Public Health England

Protecting and improving the nation's health

National Disease Registration Service (NDRS)

Case-mix adjusted percentage of cancers diagnosed at stages 1 and 2 for Clinical Commissioning Groups in England (experimental statistics)

Technical document

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Glossary

Case-mix adjustment: The use of statistical procedures to permit comparison of health outcomes between providers with differing mix of patients with regards to diagnoses, severity of illness, and other variables associated with probability of an outcome.

Reliability: In statistics, the reliability is a measure of stability or consistency of a measure. An indicator is said to have high reliability if it produces similar results under consistent conditions. In the context of this report, we specifically deal with a type of reliability as it is applied to measures of organisational variation (ranking), also known as Spearman-Brown reliability or 'rankability'. This is a measure of the proportion of the overall observed variance between organisations that is not attributable to chance.

Stage at diagnosis: A measure of the anatomical extent of a cancer. For solid tumours, a higher stage number means the cancer has extended further. This is sometimes referred to as 'advanced' stage cancer, and often there are fewer treatment options.

Introduction

Stage at diagnosis is a measure of the anatomical extent of a cancer at diagnosis. There are usually fewer treatment options for advanced stage cancers. This paper documents the methodology to produce a statistically robust indicator (reliable and case-mix adjusted) to measure the percentage of cancers diagnosed at stages 1 and 2. This indicator will be produced nationally and for Clinical Commissioning Groups (CCGs) in England.

Quality standards and indicators

Quality standards and indicators are used to promote transparency in patient outcomes and publicly report quality of healthcare provision. They can aid the identification of organisations involved in the provision of healthcare (for example, hospitals, CCGs) delivering the highest quality of care and those that may need to improve quality. The National Institute for Health and Care Excellence uses quality standards and indicators to:

- set priorities for quality improvement and support
- create local performance dashboards
- benchmark performance against national data
- support local quality improvement schemes
- demonstrate progress that healthcare-related organisations are making on outcomes

Stage of cancer at diagnosis

Cancer is a major cause of death in England and over half of the population will be diagnosed with cancer during their lifetime.

The staging system used for most cancer sites is TNM staging. This system puts cancers in a group from 1 to 4 depending on the local extent (T); whether the lymph nodes have cancer cells (N); or if the cancer has spread to other parts of the body (M).[1]

Diagnosis at an earlier stage of the development pathway is related to more effective treatment options, improved quality of life, and increased survival following diagnosis.

[1] Except gynaecological (ovary and uterus) cancers which use FIGO staging; lymphomas (non-Hodgkin lymphomas) which use Ann Arbor staging; myelomas which use ISS staging; Binet for chronic lymphocytic leukaemia (CLL). For these cancer sites, TNM stage has been used where the site-specific stage was unknown. Cervical cancer is the exception, whereby a cancer site is only considered staged if a FIGO staging value is available.

National public health interventions, such as screening programmes, information and educational campaigns (for example, Be Clear on Cancer), aim to increase the percentage of cancers diagnosed at an earlier stage and reduce those diagnosed at an advanced stage.

The ‘percentage of cancers diagnosed at stages 1 and 2’ indicator was developed to monitor the quality and effectiveness of interventions aiming to increase diagnosis at an earlier stage, and inform policy and the assessment of improvements to cancer survival. For people diagnosed from 2012, the percentage of cancers diagnosed at stage 1 and 2 was historically published on a quarterly basis and is currently available on the Cancer Data website. This has been replaced with the case-mix adjusted indicator which includes a back-series for diagnoses from 2013 onwards (and an overall summary of data completeness going back to 2001).

Through development of this indicator, we aim to overcome 2 technical issues with the historical indicators of stage at diagnosis:

1. Fair comparisons: the influence of case-mix.
2. Statistical reliability.

1. Fair comparisons: the influence of case-mix

Regional comparison of crude performance indicators has been shown to be misleading due to differences in the underlying population characteristics and distribution of risk factors. Case-mix adjustment (or risk-adjustment) is a process that statistically controls, or accounts, for these characteristics. This facilitates fair comparisons of outcomes between CCGs that have populations with different characteristics negatively or positively associated with stage at diagnosis.

Case-mix adjustment for the ‘percentage of cancers diagnosed at stages 1 and 2’ indicator will have an impact on the apparent early diagnosis related performance of a CCG if:

- cancers less likely to be diagnosed at stages 1 and 2 occur more frequently in the CCG than the national average, leading to the CCG’s unadjusted performance indicator looking worse than it actually is
- cancers more likely to be diagnosed at stages 1 and 2 occur more frequently in the CCG than the national average, leading to the CCG’s unadjusted performance indicator looking better than it actually is

For example, the case-mix related to sites of cancer diagnoses impacts the percentage of cancers diagnosed at stages 1 and 2. Breast cancer is more frequently diagnosed at stages 1 and 2 than lung cancer. Without case-mix adjustment, healthcare-related

organisations with a higher than average occurrence of breast cancer will tend to perform better on the unadjusted 'percentage of cancers diagnosed at stages 1 and 2' indicator, compared to healthcare-related organisations with a higher than average occurrence of lung cancer.

This is of additional importance given the socioeconomic variation in the incidence of certain common cancers with contrasting stage distribution, such as breast and prostate cancer (more common in areas with less deprivation and typically diagnosed at lower stage) and lung cancer (more common in more deprived areas and more frequently diagnosed at an advanced stage).

