1.96s_j /SQRT(n_j)]* nat mean Q2 –nat mean Q1

6. Updating the models and future developments

6.1 Requirement to update the models

6.1.1 There is a recognition by the Department of Health, the model developers and most of those involved in the PROMs programme that, at this point in time, our aim has been to develop a defensible model which is 'fit for purpose', but not necessarily the 'best' model. Among the reasons for this are:

- the relatively small volume of data available at the time of model development (especially in respect of varicose veins);
- the impact that this has on some of the variables in the model (see results in section 4); and
- the innovative nature of this work – the literature on risk adjustment models for PROMs instruments is limited.

6.1.2 From the outset it has been expected that these risk adjustment models will require regular updating on an annual basis and this has been built into the PROMs programme. As more data become available now that the programme is becoming established, the methodology described in section 3 can be reapplied with the expectation that the models thus produced will become more robust and the coefficients less susceptible to the impact of small numbers of patients. The second reason for producing regular updates is to ensure that the models continue to reflect clinical practice. By updating the models, provider organisations will be required to develop clinical practice in a manner that impacts on patient outcomes, similar to that of the national 'average' otherwise they will be disadvantaged by the risk adjustment process.

6.1.3 Updating the models will take place annually alongside the introduction of other developments, as agreed by the PROMs Stakeholder Reference Group. A transition

path between current and updated models will be provided by applying both to a three month 'overlap' period.

6.2 Model development

6.2.1 The earlier sections of this paper and previous discussions with the PROMs Stakeholder Reference Group have described some of the developments to the current models that we believe would be desirable and potentially improve their explanatory power. As with the initial models, such developments should accord with the principles outlined in section 3.2.

6.2.2 Among the developments that have been identified over the remaining two year of the programme are:

i) a fuller consideration of the diagnosis and procedure variables (especially the handling of secondary diagnoses and procedure codes);
ii) an analysis of interactions between those variables that have been included in their own right within earlier versions of the models;
iii) the introduction and evaluation of multi-level models, once the response levels across most provider organisations allows this;
iv) the introduction and evaluation of separate models for commissioners and providers, especially the differences between such models;
v) the value of sub-group analysis and the possible need for different analyses for individual sub-groups.

6.3 Proposed timetable

6.3.1 It is anticipated that the ongoing dialogue with the PROMs Stakeholder Reference Group and its Technical Sub-Group and others interested in this aspect of the programme will be maintained during the course of the remaining two years. Between the publication of this version of the model in September 2010 and the end of November the team will collect and catalogue proposals for model development and will present these back to the Groups towards the end of this period in order to agree the work to be undertaken and its timing. The period from December to early February will see the updating and refining of the models themselves, with the results being reviewed subsequently by the Sub-Group and agreed by the PROMs Stakeholder Reference Group for publication and implementation prior to 1st April 2011.

Variables currently available to model development

Appendix 1

Name	Source	Type of variable	Used /not used in current models as independent variables
eq5d_index_change	PROMs quest	Dependent variable	-
eq5d_scale_change	PROMs quest	Dependent variable	-
score_change	PROMs quest	Dependent variable	-
gender	PROMs quest	Demographics	Not used
q1_dob	PROMs quest	Demographics	Not used
q2_dob	PROMs quest	Demographics	Not used
endage	HES	Demographics	Not used
startage	HES	Demographics	Used
dob	HES	Demographics	Not used
mydob	HES	Demographics	Not used
ethnos	HES	Demographics	Used
sex	HES	Demographics	Used
q1_symptom_period	PROMs quest	Clinical factors	Used
q1_previous_surgery	PROMs quest	Clinical factors	Used
admimeth	HES	Clinical factors	Used
admisorc	HES	Clinical factors	Used
elecdur	HES	Clinical factors	Used
disdest	HES	Clinical factors	Used
dismeth	HES	Clinical factors	Used
speldur	HES	Clinical factors	Used
epidur	HES	Clinical factors	Used
epistat	HES	Clinical factors	Used
epitype	HES	Clinical factors	Used
operstat	HES	Clinical factors	Used
posopdur	HES	Clinical factors	Used
preopdur	HES	Clinical factors	Used
classpat	HES	Clinical factors	Used
intmanig	HES	Clinical factors	Used
mainspef	HES	Clinical factors	Not used
tretspef	HES	Clinical factors	Used
diag_01	HES	Clinical factors	Used
diag_02	HES	Clinical factors	For use in later models
diag_03	HES	Clinical factors	For use in later models
diag_04	HES	Clinical factors	For use in later models
diag_05	HES	Clinical factors	For use in later models
diag_06	HES	Clinical factors	For use in later models
diag_07	HES	Clinical factors	For use in later models
diag_08	HES	Clinical factors	For use in later models
diag_09	HES	Clinical factors	For use in later models
diag_10	HES	Clinical factors	For use in later models
diag_11	HES	Clinical factors	For use in later models
diag_12	HES	Clinical factors	For use in later models
diag_13	HES	Clinical factors	For use in later models
diag_14	HES	Clinical factors	For use in later models
diag_15	HES	Clinical factors	For use in later models
diag_16	HES	Clinical factors	For use in later models
diag_17	HES	Clinical factors	For use in later models
diag_18	HES	Clinical factors	For use in later models
diag_19	HES	Clinical factors	For use in later models
diag_20	HES	Clinical factors	For use in later models
opertn_01	HES	Clinical factors	Used
opertn_02	HES	Clinical factors	For use in later models
opertn_03	HES	Clinical factors	For use in later models
opertn_04	HES	Clinical factors	For use in later models
opertn_05	HES	Clinical factors	For use in later models
opertn_06	HES	Clinical factors	For use in later models
opertn_07	HES	Clinical factors	For use in later models
opertn_08	HES	Clinical factors	For use in later models
opertn_09	HES	Clinical factors	For use in later models
opertn_10	HES	Clinical factors	For use in later models
opertn_11	HES	Clinical factors	For use in later models
opertn_12	HES	Clinical factors	For use in later models
opertn_13	HES	Clinical factors	For use in later models
opertn_14	HES	Clinical factors	For use in later models
opertn_15	HES	Clinical factors	For use in later models
opertn_16	HES	Clinical factors	For use in later models
opertn_17	HES	Clinical factors	For use in later models
opertn_18	HES	Clinical factors	For use in later models
opertn_19	HES	Clinical factors	For use in later models
opertn_20	HES	Clinical factors	For use in later models
opertn_21	HES	Clinical factors	For use in later models
opertn_22	HES	Clinical factors	For use in later models
opertn_23	HES	Clinical factors	For use in later models
opertn_24	HES	Clinical factors	For use in later models
opdate_01	HES	Clinical factors	Not used
opdate_02	HES	Clinical factors	Not used
opdate_03	HES	Clinical factors	Not used
opdate_04	HES	Clinical factors	Not used
opdate_05	HES	Clinical factors	Not used
opdate_06	HES	Clinical factors	Not used
opdate_07	HES	Clinical factors	Not used
opdate_08	HES	Clinical factors	Not used
opdate_09	HES	Clinical factors	Not used

