Appendix 1a – Data sources and specification

Characterising the population of each practice. For all general practice populations included in the analysis, denominator information [practice list size, and practice population age (in five year age groups) and sex profiles] were obtained for each practice from the Attribution Data Set from the English Exeter GP Registration System which is extracted once a year. Data for 2008-10 practice populations size and characteristics are available from publicly available Practice Based Commissioning data sets and for 2011-13 data was provided directly to the study authors by the East of England Public Health England Knowledge and Intelligence Team.

Indicator outlier values

Initial analysis identified some outlier values for the screening uptake indicators. These were identified visually from the distributions. In all three cases there was a very long tail towards highly unlikely low uptake values, inconsistent with the variability seen for the remaining practices. In some cases there was even an indication of a secondary peak at these low values. These low values existed in the presence of large denominators indicating they were unlikely to be due to chance. A cut-off was chosen following visual inspection (Appendix 3).
## Appendix 1b. Data sources and related periods

| Indicator                        | Data Source | Date                        |
|----------------------------------|-------------|-----------------------------|
| **Process**                      |             |                             |
| Breast screening coverage        | Exeter      | April 2013†                 |
| Cervical screening coverage      | Exeter      | April 2013†                 |
| Bowel screening coverage         | Exeter      | April 2013†                 |
| Sigmoidoscopy rate               | HES         | April 2012 to March 2013*   |
| Colonoscopy rate                 | HES         | April 2012 to March 2013*   |
| Upper GI endoscopy rate          | HES         | April 2012 to March 2013*   |
| TWW referral rate                | CWT         | April 2012 to March 2013*   |
| TWW referral rate (Colorectal)   | CWT         | April 2012 to March 2013*   |
| TWW referral rate (Lung)         | CWT         | April 2012 to March 2013*   |
| TWW referral rate (Skin)         | CWT         | April 2012 to March 2013*   |
| TWW referral rate (Breast)       | CWT         | April 2012 to March 2013*   |
| **Outcome**                      |             |                             |
| TWW conversion rate              | CWT         | April 2012 to March 2013    |
| TWW detection rate               | CWT         | April 2012 to March 2013    |
| Emergency route to diagnosis     | RTD         | January to December 2008    |
| Referred route to diagnosis      | RTD         | January to December 2008    |
| Other route to diagnosis         | RTD         | January to December 2008    |

†Denominators used for these indicators are the number of eligible patients in the practice April 2013
*Denominators used for these indicators are the practice list size taken from QOF 2012/13 QOF data which is defined as the list size at January 2013

TWW; two week wait, Exeter; the Exeter database, ONS; Office of National Statistics, QOF; Quality and Outcomes Framework, HES; Hospital Episode Statistics, CWT; Cancer Waiting Times database, RTD; Routes to Diagnosis database
Appendix 2 – Estimating reliability

Unit level, or Spearman Brown, reliability is given by

\[
\text{Reliability} = \frac{\text{underlying between unit variance}}{\text{underlying between unit variance + \frac{\text{within unit variance}}{n}}}
\]

Where \( n \) is the number of observations per unit and in the case of binary or rate indicators the within unit variance is assumed to follow the binomial or Poisson distribution respectively. In the context of this study a unit is a practice, but we use the terminology unit here to be more general.

Following on from the definition above, reliability is often estimated by first estimating the between unit variance and the within unit variance. However, in the context of the binomial or Poisson distribution estimating the within unit variance is not straightforward. Although various methods have been proposed to estimate the within unit variance we employ a method which does not directly use variance estimates. Instead we utilise the relationship between “Empirical Bayes” estimates of Unit score and Maximum Likelihood estimates of the unit score. “Empirical Bayes” estimates of unit scores (also known as Best Linear Unbiased Predictions or BLUPs) are related to the observed scores (Maximum Likelihood estimates) through reliability. Specifically the observed scores (on the appropriate scale) are shrunk towards the mean of unit scores by an amount equal to the inter-unit reliability. Thus by knowing both the “Empirical Bayes” estimates of Unit scores and Maximum Likelihood estimates of the unit score we can obtain an estimate of reliability for each Unit.

The first step in estimating unit reliabilities is to fit a mixed-effect generalised linear model which contains only a constant term and a random intercept for unit, i.e.

\[
\eta_i = \beta_0 + s_i
\]

In the case of proportion indicators \( \eta_i = \logit(\pi_i) \), where \( \pi_i \) is the underlying proportion in unit \( i \) and the data within unit are assumed to be binomially distributed. In the case of rate indicators \( \eta_i = \log(\lambda_i) \), where \( \lambda_i \) is the underlying rate in unit \( i \) and the data within unit are assumed to follow the Poisson distribution. In each case \( s_i \) represents a unit effect and is assumed to be normally distributed with a mean of zero, and \( \beta_0 \) is a constant term, both of which are on the log-odds scale for proportion indicators and the log-rate scale for rate indicators. Following fitting of the model, “Empirical Bayes” estimates of unit effects, \( s_i^{EB} \), are obtained which represent the best estimate of the deviation of unit \( i \) from the mean of all units \( \beta_0 \).