Name	Source	Type of variable	Used /not used in current models as independent variables
opdate_10	HES	Clinical factors	Not used
opdate_11	HES	Clinical factors	Not used
opdate_12	HES	Clinical factors	Not used
opdate_13	HES	Clinical factors	Not used
opdate_14	HES	Clinical factors	Not used
opdate_15	HES	Clinical factors	Not used
opdate_16	HES	Clinical factors	Not used
opdate_17	HES	Clinical factors	Not used
opdate_18	HES	Clinical factors	Not used
opdate_19	HES	Clinical factors	Not used
opdate_20	HES	Clinical factors	Not used
opdate_21	HES	Clinical factors	Not used
opdate_22	HES	Clinical factors	Not used
opdate_23	HES	Clinical factors	Not used
opdate_24	HES	Clinical factors	Not used
domproc	HES	Clinical factors	Not used
hrgorig35	HES	Clinical factors	Not used
hrglate35	HES	Clinical factors	Not used
hrgnhs	HES	Clinical factors	Not used
hrgnhsvn	HES	Clinical factors	Not used
q1_assisted	PROMs quest	Socio-economic factors	Used
q1_assisted_by	PROMs quest	Socio-economic factors	Not used
q1_living_arrangements	PROMs quest	Socio-economic factors	Used
q2_assisted	PROMs quest	Socio-economic factors	Used
q2_assisted_by	PROMs quest	Socio-economic factors	Not used
q2_living_arrangements	PROMs quest	Socio-economic factors	Not used
imd04	HES	Socio-economic factors	Used
imd04c	HES	Socio-economic factors	Not used
imd04ed	HES	Socio-economic factors	Not used
imd04em	HES	Socio-economic factors	Not used
imd04hd	HES	Socio-economic factors	Not used
imd04hs	HES	Socio-economic factors	Not used
imd04i	HES	Socio-economic factors	Not used
imd04ia	HES	Socio-economic factors	Not used
imd04ic	HES	Socio-economic factors	Not used
imd04le	HES	Socio-economic factors	Not used
imd04rk	HES	Socio-economic factors	Not used
q1_score	PROMs quest	Attitudes / perceptions	Used
q1_general_health	PROMs quest	Attitudes / perceptions	Used
q1_disability	PROMs quest	Attitudes / perceptions	Used
q1_mobility	PROMs quest	Attitudes / perceptions	Used
q1_self_care	PROMs quest	Attitudes / perceptions	Used
q1_activity	PROMs quest	Attitudes / perceptions	Used
q1_discomfort	PROMs quest	Attitudes / perceptions	Used
q1_anxiety	PROMs quest	Attitudes / perceptions	Used
q1_eq5d_profile	PROMs quest	Attitudes / perceptions	Not used
q1_eq5d_index	PROMs quest	Attitudes / perceptions	Used
q1_eq5d_health_scale	PROMs quest	Attitudes / perceptions	Used
q2_score	PROMs quest	Attitudes / perceptions	Used
q2_allergy	PROMs quest	Attitudes / perceptions	Not used
q2_urine	PROMs quest	Attitudes / perceptions	Not used
q2_bleeding	PROMs quest	Attitudes / perceptions	Not used
q2_wound	PROMs quest	Attitudes / perceptions	Not used
q2_readmitted	PROMs quest	Attitudes / perceptions	Not used
q2_further_surgery	PROMs quest	Attitudes / perceptions	Not used
q2_satisfaction	PROMs quest	Attitudes / perceptions	Not used
q2_success	PROMs quest	Attitudes / perceptions	Not used
q2_general_health	PROMs quest	Attitudes / perceptions	Not used
q2_disability	PROMs quest	Attitudes / perceptions	Not used
hr_q1_score	OHR score document	Attitudes / perceptions	Used
hr_q1_pain	OHR score document	Attitudes / perceptions	Not used
hr_q1_sudden_pain	OHR score document	Attitudes / perceptions	Not used
hr_q1_night_pain	OHR score document	Attitudes / perceptions	Not used
hr_q1_washing	OHR score document	Attitudes / perceptions	Not used
hr_q1_transport	OHR score document	Attitudes / perceptions	Not used
hr_q1_dressing	OHR score document	Attitudes / perceptions	Not used
hr_q1_shopping	OHR score document	Attitudes / perceptions	Not used
hr_q1_walking	OHR score document	Attitudes / perceptions	Not used
hr_q1_limping	OHR score document	Attitudes / perceptions	Not used
hr_q1_stairs	OHR score document	Attitudes / perceptions	Not used
hr_q1_standing	OHR score document	Attitudes / perceptions	Not used
hr_q1_work	OHR score document	Attitudes / perceptions	Not used
hr_q1_orig_pain	PROMs quest	Attitudes / perceptions	Used
hr_q1_orig_sudden_pain	PROMs quest	Attitudes / perceptions	Used
hr_q1_orig_night_pain	PROMs quest	Attitudes / perceptions	Used
hr_q1_orig_washing	PROMs quest	Attitudes / perceptions	Used
hr_q1_orig_transport	PROMs quest	Attitudes / perceptions	Used
hr_q1_orig_dressing	PROMs quest	Attitudes / perceptions	Used
hr_q1_orig_shopping	PROMs quest	Attitudes / perceptions	Used
hr_q1_orig_walking	PROMs quest	Attitudes / perceptions	Used
hr_q1_orig_limping	PROMs quest	Attitudes / perceptions	Used
hr_q1_orig_stairs	PROMs quest	Attitudes / perceptions	Used
hr_q1_orig_standing	PROMs quest	Attitudes / perceptions	Used
hr_q1_orig_work	PROMs quest	Attitudes / perceptions	Used

Name	Source		Type of variable	Used /not used in current models as independent variables
kr_q1_score	PROMs quest		Attitudes / perceptions	Used
kr_q1_pain	OHR score document		Attitudes / perceptions	Not used
kr_q1_night_pain	OHR score document		Attitudes / perceptions	Not used
kr_q1_washing	OHR score document		Attitudes / perceptions	Not used
kr_q1_transport	OHR score document		Attitudes / perceptions	Not used
kr_q1_walking	OHR score document		Attitudes / perceptions	Not used
kr_q1_standing	OHR score document		Attitudes / perceptions	Not used
kr_q1_limping	OHR score document		Attitudes / perceptions	Not used
kr_q1_kneeling	OHR score document		Attitudes / perceptions	Not used
kr_q1_work	OHR score document		Attitudes / perceptions	Not used
kr_q1_confidence	OHR score document		Attitudes / perceptions	Not used
kr_q1_shopping	OHR score document		Attitudes / perceptions	Not used
kr_q1_stairs	OHR score document		Attitudes / perceptions	Not used
kr_q1_orig_pain	PROMs quest		Attitudes / perceptions	Used
kr_q1_orig_night_pain	PROMs quest		Attitudes / perceptions	Used
kr_q1_orig_washing	PROMs quest		Attitudes / perceptions	Used
kr_q1_orig_transport	PROMs quest		Attitudes / perceptions	Used
kr_q1_orig_walking	PROMs quest		Attitudes / perceptions	Used
kr_q1_orig_standing	PROMs quest		Attitudes / perceptions	Used
kr_q1_orig_limping	PROMs quest		Attitudes / perceptions	Used
kr_q1_orig_kneeling	PROMs quest		Attitudes / perceptions	Used
kr_q1_orig_work	PROMs quest		Attitudes / perceptions	Used
kr_q1_orig_confidence	PROMs quest		Attitudes / perceptions	Used
kr_q1_orig_shopping	PROMs quest		Attitudes / perceptions	Used
kr_q1_orig_stairs	PROMs quest		Attitudes / perceptions	Used
vv_q1_score	VV scoring document		Attitudes / perceptions	Used
vv_q1_painkiller_days	PROMs quest		Attitudes / perceptions	Not used
vv_q1_swelling	PROMs quest		Attitudes / perceptions	Not used
vv_q1_concern	PROMs quest		Attitudes / perceptions	Not used
vv_q1_clothing	PROMs quest		Attitudes / perceptions	Not used
vv_q1_work	PROMs quest		Attitudes / perceptions	Not used
vv_q1_leisure	PROMs quest		Attitudes / perceptions	Not used
vv_q1_left_front_count	PROMs quest		Attitudes / perceptions	Not used
vv_q1_left_back_count	PROMs quest		Attitudes / perceptions	Not used
vv_q1_left_pain_days	PROMs quest		Attitudes / perceptions	Not used
vv_q1_left_support	PROMs quest		Attitudes / perceptions	Not used
vv_q1_left_itch	PROMs quest		Attitudes / perceptions	Not used
vv_q1_left_discolour	PROMs quest		Attitudes / perceptions	Not used
vv_q1_left_rash	PROMs quest		Attitudes / perceptions	Not used
vv_q1_left_ulcer	PROMs quest		Attitudes / perceptions	Not used
vv_q1_right_front_count	PROMs quest		Attitudes / perceptions	Not used
vv_q1_right_back_count	PROMs quest		Attitudes / perceptions	Not used
vv_q1_right_pain_days	PROMs quest		Attitudes / perceptions	Not used
vv_q1_right_support	PROMs quest		Attitudes / perceptions	Not used
vv_q1_right_itch	PROMs quest		Attitudes / perceptions	Not used
vv_q1_right_discolour	PROMs quest		Attitudes / perceptions	Not used
vv_q1_right_rash	PROMs quest		Attitudes / perceptions	Not used
vv_q1_right_ulcer	PROMs quest		Attitudes / perceptions	Not used
vv_q2_painkiller_days	PROMs quest		Attitudes / perceptions	Not used
vv_q2_swelling	PROMs quest		Attitudes / perceptions	Not used
vv_q2_concern	PROMs quest		Attitudes / perceptions	Not used
vv_q2_clothing	PROMs quest		Attitudes / perceptions	Not used
vv_q2_work	PROMs quest		Attitudes / perceptions	Not used
vv_q2_leisure	PROMs quest		Attitudes / perceptions	Not used
vv_q2_left_front_count	PROMs quest		Attitudes / perceptions	Not used
vv_q2_left_back_count	PROMs quest		Attitudes / perceptions	Not used
vv_q2_left_pain_days	PROMs quest		Attitudes / perceptions	Not used
vv_q2_left_support	PROMs quest		Attitudes / perceptions	Not used
vv_q2_left_itch	PROMs quest		Attitudes / perceptions	Not used
vv_q2_left_discolour	PROMs quest		Attitudes / perceptions	Not used
vv_q2_left_rash	PROMs quest		Attitudes / perceptions	Not used
vv_q2_left_ulcer	PROMs quest		Attitudes / perceptions	Not used
vv_q2_right_front_count	PROMs quest		Attitudes / perceptions	Not used
vv_q2_right_back_count	PROMs quest		Attitudes / perceptions	Not used
vv_q2_right_pain_days	PROMs quest		Attitudes / perceptions	Not used
vv_q2_right_support	PROMs quest		Attitudes / perceptions	Not used
vv_q2_right_itch	PROMs quest		Attitudes / perceptions	Not used
vv_q2_right_discolour	PROMs quest		Attitudes / perceptions	Not used
vv_q2_right_rash	PROMs quest		Attitudes / perceptions	Not used
vv_q2_right_ulcer	PROMs quest		Attitudes / perceptions	Not used
proms_proc_date	HES		Attitudes / perceptions	Used
heart_disease	PROMs quest		Attitudes / perceptions - Comorbidities	Used
high_bp	PROMs quest		Attitudes / perceptions - Comorbidities	Used
stroke	PROMs quest		Attitudes / perceptions - Comorbidities	Used
circulation	PROMs quest		Attitudes / perceptions - Comorbidities	Used
lung_disease	PROMs quest		Attitudes / perceptions - Comorbidities	Used
diabetes	PROMs quest		Attitudes / perceptions - Comorbidities	Used
kidney_disease	PROMs quest		Attitudes / perceptions - Comorbidities	Used
nervous_system	PROMs quest		Attitudes / perceptions - Comorbidities	Used
liver_disease	PROMs quest		Attitudes / perceptions - Comorbidities	Used
cancer	PROMs quest		Attitudes / perceptions - Comorbidities	Used
depression	PROMs quest		Attitudes / perceptions - Comorbidities	Used
arthritis	PROMs quest		Attitudes / perceptions - Comorbidities	Used

Name	Source		Type of variable	Used /not used in current models as independent variables
procode	HES		Provider or purchaser	Not used
purcode	HES		Provider or purchaser	For use in later models
purval	HES		Provider or purchaser	Not used
purro	HES		Provider or purchaser	Not used
purstha	HES		Provider or purchaser	For use in later models
csnum	HES		Provider or purchaser	Not used
gppracha	HES		Provider or purchaser	Not used
pcgcode	HES		Provider or purchaser	Not used
pctcode02	HES		Provider or purchaser	Not used
pctcode06	HES		Provider or purchaser	Not used
gpprpct	HES		Provider or purchaser	Not used
procode	HES		Provider or purchaser	Not used
procodet	HES		Provider or purchaser	For use in later models
sitetret	HES		Provider or purchaser	Not used
protype	HES		Provider or purchaser	Used
gppracro	HES		Provider or purchaser	Not used
gpprstha	HES		Provider or purchaser	Not used
oacode	HES		Provider or purchaser	Not used
oacode6	HES		Provider or purchaser	Not used
rescty	HES		Provider or purchaser	Not used
currward	HES		Provider or purchaser	Not used
resladst	HES		Provider or purchaser	Not used
ward91	HES		Provider or purchaser	Not used
ward98	HES		Provider or purchaser	Not used
resgor	HES		Provider or purchaser	Not used
gortreat	HES		Provider or purchaser	Not used
resha	HES		Provider or purchaser	Not used
hatreat	HES		Provider or purchaser	Not used
gridlink	HES		Provider or purchaser	Not used
pctnhs	HES		Provider or purchaser	Not used
respct06	HES		Provider or purchaser	Not used
resstha06	HES		Provider or purchaser	Not used
pcttreat	HES		Provider or purchaser	Not used
rotreat	HES		Provider or purchaser	Not used
resro	HES		Provider or purchaser	Not used
sthatret	HES		Provider or purchaser	Used
soal	HES		Provider or purchaser	Not used
soam	HES		Provider or purchaser	Not used
rururb_ind	HES		Provider or purchaser	Not used
gpprac	HES		Provider or purchaser	Not used
consult	HES		Provider or purchaser	Not used
reggmp	HES		Provider or purchaser	Not used
referrer	HES		Provider or purchaser	Not used
pconsult	HES		Provider or purchaser	Not used
preggmp	HES		Provider or purchaser	Not used
preferer	HES		Provider or purchaser	Not used
referorg	HES		Provider or purchaser	Not used
admincat	HES		Administrative variables	Used
leglcat	HES		Administrative variables	Not used
legalgpa	HES		Administrative variables	Not used
lopatid	HES		Administrative variables	Not used
newnhsno	HES		Administrative variables	Not used
postdist	HES		Administrative variables	Not used
homeadd	HES		Administrative variables	Not used
admidate	HES		Administrative variables	Not used
elecdate	HES		Administrative variables	Not used
firstreg	HES		Administrative variables	Not used
disdate	HES		Administrative variables	Not used
bedyear	HES		Administrative variables	Not used
spelbgin	HES		Administrative variables	Not used
epiend	HES		Administrative variables	Not used
epistart	HES		Administrative variables	Not used
spelend	HES		Administrative variables	Not used
epiorder	HES		Administrative variables	Not used
provspno	HES		Administrative variables	Not used
cause	HES		Administrative variables	Not used
q1_completed_date	PROMs quest		Intermediate (used to derive other variable)	Used
q2_completed_date	PROMs quest		Intermediate (used to derive other variable)	Used
q2_mobility	PROMs quest		Intermediate (used to derive other variable)	Not used
q2_self_care	PROMs quest		Intermediate (used to derive other variable)	Not used
q2_activity	PROMs quest		Intermediate (used to derive other variable)	Not used
q2_discomfort	PROMs quest		Intermediate (used to derive other variable)	Not used
q2_anxiety	PROMs quest		Intermediate (used to derive other variable)	Not used
q2_eq5d_profile	PROMs quest		Intermediate (used to derive other variable)	Not used
q2_eq5d_index	PROMs quest		Intermediate (used to derive other variable)	Not used
q2_eq5d_health_scale	PROMs quest		Intermediate (used to derive other variable)	Not used
hr_q2_score	PROMs quest		Intermediate (used to derive other variable)	Used
hr_q2_pain	PROMs quest		Intermediate (used to derive other variable)	Not used
hr_q2_sudden_pain	PROMs quest		Intermediate (used to derive other variable)	Not used
hr_q2_night_pain	PROMs quest		Intermediate (used to derive other variable)	Not used
hr_q2_washing	PROMs quest		Intermediate (used to derive other variable)	Not used
hr_q2_transport	PROMs quest		Intermediate (used to derive other variable)	Not used
hr_q2_dressing	PROMs quest		Intermediate (used to derive other variable)	Not used
hr_q2_shopping	PROMs quest		Intermediate (used to derive other variable)	Not used

Name	Source		Type of variable	Used /not used in current models as independent variables
vv_q2_max_score_painkiller	VV scoring document		Intermediate (used to derive other variable)	Not used
vv_q2_max_score_swelling	VV scoring document		Intermediate (used to derive other variable)	Not used
vv_q2_max_score_concern	VV scoring document		Intermediate (used to derive other variable)	Not used
vv_q2_max_score_clothing	VV scoring document		Intermediate (used to derive other variable)	Not used
vv_q2_max_score_work	VV scoring document		Intermediate (used to derive other variable)	Not used
vv_q2_max_score_leisure	VV scoring document		Intermediate (used to derive other variable)	Not used
vv_q2_max_score_vein_count	VV scoring document		Intermediate (used to derive other variable)	Not used
vv_q2_max_score_pain	VV scoring document		Intermediate (used to derive other variable)	Not used
vv_q2_max_score_support	VV scoring document		Intermediate (used to derive other variable)	Not used
vv_q2_max_score_itch	VV scoring document		Intermediate (used to derive other variable)	Not used
vv_q2_max_score_discolour	VV scoring document		Intermediate (used to derive other variable)	Not used
vv_q2_max_score_rash	VV scoring document		Intermediate (used to derive other variable)	Not used
vv_q2_max_score_ulcer	VV scoring document		Intermediate (used to derive other variable)	Not used
proms_serial_no	PROMs admin		Identifier / check	Not used
proms_proc_code	PROMs admin		Identifier / check	Not used
proms_proc_group	PROMs admin		Identifier / check	Not used
nhs_number	PROMs quest		Identifier / check	Not used
patient_death	PROMs admin		Identifier / check	Not used
dod	PROMs admin		Identifier / check	Not used
postcode	PROMs admin		Identifier / check	Not used
eq5d_version	PROMs quest		Identifier / check	Not used
score_version	PROMs quest		Identifier / check	Not used
hesid	HES		Identifier / check	Not used
hesid_rank	PROMs admin		Identifier / check	Not used
episode_match_rank	PROMs admin		Identifier / check	Not used
njr_matched	PROMs admin		Identifier / check	Not used
njr_match_rank	PROMs admin		Identifier / check	Not used
njr_hesid_rank	PROMs admin		Identifier / check	Not used
q1_score_complete	PROMs quest		Identifier / check	Used
q1_score_version	PROMs quest		Identifier / check	Not used
q1_form_version	PROMs quest		Identifier / check	Not used
q1_language	PROMs quest		Identifier / check	Not used
q1_eq5d_version	PROMs quest		Identifier / check	Not used
q1_eq5d_scale_complete	PROMs quest		Identifier / check	Used
q1_eq5d_profile_complete	PROMs quest		Identifier / check	Used
q2_score_complete	PROMs quest		Identifier / check	Used
q2_score_version	PROMs quest		Identifier / check	Not used
q2_form_version	PROMs quest		Identifier / check	Not used
q2_language	PROMs quest		Identifier / check	Not used
q2_match_rank	PROMs quest		Identifier / check	Used
q2_surgery_date	PROMs quest		Identifier / check	Used
q2_eq5d_version	PROMs quest		Identifier / check	Not used
q2_eq5d_scale_complete	PROMs quest		Identifier / check	Used
q2_eq5d_profile_complete	PROMs quest		Identifier / check	Used
hr_q1_score_complete	PROMs quest		Identifier / check	Used
hr_q1_score_version	PROMs quest		Identifier / check	Not used
hr_q2_score_complete	PROMs quest		Identifier / check	Used
hr_q2_score_version	PROMs quest		Identifier / check	Not used
kr_q1_score_complete	PROMs quest		Identifier / check	Used
kr_q1_score_version	PROMs quest		Identifier / check	Not used
kr_q2_score_complete	PROMs quest		Identifier / check	Used
kr_q2_score_version	PROMs quest		Identifier / check	Not used
vv_q1_score_complete	PROMs quest		Identifier / check	Used
vv_q1_score_version	PROMs quest		Identifier / check	Not used
vv_q2_score_complete	PROMs quest		Identifier / check	Used
vv_q2_score_version	PROMs quest		Identifier / check	Not used
hes_year	HES		Identifier / check	Not used
epikey	HES		Identifier / check	Not used
epikey_rank	HES		Identifier / check	Not used

Appendix 2

Summary of findings from literature review

A2.1 Risk adjustment for measuring outcomes – general

Much of the literature discussing risk factors is condition specific and tends to focus on their impact on achieving a clinically led and quite narrowly focussed set of outcomes for that particular condition. While PROMs are now increasingly used as an outcome within Randomised Controlled Trials, the selection and randomisation of patients tends to focus on controlling for factors that are known to have a clinical impact e.g. age, severity of condition, comorbidities. However, while one might have an *a priori* reason for expecting these factors to have an effect on PROMs reported scores, there seems to be little in the way of primary research to identify those factors that impact on the way that patients complete the particular instruments.