The estimated inter-unit reliability for proportion indicators is given by
Reliability\(_i\) = \frac{\hat{S}_{i}^{EB}}{\logit(\hat{p}_i) - \beta_0}

And for rate indicators is given by

Reliability\(_i\) = \frac{\hat{S}_{i}^{EB}}{\log(\hat{\lambda}_i) - \beta_0}

Where \(\hat{p}_i\) and \(\hat{\lambda}_i\) are the observed proportion or rate in unit \(i\) respectively.

Initial work showed that for binary indicators, reliability estimated in this way was indistinguishable from that estimated using the method applied by Lawson et al.\(^1\)

1. Lawson EH, Ko CY, Adams JL, Chow WB, Hall BL. Reliability of evaluating hospital quality by colorectal surgical site infection type. Ann Surg. 2013;258(6):994-1000.
### Appendix 3. Details of practice exclusions and final number of included practices for each indicator.

| Indicators                  | Number of 2013 practice profiles practices | Number of profiles with missing numerators | Number of profiles with missing denominator | Number of practices with zero denominators | Number of practices with missing practice population age/sex information | Outlier indicator values | N (%) practices not included | Total number of practices included |
|-----------------------------|-------------------------------------------|-------------------------------------------|---------------------------------------------|-------------------------------------------|------------------------------------------------------------------------|--------------------------|-------------------------------|----------------------------------|
| **Process indicators**      |                                           |                                           |                                             |                                           |                                                                        |                          |                               |                                  |
| Breast screening coverage   | 7962                                      | 2                                         | 2                                           | 0                                         | 0                                                                     | 7                        | 11 (0.1)                      | 7951                             |
| Cervical screening coverage | 7962                                      | 20                                        | 10                                          | 0                                         | 1                                                                     | 21                       | 52 (0.7)                      | 7910                             |
| Bowel screening coverage    | 7962                                      | 37                                        | 0                                           | 0                                         | 0                                                                     | 1                        | 38 (0.5)                      | 7924                             |
| Sigmoidoscopy rate          | 7962                                      | 0                                         | 0                                           | n/a                                       | 8                                                                     | 0                        | 8 (0.1)                       | 7954                             |
| Colonoscopy rate            | 7962                                      | 0                                         | 0                                           | n/a                                       | 8                                                                     | 0                        | 8 (0.1)                       | 7954                             |
| Upper GI endoscopy rate     | 7962                                      | 0                                         | 0                                           | n/a                                       | 8                                                                     | 0                        | 8 (0.1)                       | 7954                             |
| TWW referral rate           | 7962                                      | 1                                         | 0                                           | n/a                                       | 7                                                                     | 0                        | 8 (0.1)                       | 7954                             |
| TWW referral rate (Colorectal) | 7962                               | 1                                         | 0                                           | n/a                                       | 7                                                                     | 0                        | 8 (0.1)                       | 7954                             |
| TWW referral rate (Lung)    | 7962                                      | 1                                         | 0                                           | n/a                                       | 7                                                                     | 0                        | 8 (0.1)                       | 7954                             |
| TWW referral rate (Skin)    | 7962                                      | 1                                         | 0                                           | n/a                                       | 7                                                                     | 0                        | 8 (0.1)                       | 7954                             |
| TWW referral rate (Breast)  | 7962                                      | 1                                         | 0                                           | n/a                                       | 7                                                                     | 0                        | 8 (0.1)                       | 7954                             |
| **Outcome indicators**      |                                           |                                           |                                             |                                           |                                                                        |                          |                               |                                  |
| TWW conversion rate         | 7962                                      | 1                                         | 0                                           | 0                                         | 7                                                                     | 0                        | 8 (0.1)                       | 7954                             |
| TWW detection rate          | 7962                                      | 1                                         | 0                                           | 14                                        | 6                                                                     | 0                        | 21 (0.3)                      | 7941                             |
| Emergency route to diagnosis| 7962                                      | 55                                        | 0                                           | 87                                        | 133                                                                   | 0                        | 275 (3.5)                     | 7687                             |
| Referred route to diagnosis | 7962                                      | 55                                        | 0                                           | 87                                        | 133                                                                   | 0                        | 275 (3.5)                     | 7687                             |
| Other route to diagnosis    | 7962                                      | 55                                        | 0                                           | 87                                        | 133                                                                   | 0                        | 275 (3.5)                     | 7687                             |
| **Other indicators**        |                                           |                                           |                                             |                                           |                                                                        |                          |                               |                                  |
| Cancer mortality            | 7962                                      | 0                                         | 0                                           | n/a                                       | 8                                                                     | 0                        | 8 (0.1)                       | 7954                             |
| Emergency cancer hospitalisations | 7962                             | 26                                        | 0                                           | n/a                                       | 1                                                                     | 0                        | 27 (0.3)                      | 7935                             |
| Incident cases              | 7962                                      | 0                                         | 0                                           | n/a                                       | 16                                                                    | 0                        | 16 (0.2)                      | 7946                             |
| Prevalent cases             | 7962                                      | 0                                         | 0                                           | 0                                         | 2                                                                     | 0                        | 2 (0.0)                       | 7960                             |