Perhaps, the most generic discussion on risk adjustment for health outcomes is provided by Iezzoni[8] who identifies a range of selected human attributes that might be important risk factors in specific settings. These include:

Demographics: Age, Sex, Race and Ethnicity

Clinical factors: Acute physiological stability, Principal diagnosis, Severity of principal diagnosis, Extent and severity of comorbidities, Physical functional status, Cognitive status, Mental health

Socio-economic factors: Familial characteristics and household composition, Educational attainment, Health literacy, Economic resources, Employment and occupation, Housing and neighbourhood characteristics, Health insurance coverage, Cultural beliefs and behaviours

Health related behaviours and activities: Tobacco use, Alcohol use, Use of illicit drugs, Sexual practices ('safe sex'), Diet and nutrition, Obesity and overweight

Attitudes and perceptions: Overall health status and quality of life, Religious beliefs and behaviours, Preferences and expectations for health care services.

She emphasises that the impact of each of these factors on the overall outcome for the patient will vary across conditions (and that some may be irrelevant for certain conditions), while also cautioning about the use of some e.g. age or ethnicity as a proxy for other underlying health issues.

As the aim of risk adjustment is often to isolate the effectiveness or quality of care from patient-related risk factors, the inclusion of treatment related variables is often questioned in the literature. However some[9] have argued that, on some occasions,

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[8] Iezzoni LI (ed). *Risk Adjustment for Measuring Health Care Outcomes (3rd edition)*. Health Administration Press, Chicago, 2002

[9] Jenkins KJ, Gauvreau K, Newburger JW et al. Consensus-Based Method for Risk Adjustment for Surgery for Congenital Heart Disease. *Journal of Thoracic and Cardiovascular Surgery* 123 (1): 110-118. 2002

clinicians have little or no discretion in their treatment protocols. Within the current study, the patient population has been defined by those undergoing groin hernia or varicose vein surgery so the consideration of whether the patient should have surgery or not has been removed from the risk adjustment discussion. However, variation in the actual procedure used (and hence the procedure coded) might be considered to be a clinician's choice but within the relatively narrow context of the case types being examined is more probably determined by the severity or clinical needs of the patient.

A number of the attributes identified by Iezzoni were operationalised within the pilot study for the current work undertaken by the London School of Hygiene and Tropical Medicine (LSHTM) and the Clinical Effectiveness Unit of Royal College of Surgeons of England. The work by Browne, Black et al[3] found general health status, comorbidities and previous surgery to be useful in adjusting post-operative PROMs scores with the selected comorbidities based on previous work by Bayliss et al[4].

For completeness, we decided to look also at comorbidities that could be derived from the clinical record as recorded by the HES system. This was used to derive the Charlson Index[5] but as well as using the Index, which had been derived to predict mortality rather than PROMs based outcomes, we also used the base definitions[6] of the comorbidities themselves (such as Peripheral Vascular Disease) which underpin the Index's construction.

A2.2 Risk adjustment and particular instruments

In looking at the general population, many authors have found that differences in the EQ5D instrument can be determined for particular sub-groups. Lubetkin et al[10] found that age, lower income and lower educational attainment resulted in lower scores in the EQ5D. Sex and ethnic differences (White – Black) were not considered significant.

As mentioned earlier Browne and Black's team[3] found that general health status, age and comorbidity as well as baseline scores were important factors in predicting the follow up scores for the EQ5D index (Varicose veins) and for the Aberdeen Varicose vein Score, while in predicting the EQ5D index (Groin Hernias) the age variable was replaced by previous hernia surgery.

Grandy and Fox[11] report using both the EQ5D Index and Visual Analogue Scale in a study of patients with diabetes and at risk for diabetes. The risk factors that they introduced were typically those associated with the clinical condition namely obesity, BMI, dyslipidaemia, hypertension and history of cardiovascular disease. The authors' report face and construct

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[10] Lubetkin EI, Jia H, Franks P and Gold MR. Relationship among sociodemographic factors, clinical conditions and health-related quality of life: Examining the EQ5D in the US general population. *Qual Life Research.* 2005 Dec.; 14(10):2187-96

[11] Grandy S, Fox K M. EQ-5D visual analogue scale and utility index values in individuals with diabetes and at risk for diabetes: Findings from the Study to Help Improve Early evaluation and management of risk factors leading to Diabetes (SHIELD). *Health and Quality of Life Outcomes* 2008 6:18.

validity with respect to the results obtained from both measures for various patient sub-groups, although the VAS results for some age groups produced some anomalous results.

A2.3 Risk adjustment for outcomes of general surgical procedures – groin hernias

Among the risk factors associated with poor outcomes of groin hernia surgery (which may in turn be expected to translate into poor post-operative PROMs scores) are:

- propensity of the patient to develop a hernia and their underlying condition. Gilbert et al[12] report that obesity and pregnancy are risk factors in an increasing incidence of hernias but that tissue breakdown related to the aging of the patient is perhaps the most important risk factor;
- long term pain after procedure. Franneby U, Sandblom G et al[13] have found that the strongest predictors of long – term pain post-operatively were a high level of pre-operative pain, postoperative complications, while operation by posterior approach caused less pain than groin incision and therefore had better outcome;
- the volume of procedures done by an individual surgeon. Nordin P and van der Linden[14] report that there was a significantly higher rate of re-operation in surgeons who carried out 1 to 5 repairs a year than in surgeons who carried out more repairs.

A2.4 Risk adjustment for outcomes of general surgical procedures – varicose veins

The risk factors that are commonly identified[15] as being a cause of varicose veins are age, sex, pregnancy, genetics, obesity, standing for long periods or other causes of immobility. Clearly this last factor can be the result of a range of problems including a patient's disability, or generally poor health.

Theivacumar et al[16] consider that the Endovenous Laser Ablation (EVLA) approach is more effective than conventional surgery. Their study showed an improved Aberdeen varicose vein score together with a reduced use of post-operative analgesia and a fast return (1 to 4 days) to normal activities. Other papers suggest that other approaches e.g. using radio frequencies (RF approach) can produce similar results.

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[12] Gilbert AI, Graham MF, Voight WJ. *Inguinal Hernia: Anatomy and Management*. Medscape CME. 2009
[13] Franneby U, Sandblom G, Nordin P, Nyren O, Gunnarsson U. Risk Factors for Long-Term Pain after Hernia Surgery. *Annals of Surgery*. 244(2):212-219. 2006
[14] Nordin P, van der Linden. Volume of procedures and risk of recurrence after repair of groin hernia: national register study. *BMJ.com*. 2008, doi:10.1136/bmj.39525.514572.25
[15] http://www.mayoclinic.com/health/varicose-veins/DS00256/DSECTION=risk-factors
[16] Theivacumar NS, Beale RJ, Mavor AI, Gough MJ. Initial Experience in Endovenous Laser Ablation (EVLA) of Varicose Veins Due to Small Saphenous Vein Reflux. *Eur. J. Vasc. Endovasc. Surg.* (13 Jan 2007)

Appendix 3

Descriptive statistics for the variables included in the five General Surgical models

Means (and standard deviations) for those variables in the final models						
		Groin Hernias				
Variable		EQ5d Index			EQ5d VAS Scale	
Number of provider units providing at least one response		242			242	
Number of patient responses used in the model		10674			10012	
Mean Q1 EQ5d Index score (St.Dev.)		0.79 (0.20)			-	
Mean Q1 EQ5d VAS score (St.Dev.)		-			80.27 (14.71)	
Mean Age at start of PROMs procedure spell (St.Dev.)		62.03 (14.47)			-	
Mean Index of Multiple Deprivation Score, IMD04 (St.Dev.)		18.08 (13.75)			18.11(13.77)	
Mean post operative length of stay following PROMs procedure (St.Dev.)		0.43 (1.23)			0.43 (1.220	
Time from PROMs procedure to completion of Q2 (St.Dev.)		133.5 (36.25)			134.08 (37.34)	
		Incidence	%		Incidence	%
Sex (Percentage of female patients)		885	8.29		-	
Percentage of patients who had assistance in completing the Q2 questionnaire		590	5.53		589	5.88
Percentage of patients who considered themselves disabled		1489	13.95		1519	15.17
Percentage of patients with a comorbidity of COPD according to HES		-			855	8.54
Patients who reported having had previous treatment (injections / surgery) for this condition		-			8767	87.57
Patients reporting a comorbidity of heart disease		-			1184	11.83
Patients reporting a comorbidity of circulatory problems		569	5.33		586	5.85
Patients reporting a comorbidity affecting the nervous system		112	1.05		117	1.17
Patients reporting a comorbidity of cancer		-			555	5.54
Patients reporting a comorbidity of anxiety or depression		449	4.21		460	4.59
Patients reporting a comorbidity of arthritis		2067	19.36		2098	20.95
Patients reporting general health as being Excellent		1213	11.36		1200	11.99
Patients reporting general health as being Very Good		4705	44.08		4723	47.17
Patients reporting general health as being Fair		1226	11.49		1246	12.45
Patients reporting general health as being Poor		129	1.21		133	1.33
Patients from Strategic Health Authority Q39		1361	12.75		-	
Percentage of patients with Admission source = Usual place of residence		10645	99.73		-	
Patients whose provider organisation was an Independent Treatment Centre		-			651	6.50

Means (and standard deviations) for those variables in the final models									
		Varicose Veins							
Variable		EQ5d Index			EQ5d VAS Scale			Aberdeen VV Score	
Number of provider units providing at least one response		169			169			169	
Number of patient responses used in the model		4412			4180			4664	
Mean Q1 EQ5d Index score (St.Dev.)		0.77 (0.21)			-			-	
Mean Q1 EQ5d VAS score (St.Dev.)		-			80.52 (15.26)			-	
Mean Q1 Aberdeen VV score (St.Dev.)		-			-			18.88 (9.88)	
Median Charlson Index (calculated from HES data)		-			0.09 (0.35)			-	
Mean Index of Multiple Deprivation Score, IMD04 (St.Dev.)		21.14 (14.52)			-			-	
Mean post operative length of stay following PROMs procedure (St.Dev.)		-			-			0.13 (0.42)	
Mean time from completion of Q1 to PROMs procedure (St.Dev.)		-			12.17 (24.19)			-	
		Incidence	%		Incidence	%		Incidence	%
Sex (Percentage of female patients)		-			-			3053	65.46
Percentage of patients who responded who were of Asian origin		-			-			82	1.76
Percentage of patients who were living in a nursing home, hospital or long-term care		-			1	0.02		1	0.02
Percentage of patients who considered themselves disabled		414	9.38		427	10.22		443	9.50
Patients with a comorbidity of metastatic tumour according to HES		1	0.02		-			-	
Percentage of patients who had not had previous treatment (injections / surgery) for their varicose veins		1845	41.82		1858	44.45		1900	40.74
Percentage of patients reporting a comorbidity of circulatory problems		-			756	18.09		784	16.81
Percentage of patients reporting a comorbidity of liver disease		18	0.41		-			-	
Percentage of patients reporting a comorbidity of anxiety or depression		327	7.41		327	7.82		337	7.23
Percentage of patients reporting a comorbidity of arthritis		861	19.51		874	20.91		-	
Percentage of patients reporting general health as being Excellent		471	10.68		470	11.24		-	
Percentage of patients reporting general health as being Very Good		-			1886	45.12		-	
Percentage of patients reporting general health as being Fair		417	9.45		430	10.29		-	
Percentage of patients reporting general health as being Poor		63	1.43		62	1.48		65	1.39
Percentage of patients from Strategic Health Authority Q31		-			604	14.45		617	13.23
Percentage of patients from Strategic Health Authority Q36		-			583	13.95		598	12.82
Percentage of patients whose provider organisation was a PCT		42	0.95		-			-	

Descriptive statistics for the variables included in the six Orthopaedic models

Means (and standard deviations) for those variables in the final models								
		Hip Replacements						
Variable		EQ5d Index		EQ VAS			Oxford Hip Score	
Number of provider units providing at least one response		240		236			240	
Number of patient responses used in the model		11622		10884			12157	
Mean Q1 EQ5d Index score (St. Dev.)		0.35		-			-	
Mean Q1 EQ5d VAS Scale score (St. Dev.)		-		66.10			-	
Mean Q1 Oxford Hip / Oxford Knee Score (St. Dev.)		-		-			18.12	
Mean age at start of PROMs procedure spell (St. Dev.)		-		-			-	
Mean Index of Multiple Deprivation Score, IMD04 (St. Dev.)		17.50		17.37			17.57	
Mean post operative length of stay following PROMs procedure (St. Dev.)		5.54		5.51			5.57	
Mean time from completion of Q1 to PROMs procedure (St. Dev.)		-		25.09			-	
Mean time from PROMs procedure to completion of Q2 (St. Dev.)		208.92		-			208.94	
		Incidence	%	Incidence	%		Incidence	%
Sex (Percentage of female patients)		7099	61.08	6637	60.98		7447	61.26
Percentage of patients who had assistance in completing the Q2 questionnaire		908	7.81	846	7.77		950	7.81
Percentage of patients who were living alone		-		-			-	
Percentage of patients who considered themselves disabled		-		-			7173	59.00
Percentage of patients who did not consider themselves disabled		4126	35.50	3913	35.95		-	
Percentage of patients with principal procedure of THR / TKR revision		802	6.90	-			-	
Percentage of patients with principal procedure of hybrid prosthetic hip revision		79	0.68	-			-	
Percentage of patients with a comorbidity of COPD according to HES		1201	10.33	1104	10.14		1261	10.37
Percentage of patients with a comorbidity of rheumatoid arthritis according to HES		323	2.78	303	2.78		-	
Percentage of patients with a comorbidity of diabetes according to HES		-		857	7.87		-	
Percentage of patients who reported having had previous treatment (injections / surgery) for this condition		-		-			1214	9.99
Percentage of patients reporting a comorbidity of heart disease		-		1070	9.83		-	
Percentage of patients reporting a comorbidity of circulatory problems		851	7.32	780	7.17		891	7.33
Percentage of patients reporting a comorbidity of anxiety or depression		724	6.23	673	6.18		752	6.19
Percentage of patients reporting a comorbidity of arthritis		8255	71.03	7806	71.72		-	
Percentage of patients reporting general health as being Excellent		567	4.88	536	4.92		601	4.94
Percentage of patients reporting general health as being Very Good		3187	27.42	3031	27.85		3330	27.39
Percentage of patients reporting general health as being Good		-		-			5151	42.37
Percentage of patients reporting general health as being Fair		2132	18.34	1993	18.31		-	
Percentage of patients reporting general health as being Poor		374	3.22	351	3.22		389	3.20
Percentage of patients with discharge destination = 19		-		-			11337	93.25

Means (and standard deviations) for those variables in the final models									
		Knee Replacements							
Variable		EQ5d Index			EQ VAS			Oxford Knee Score	
Number of provider units providing at least one response		235			237			236	
Number of patient responses used in the model		15161			14456			15940	
Mean Q1 EQ5d Index score (St. Dev.)		0.41			-			-	
Mean Q1 EQ5d VAS Scale score (St. Dev.)		-			68.80			-	
Mean Q1 Oxford Hip / Oxford Knee Score (St. Dev.)		-			-			18.78	
Mean age at start of PROMs procedure spell (St. Dev.)		69.65			69.59			69.72	
Mean Index of Multiple Deprivation Score, IMD04 (St. Dev.)		19.15			18.90			19.13	
Mean post operative length of stay following PROMs procedure (St. Dev.)		5.34			5.35			5.35	
Mean time from completion of Q1 to PROMs procedure (St. Dev.)		-			-			-	
Mean time from PROMs procedure to completion of Q2 (St. Dev.)		207.23			208.36			-	
		Incidence	%		Incidence	%		Incidence	%
Percentage of patients who responded who were of Asian origin		-			-			381	2.39
Percentage of patients who did not give their ethnicity		1275	8.41		1211	8.38		1346	8.44
Percentage of patients who had assistance in completing the Q2 questionnaire		1361	8.98		-			-	
Percentage of patients who were living alone		-			3545	24.52		-	
Percentage of patients who did not consider themselves disabled		5238	34.55		5076	35.11		5475	34.35
Percentage of patients with principal procedure of THR / TKR revision		701	4.62		-			-	
Percentage of patients with a comorbidity of dementia according to HES		19	0.13		-			-	
Percentage of patients with a comorbidity of COPD according to HES		-			1589	10.99		-	
Percentage of patients reporting that they had problems with their knee for less than 1 year		-			-			868	5.45
Percentage of patients reporting that they had problems with their knee for between 1 and 5 years		-			-			8290	52.01
Percentage of patients reporting that they had problems with their knee for between 6 and 10 years		-			-			3415	21.42
Percentage of patients reporting that they had problems with their knee for more than 10 years		-			-			3300	20.70
Patients who reported not having had previous treatment (injections / surgery) for this condition		-			-			14668	92.02
Percentage of patients reporting a comorbidity of heart disease		-			1664	11.51		-	
Percentage of patients reporting a comorbidity of stroke		-			231	1.60		-	
Percentage of patients reporting a comorbidity of circulatory problems		1416	9.34		1341	9.28		1505	9.44
Percentage of patients reporting a comorbidity affecting the nervous system		-			135	0.93		-	
Percentage of patients reporting a comorbidity of anxiety or depression		1056	6.97		1026	7.10		1108	6.95
Percentage of patients reporting general health as being Excellent		520	3.43		488	3.38		548	3.44
Percentage of patients reporting general health as being Very Good		3668	24.19		3569	24.69		3856	24.19
Percentage of patients reporting general health as being Fair		3141	20.72		2995	20.72		3305	20.73
Percentage of patients reporting general health as being Poor		499	3.29		463	3.20		520	3.26
Percentage of patients with discharge destination = 19		-			-			15105	94.76
Percentage of patients with operating status = 8		249	1.64		-			273	1.71

Appendix 4

Model construction: Groin hernia - EQ5D Index

	Variable name	Groin Hernia Index									
		Demographics		Demographics (age) + Patient characteristics. (Non responses & collinear variables excluded)		Demographics (age), Patient characteristics + HES surgical risk variables. (Non responses & collinear variables excluded)		Demographics (age), Patient characteristics, HES and selected PROMs surgical risk variables (Non responses & collinear variables excluded)		Repeat of previous column with General Health question (from PROMs questionnaire) included (Non responses & collinear variables excluded)	
		Regression coefft.	t- stat	Regression coefft.	t- stat	Regression coefft.	t- stat	Regression coefft.	t- stat	Regression coefft.	t- stat
Dependent variables:											
	q2_eq5d_index										
Constant term:		0.888	13.22	0.857	63.93	0.903	37.62	0.639	22.66	0.666	36.80
Demographics:											
	startage	-0.001	-5.36	0.001	5.30	0.001	5.31	0.001	8.13	0.001	8.22
	ethnos_white	0.028	0.42	-	-	-	-	-	-	-	-
	ethnos_mixed	excl.	excl.	-0.011	-0.17	-	-	-	-	-	-
	ethnos_asian	-0.035	-0.51	-	-	-	-	-	-	-	-
	ethnos_black	-0.008	-0.12	-	-	-	-	-	-	-	-
	ethnos_other	-0.003	-0.04	-	-	-	-	-	-	-	-
	ethnos_notgiven	0.047	0.71	-	-	-	-	-	-	-	-
	genderless1	-0.031	-4.40	-0.026	-4.26	-0.030	-4.46	-0.018	-3.20	-0.014	-2.71
Other patient characteristics:											
	q1_assisted1			-0.011	-1.70	-	-	-	-	-	-
	q1_assisted2			-	-	-	-	-	-	-	-
	q2_assisted1			-0.078	-6.72	-0.083	-7.71	-0.059	-5.86	-0.049	-5.10
	q2_assisted2			-	-	-	-	-	-	-	-
	q1_living_arrangements1			0.021	1.89	-	-	-	-	-	-
	q1_living_arrangements2			-0.001	-0.05	-	-	-	-	-	-
	q1_living_arrangements3			-0.069	-0.94	-	-	-	-	-	-
	q1_living_arrangements4			0.002	0.06	-	-	-	-	-	-
	q1_disability1			-0.229	-29.76	-0.225	-29.41	-0.143	-19.31	-0.114	-15.85
	q1_disability2 (do not consider myself disabled)			-	-	-	-	-	-	-	-
Surgical risk variables (HES):											
	diag_01										
	Operation Code_T201 as principal procedure					-0.003	-0.09	-	-	-	-
	OP_T202					-0.025	-1.09	-	-	-	-
	OP_T203					-0.021	-0.80	-	-	-	-
	OP_T209					-0.043	-1.69	-	-	-	-
	OP_T212					-0.038	-1.58	-	-	-	-
	OP_T222					-0.021	-0.76	-	-	-	-
	OP_T223					excl.	excl.	0.035	1.48	-	-
	OP_Oth					-0.028	-1.12	-	-	-	-
	Charlson Index					-0.012	-2.04	-0.010	-2.18	-0.003	-0.89
	Comorbidities used to calculate Charlson: C1MI					0.003	0.13	-	-	-	-
	C2CHF					-0.016	-0.48	-	-	-	-
	C3PeriVasc					-0.055	-2.24	-0.020	-0.84	-	-
	C4Cerebro					-0.011	-0.32	-	-	-	-
	C5Dem					-0.057	-0.53	-	-	-	-
	C6COPD					-0.018	-1.95	-	-	-	-
	C7Rheum					-0.076	-2.70	-0.057	-2.13	-0.042	-1.68
	C8PepUlc					-0.045	-1.03	-	-	-	-
	C9MildLiver					-0.212	-2.38	-0.216	-2.83	-0.173	-2.48
	C10DiabNoCC					0.005	0.39	-	-	-	-
	C11DiabCC					0.209	3.61	0.236	15.37	0.224	10.47
	C12Plegia					-0.080	-1.04	-	-	-	-
	C13Renal					0.009	0.38	-	-	-	-
	C14 Cancer					0.019	0.76	-	-	-	-
	C15ModLiver					excl.	excl.	excl.	excl.	excl.	excl.
	C16MetastTum					excl.	excl.	0.096	2.40	0.049	1.23
	C17HIV					excl.	excl.	excl.	excl.	excl.	excl.
Surgical risk variables (PROMs Quest):											
	q1_symptom_period1							0.023	0.91	-	-
	q1_symptom_period2							0.015	0.60	-	-
	q1_symptom_period3							excl.	excl.	excl.	excl.
	q1_symptom_period4							excl.	excl.	excl.	excl.
	q1_previous_surgery1							0.009	1.91	-	-
	q1_previous_surgery2							-	-	-	-
	comorbidities: heart_disease							-0.018	-2.88	-0.006	-1.06
	high_bp							-0.004	-1.17	-	-
	stroke							-0.007	-0.43	-	-
	circulation							-0.058	-5.44	-0.044	-4.33
	lung_disease							-0.008	-1.06	-	-
	diabetes							0.001	0.06	-	-
	kidney_disease							-0.014	-0.77	-	-
	nervous_system							-0.083	-3.88	-0.062	-3.05
	liver_disease							0.015	0.47	-	-
	cancer							-0.004	-0.55	-	-
	depression							-0.094	-7.74	-0.080	-6.88
	arthritis							-0.050	-10.41	-0.041	-8.74
	q1_eq5d_index							0.246	21.45	0.202	17.86
Add't'nal risk variable (GH question from PROMs Quest):											
	q1_general_health1 (Excellent)									0.066	4.68
	q1_general_health2 (Very Good)									0.050	3.58
	q1_general_health3 (Good)									0.022	1.60
	q1_general_health4 (Fair)									-0.057	-3.68
	q1_general_health5 (Poor)									-0.193	-6.23
Local area related variables:											
	sthatret q30										
	sthatret q31										
	sthatret q32										
	sthatret q33										
	sthatret q34										
	sthatret q35										
	sthatret q36										
	sthatret q37										
	sthatret q38										
	sthatret q39										
	imd04										
Provider related variables:											
	admisorc19 (usual place of residence)										
	admisorc_oth										
	disdest19 (usual place of residence)										
	disdest_oth										
	posopdur (Post operative length of stay)										
	preopdur										
	protypeFOU										
	protypeIND										
	protypeINDTC										
	protypePCT										
	protypeTRU										
	protypeTRUTC										
	time_q1_to_proc										
	time_proc_to_q2										
		11688		11688		11688		11366		11366	
		0.008		0.190		0.195		0.294		0.326	

NOTES: excl indicates variables excluded by the model either to avoid collinearity, or because the variable is constant or missing across all observations

\- indicates variables that have been removed from future analyses due to their lack of significance at 5% level

		Variable name	Groin Hernia Index							
			Patient characteristics, HES and PROMs surgical risk variables, Local area related variables (Non responses & collinear variables excluded)		Patient characteristics, HES and PROMs surgical risk variables, Local area and Provider related variables (Non responses & collinear variables excluded)		Repeat of previous column with further non-significant (and excluded) variables removed		Final proposed Full model	
			Regression coefft.	t- stat	Regression coefft.	t- stat	Regression coefft.	t- stat	Regression coefft.	t- stat
	Dependent variables:									
		q2_eq5d_index								
	Constant term:		0.700	52.26	0.769	20.64	0.771	27.82	0.774	27.67
	Demographics:									
		startage	0.001	7.05	0.001	7.55	0.001	7.58	0.001	7.72
		ethnos_white	-	-	-	-	-	-	-	-
		ethnos_mixed	-	-	-	-	-	-	-	-
		ethnos_asian	-	-	-	-	-	-	-	-
		ethnos_black	-	-	-	-	-	-	-	-
		ethnos_other	-	-	-	-	-	-	-	-
		ethnos_notgiven	-	-	-	-	-	-	-	-
		genderless1	-0.014	-2.74	-0.015	-2.71	-0.015	-2.74	-0.014	-2.70
	Other patient characteristics:									
		q1_assisted1	-	-	-	-	-	-	-	-
		q1_assisted2	-	-	-	-	-	-	-	-
		q2_assisted1	-0.048	-4.90	-0.044	-4.39	-0.044	-4.40	-0.048	-4.81
		q2_assisted2	-	-	-	-	-	-	-	-
		q1_living_arrangements1	-	-	-	-	-	-	-	-
		q1_living_arrangements2	-	-	-	-	-	-	-	-
		q1_living_arrangements3	-	-	-	-	-	-	-	-
		q1_living_arrangements4	-	-	-	-	-	-	-	-
		q1_disability1	-0.113	-15.81	-0.114	-15.07	-0.114	-15.11	-0.114	-15.31
		q1_disability2 (do not consider myself disabled)	-	-	-	-	-	-	-	-
	Surgical risk variables (HES):									
		diag_01								
		Operation Code_T201 as principal procedure	-	-	-	-	-	-	-	-
		OP_T202	-	-	-	-	-	-	-	-
		OP_T203	-	-	-	-	-	-	-	-
		OP_T209	-	-	-	-	-	-	-	-
		OP_T212	-	-	-	-	-	-	-	-
		OP_T222	-	-	-	-	-	-	-	-
		OP_T223	-	-	-	-	-	-	-	-
		OP_Oth	-	-	-	-	-	-	-	-
		Charlson Index	-	-	-	-	-	-	-	-
		Comorbidities used to calculate Charlson: C1MI	-	-	-	-	-	-	-	-
		C2CHF	-	-	-	-	-	-	-	-
		C3PeriVasc	-	-	-	-	-	-	-	-
		C4Cerebro	-	-	-	-	-	-	-	-
		C5Dem	-	-	-	-	-	-	-	-
		C6COPD	-	-	-	-	-	-	-	-
		C7Rheum	-	-	-	-	-	-	-	-
		C8PepUlc	-	-	-	-	-	-	-	-
		C9MildLiver	-0.176	-2.54	-0.179	-2.61	-0.180	-2.61	-	-
		C10DiabNoCC	-	-	-	-	-	-	-	-
		C11DiabCC	0.211	14.56	0.208	13.85	0.211	16.65	-	-
		C12Plegia	-	-	-	-	-	-	-	-
		C13Renal	-	-	-	-	-	-	-	-
		C14 Cancer	-	-	-	-	-	-	-	-
		C15ModLiver	excl.	excl.	excl.	excl.	excl.	excl.	-	-
		C16MetastTum	-	-	-	-	-	-	-	-
		C17HIV	excl.	excl.	excl.	excl.	excl.	excl.	-	-
	Surgical risk variables (PROMs Quest):									
		q1_symptom_period1	-	-	-	-	-	-	-	-
		q1_symptom_period2	-	-	-	-	-	-	-	-
		q1_symptom_period3	excl.	excl.	excl.	excl.	excl.	excl.	-	-
		q1_symptom_period4	excl.	excl.	excl.	excl.	excl.	excl.	-	-
		q1_previous_surgery1	-	-	-	-	-	-	-	-
		q1_previous_surgery2	-	-	-	-	-	-	-	-
		comorbidities: heart_disease	-	-	-	-	-	-	-	-
		high_bp	-	-	-	-	-	-	-	-
		stroke	-	-	-	-	-	-	-	-
		circulation	-0.044	-4.33	-0.041	-3.79	-0.041	-3.81	-0.037	-3.56
		lung_disease	-	-	-	-	-	-	-	-
		diabetes	-	-	-	-	-	-	-	-
		kidney_disease	-	-	-	-	-	-	-	-
		nervous_system	-0.063	-3.09	-0.052	-2.51	-0.052	-2.51	-0.054	-2.72
		liver_disease	-	-	-	-	-	-	-	-
		cancer	-	-	-	-	-	-	-	-
		depression	-0.079	-6.78	-0.078	-6.60	-0.078	-6.56	-0.080	-6.86
		arthritis	-0.041	-8.55	-0.042	-8.48	-0.042	-8.50	-0.041	-8.49
		q1_eq5d_index	0.200	17.67	0.197	16.90	0.198	16.92	0.198	17.23
	Add't'nal risk variable (GH question from PROMs Quest):									
		q1_general_health1 (Excellent)	0.044	10.50	0.041	9.43	0.041	9.48	0.042	9.73
		q1_general_health2 (Very Good)	0.027	8.83	0.025	7.76	0.025	7.81	0.025	7.94
		q1_general_health3 (Good)	-	-	-	-	-	-	-	-
		q1_general_health4 (Fair)	-0.080	-10.50	-0.078	-9.85	-0.078	-9.84	-0.077	-9.94
		q1_general_health5 (Poor)	-0.217	-7.83	-0.207	-7.27	-0.207	-7.28	-0.206	-7.40
	Local area related variables:									
		sthatret q30	excl.	excl.	-0.006	-0.86	-	-	-	-
		sthatret q31	0.003	0.42	-	-	-	-	-	-
		sthatret q32	0.007	0.91	-	-	-	-	-	-
		sthatret q33	0.006	0.70	-	-	-	-	-	-
		sthatret q34	0.006	0.81	-	-	-	-	-	-
		sthatret q35	0.011	1.48	-	-	-	-	-	-
		sthatret q36	0.005	0.62	-	-	-	-	-	-
		sthatret q37	0.009	1.13	-	-	-	-	-	-
		sthatret q38	0.006	0.72	-	-	-	-	-	-
		sthatret q39	0.017	2.29	0.009	2.19	0.009	2.25	0.009	2.41
		imd04	-0.001	-4.73	-0.001	-3.98	-0.001	-4.14	-0.001	-4.46
	Provider related variables:									
		admisorc19 (usual place of residence)			-0.051	-2.15	-0.052	-2.17	-0.054	-2.20
		admisorc_oth			excl.	excl.	excl.	excl.	-	-
		disdest19 (usual place of residence)			0.008	0.50	-	-	-	-
		disdest_oth			excl.	excl.	-0.006	-0.36	-	-
		posopdur (Post operative length of stay)			-0.011	-3.78	-0.010	-3.67	-0.011	-3.94
		preopdur			0.009	1.70	-	-	-	-
		protypeFOU			-0.006	-0.34	-	-	-	-
		protypeIND			0.004	0.20	-	-	-	-
		protypeINDTC			0.005	0.26	-	-	-	-
		protypePCT			-0.005	-0.27	-	-	-	-
		protypeTRU			-0.010	-0.53	-	-	-	-
		protypeTRUTC			excl.	excl.	0.006	0.35	-	-
		time_q1_to_proc			0.000	2.05	0.000	1.79	-	-
		time_proc_to_q2			0.000	-2.53	0.000	-2.45	0.000	-2.60
			11301		10421		10421		10674	
			0.328		0.330		0.330		0.329	

NOTES:	excl	indicates variables excluded by the model either to avoid collinearity, or because the variable is constant or missing across all observations
	-	indicates variables that have been removed from future analyses due to their lack of significance at 5% level

Groin Hernia models (OLS)						
				EQ5d Index		EQ VAS
Variable	Variable name	Variable values		Coefft		Coefft
Constant term				0.774		55.648
Q1 EQ5d Index score	q1_eq5d_index	Continuous		0.198		-
Q1 EQ VAS score	q1_eq5d_health_scale	Continuous		-		0.306
Age at start of PROMs procedure spell	startage	Continuous		0.001		-
Sex (Female patients)	sex	2 (or 1 if transformed)		-0.014		-
Sex (Male patients)	sex	1 (or 0 if transformed)		-		-
Patients who had assistance in completing the Q2 questionnaire	q2_assisted	1		-0.048		-3.277
	q2_assisted	2 or 9		-		-
Patients who considered themselves disabled	q1_disability	1		-0.114		-5.228
	q1_disability	2 or 9		-		-
Patients with a comorbidity of COPD according to HES	diag02 to diag 20	See def'n		-		-1.997
	diag02 to diag 20	See def'n		-		-
Patients who reported having had previous treatment (injections / surgery) for this condition	q1_previous_surgery	1		-		0.845
		2 or 9		-		-
Patients reporting a comorbidity of heart disease	heart_disease	1		-		-2.298
		0		-		-
Patients reporting a comorbidity of circulatory problems	circulation	1		-0.037		-2.525
		0		-		-
Patients reporting a comorbidity affecting the nervous system	nervous_system	1		-0.054		-3.808
		0		-		-
Patients reporting a comorbidity of cancer	cancer	1		-		-1.362
		0		-		-
Patients reporting a comorbidity of anxiety or depression	depression	1		-0.080		-3.039
		0		-		-
Patients reporting a comorbidity of arthritis	arthritis	1		-0.041		-1.312
		0		-		-
Patients reporting general health as being Excellent	q1_general_health	1		0.042		9.144
Patients reporting general health as being Very Good	q1_general_health	2		0.025		4.858
Patients reporting general health as being Fair	q1_general_health	4		-0.077		-8.050
Patients reporting general health as being Poor	q1_general_health	5		-0.206		-15.795
	q1_general_health	3		-		-
	q1_general_health	9		-		-
Strategic Health Authority of treatment = Q39	sthatret	Q39		0.009		-
	sthatret	not Q39		-		-
Index of Multiple Deprivation Score, IMD04	imd04	Continuous		-0.001		-0.027
Admission source = 19	admisorc	19		-0.054		-
	admisorc	not 19		-		-
Post operative length of stay following PROMs procedure	posopdur	Continuous		-0.011		-0.593
Provider is an independent treatment centre	protype	INDSITETC		-		0.951
	protype	not INDSITETC		-		-
Time from PROMs procedure to completion of Q2	q2_completed_date - proms_proc_date	Continuous		0.000		-0.008

Varicose Vein models (OLS)							
			EQ5d Index		EQ VAS		Aberdeen Sco
Variable	Variable name	Variable values	Coefft		Coefft		Coefft
Constant term			0.680		59.374		-0.774
Q1 EQ5d Index score	q1_eq5d_index	Continuous	0.321		-		-
Q1 EQ VAS score	q1_eq5d_health_scale	Continuous	-		0.260		-
Q1 Aberdeen VV score	q1_score		-		-		0.456
Sex (Female patients)	sex	2 (or 1 if transformed)	-		-		0.892
Sex (Male patients)	sex	1 (or 0 if transformed)	-		-		-
Ethnicity (Asian)	ethnos	H, J, K or L	-		-		4.529
Ethnicity (not Asian)	ethnos	Others	-		-		-
Patients who considered themselves disabled	q1_disability	1	-0.118		-5.199		2.391
	q1_disability	2 or 9	-		-		-
Patients living in nursing home, hospital, long term care	q1_living_arrangements	3	-		18.903		6.021
Patients with other living arrangements	q1_living_arrangements	not 3	-		-		-
Charlson Index	charlson	Continuous	-		-1.757		-
Patients with a comorbidity of metastatic tumours according to HES	diag02 to diag 20	See def'n for 1	0.080		-		-
	diag02 to diag 20	0	-		-		-
Patients who reported having had previous treatment (injections / surgery) for this condition	q1_previous_surgery	1	-0.030		-1.243		2.656
		2 or 9	-		-		-
Patients reporting a comorbidity of circulatory problems	circulation	1	-		-2.025		1.200
		0	-		-		-
Patients reporting a comorbidity of liver disease	liver_disease	1	0.145		-		-
		0	-		-		-
Patients reporting a comorbidity of anxiety or depression	depression	1	-0.078		-3.046		1.222
		0	-		-		-
Patients reporting a comorbidity of arthritis	arthritis	1	-0.044		-1.692		-
		0	-		-		-
Patients reporting general health as being Excellent	q1_general_health	1	0.027		10.194		-
Patients reporting general health as being Very Good	q1_general_health	2	-		5.738		-
Patients reporting general health as being Fair	q1_general_health	4	-0.060		-9.157		-
Patients reporting general health as being Poor	q1_general_health	5	-0.167		-13.846		3.400
	q1_general_health	3	-		-		-
	q1_general_health	9	-		-		-
Strategic Health Authority of treatment	sthatret	Q31	-		-1.517		0.981
	sthatret	Q36	-		-1.586		1.475
	sthatret	not Q31 or Q36	-		-		-
Index of Multiple Deprivation Score, IMD04	imd04	Continuous	-0.001		-		-
Post operative length of stay following PROMs procedure	posopdur	Continuous	-		-		-0.534
Provider is a PCT	protype	PCT	0.038		-		-
	protype	not PCT	-		-		-
Time from completion of Q1 to PROMs procedure	proms_proc_date - q1_completed_date	Continuous	-		0.001		-

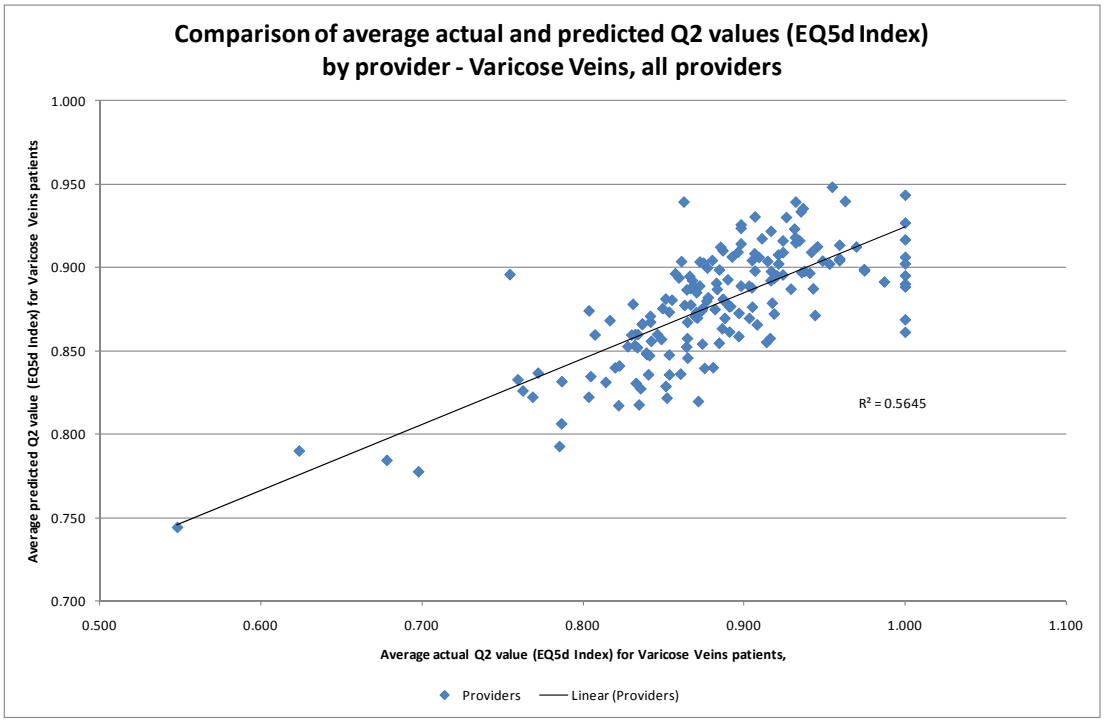
Hip replacement models (OLS)							
			EQ5d Index		EQ VAS		Oxford Hip Score
Variable	Variable name	Variable values	Coefft		Coefft		Coefft
Constant term			0.795		72.172		35.597
Q1 EQ5d Index score	q1_eq5d_index	Continuous	0.139		-		-
Q1 EQ VAS score	q1_eq5d_health_scale	Continuous	-		0.108		-
Q1 Oxford Hip score	q1_score	Continuous	-		-		0.236
Sex (Female patients)	sex	2 (or 1 if transformed)	-0.015		-0.736		-0.880
Sex (Male patients)	sex	1 (or 0 if transformed)	-		-		-
Patients who had assistance in completing the Q2 questionnaire	q2_assisted	1	-0.093		-6.779		-2.330
	q2_assisted	2 or 9	-		-		-
Patients who considered themselves disabled	q1_disability	1	-		-		-2.078
Patients who did not consider themselves disabled	q1_disability	2	0.061		4.104		-
	q1_disability	9	-		-		-
Patient with principal procedure of THR revision	opertn_01	See def'n for 1	-0.093		-		-
	opertn_01	0	-		-		-
Patient with principal procedure of hybrid prosthetic hip revision	opertn_01	See def'n for 1	-0.092		-		-
	opertn_01	0	-		-		-
Patients with a comorbidity of COPD according to HES	diag02 to diag 20	See def'n for 1	-0.026		-2.650		-0.798
	diag02 to diag 20	0	-		-		-
Patients with a comorbidity of rheumatoid arthritis according to HES	diag02 to diag 20	See def'n for 1	-0.033		-2.749		-
	diag02 to diag 20	0	-		-		-
Patients with a comorbidity of diabetes without complications or comorbidities according to HES	diag02 to diag 20	See def'n for 1	-		-1.964		-
	diag02 to diag 20	0	-		-		-
Patients who reported having had previous treatment (injections / surgery) for this condition	q1_previous_surgery	1			-		-4.087
		2 or 9	-		-		-
Patients reporting a comorbidity of heart disease	heart_disease	1	-		-1.968		-
		0	-		-		-
Patients reporting a comorbidity of circulatory problems	circulation	1	-0.049		-3.052		-2.698
		0	-		-		-
Patients reporting a comorbidity of anxiety or depression	depression	1	-0.097		-5.817		-1.916
		0	-		-		-
Patients reporting a comorbidity of arthritis	arthritis	1	-0.017		-1.296		-
		0	-		-		-
Patients reporting general health as being Excellent	q1_general_health	1	0.061		9.603		4.352
Patients reporting general health as being Very Good	q1_general_health	2	0.035		4.962		3.360
Patients reporting general health as being Good	q1_general_health	3	-		-		1.953
Patients reporting general health as being Fair	q1_general_health	4	-0.069		-7.094		-
Patients reporting general health as being Poor	q1_general_health	5	-0.140		-10.151		-1.955
	q1_general_health	9	-		-		-
Index of Multiple Deprivation Score, IMD04	imd04	Continuous	-0.001		-0.059		-0.061
Discharge destination = 19	disdest	19	-		-		1.346
	disdest	Other	-		-		-
Post operative length of stay following PROMs procedure	posopdur	Continuous	-0.005		-0.282		-0.241
Time from completion of Q1 to PROMs procedure	proms_proc_date - q1_completed_date	Continuous	-		0.001		-
Time from PROMs procedure to completion of Q2	q2_completed_date - proms_proc_date	Continuous	0.000		-		-0.001

Knee replacement models (OLS)							
			EQ5d Index		EQ VAS		Oxford Knee Score
Variable	Variable name	Variable values	Coefft		Coefft		Coefft
Constant term			0.449		46.403		18.033
Q1 EQ5d Index score	q1_eq5d_index	Continuous	0.178		-		-
Q1 EQ VAS score	q1_eq5d_health_scale	Continuous	-		0.193		-
Q1 Oxford Knee score	q1_score	Continuous	-		-		0.340
Age at start of PROMs procedure spell	startage	Continuous	0.004		0.149		0.119
Ethnicity (Asian)	ethnos	H, J, K or L	-		-		-2.075
Ethnicity (not given)	ethnos	X or Z	0.030		1.234		0.978
Ethnicity (neither Asian nor 'not given')	ethnos	Others	-		-		-
Patients who had assistance in completing the Q2 questionnaire	q2_assisted	1	-0.072		-		-
	q2_assisted	2 or 9	-		-		-
Patients who did not consider themselves disabled	q1_disability	2	0.063		4.593		1.838
	q1_disability	1 or 9	-		-		-
Patient's living arrangements = 2 (PROMs questionnaire)	q1_living_arrangements	2	-		-0.894		-
Patients with other living arrangements	q1_living_arrangements	not 2	-		-		-
Patient with principal procedure of TKR revision	opertn_01	See def'n for 1	-0.088		-		-
	opertn_01	0	-		-		-
Patients with a comorbidity of dementia according to HES	diag02 to diag 20	See def'n for 1	-0.319		-		-
	diag02 to diag 20	0	-		-		-
Patients with a comorbidity of COPD according to HES	diag02 to diag 20	See def'n for 1	-		-2.507		-
	diag02 to diag 20	0	-		-		-
Duration of symptoms prior to current treatment	q1_symptom_period	1	-		-		-3.179
	q1_symptom_period	2	-		-		-3.154
	q1_symptom_period	3	-		-		-2.404
	q1_symptom_period	4	-		-		-2.868
	q1_symptom_period	9	-		-		-
Patients who reported not having had previous treatment (injections / surgery) for this condition	q1_previous_surgery	2	-		-		3.849
		1 or 9	-		-		-
Patients reporting a comorbidity of heart disease	heart_disease	1	-		-1.842		-
		0	-		-		-
Patients reporting a comorbidity of stroke	stroke	1	-		-3.049		-
		0	-		-		-
Patients reporting a comorbidity of circulatory problems	circulation	1	-0.036		-2.248		-2.051
		0	-		-		-
Patients reporting a comorbidity of nervous system problems	nervous_system	1	-		-6.835		-
		0	-		-		-
Patients reporting a comorbidity of anxiety or depression	depression	1	-0.084		-2.502		-1.498
		0	-		-		-
Patients reporting general health as being Excellent	q1_general_health	1	0.074		7.820		3.201
Patients reporting general health as being Very Good	q1_general_health	2	0.039		5.090		1.533
Patients reporting general health as being Fair	q1_general_health	4	-0.069		-6.659		-2.136
Patients reporting general health as being Poor	q1_general_health	5	-0.167		-12.748		-4.306
	q1_general_health	3	-		-		-
	q1_general_health	9	-		-		-
Index of Multiple Deprivation Score, IMD04	imd04	Continuous	-0.001		-0.064		-0.056
Discharge destination = 19	disdest	19	-		-		1.109
	disdest	Other	-		-		-
Operating status = 8	operstat	8	0.050		-		1.510
	operstat	Other	-		-		-
Post operative length of stay following PROMs procedure	posopdur	Continuous	-0.007		-0.390		-0.310
Time from PROMs procedure to completion of Q2	q2_completed_date - proms_proc_date	Continuous	0.000		-0.004		-

Appendix 5

Provider level charts comparing actual and predicted Q2 values

a) EQ5D Index (Varicose vein) for all providers



b) EQ5D Index (Varicose vein) for those providers for which more than 30 response have been received