2. Statistical reliability

The statistical reliability of the indicator should also be considered. Previous analyses using 12 months of data has shown that observed (apparent) variability of a crude indicator is dominated by chance.[2] This reflects insufficient sample size, in addition to variability between CCGs. An indicator that is unreliable will more frequently classify CCGs into high or low ranks by chance. Further empirical work is required to establish the appropriate choice of reporting periods (sample sizes) and ensure sufficient reliability.

Policy context and use

The policy area most likely to be influenced by these results is early diagnosis. Users of the 'percentage of cancers diagnosed at stages 1 and 2' indicator include government organisations including the NHS, local bodies responsible for commissioning cancer services, health policymakers, cancer charities, academics and researchers, cancer registries, the public, and the media.

The data can be used to inform national cancer plans such as the 6 strategic priorities set out by the Independent Cancer Task Force. These include reducing CCG variation and the ambition to increase 12 month survival to 75% by 2020 for all cancers combined. Building on this, the NHS Long Term Plan for cancer aims that 75% of patients with cancer will be diagnosed at stages 1 and 2 by 2028.

Further, the data can inform the NHS Outcomes Framework, which was established to monitor overall changes in performance of the NHS and the quality of health outcomes, which include cancers detected at stage 1 or 2 and a record of lung cancer stage at decision to treat.

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[2] Barclay M, *et al* (2018). Missing data and chance variation in public reporting of cancer stage at diagnosis: Cross-sectional analysis of population-based data in England. *Cancer Epidemiology*, 52, 28-42

Strengths and limitations

The main strengths of the ‘percentage of cancers diagnosed at stages 1 and 2’ indicator include that:

- users can make fair comparisons between CCGs because case-mix adjustment methodology adjusts for different underlying population characteristics
- the data used in the indicator is the same as that used in other national statistics on cancer registrations
- users can make meaningful comparisons over time as the methodology makes allowances for changes in populations
- the indicator shows the potential effect of health policy on the percentage of cancers diagnosed at stages 1 and 2, in England and by different geographic areas

The main limitations of the ‘percentage of cancers diagnosed at stages 1 and 2’ indicator comprise:

- a recognised system for staging is not currently available for all types of cancer
- not all cancer sites are included in the indicator as for some types of cancer data completeness is not high enough to allow for quality estimates
- cancer data files are dynamic as after registration years are published further cases may be added. Changes are expected to be small, but the dynamic nature of the registration database may lead to small differences in numbers between this publication and other publications based on incident cancers in the included years
- associated outcomes with a diagnosis at stages 1 and 2 are heavily influenced by treatment decisions and responses, as well as stage

Methodology

Data source

The indicator uses information routinely collected by the National Disease Registration Service within Public Health England (PHE). In brief, NDRS is responsible for the collection, quality assurance, analysis, and provision of data over the entire cancer care pathway. NDRS maintains a comprehensive, population-based registry which contains data on all people in England who are diagnosed with malignant and pre-malignant neoplasms. Further information is available in the published Data Resource profile.

Data quality

This publication uses cancer registration data, which is investigated in the Quality assurance of administrative data report and underpins all statistical publications on cancer.

Completeness

In recent years, data quality for the stage at diagnosis indicator has improved. By 2017, staging data were complete for nearly 82% of all cases of cancer. Although some exceptions by cancer site exist, data quality continues to improve in terms of completeness.

Derivation of stage at diagnosis

The ‘stage at diagnosis’ indicator is based on registry-collected information from clinical, pathology, and imaging records. All relevant information available is used to give a single anatomical stage at diagnosis. Where available, the TNM classification system is used to stage the cancer site.

For this indicator, stage at diagnosis was defined as TNM stage 1 (least advanced) to TNM stage 4 (most advanced). This system puts cancers in a group from 1 to 4 depending on local extent (T); whether the lymph nodes have cancer cells (N); and if the cancer has spread to other parts of the body (M).

For cervical cancer a cancer site is only considered staged if a FIGO staging value is available. For the following cancer sites, TNM stage has been used where the site-specific stage was unknown: gynaecological (ovary and uterus) cancers which use

FIGO staging; lymphomas (non-Hodgkin lymphomas) which use Ann Arbor staging; myelomas which use ISS staging; Binet for chronic lymphocytic leukaemia (CLL).

Cases where staging information was unknown or not available were excluded and have not been included in the denominator. The ‘stage at diagnosis’ indicator included in this analysis uses a complete case approach i.e. the denominator is all cancers diagnosed which have a valid recorded stage. This was based on previous research supporting the validity of complete case analysis for comparing diagnoses of cancer at stages 1 and 2 between CCGs.

Cancer sites

The cancer sites eligible for inclusion are listed below (Table 1). The selection of the sites was carefully considered based on the criteria:

- in order for a statistically robust and meaningful indicator to be developed staging completeness is at least 70%
- for the sample size to be meaningful at a CCG level, at least 1,500 cancers are diagnosed in England per year during the 2013 to 2017 period

The criteria will be assessed for the publication in 2023, to review whether additional sites meet the criteria.

The staging classification system (TNM) was updated to version 8, and introduced for all cancers (except head and neck) registered since January 2018. This has an impact on the time series of some individual tumours. Details of the changes to the TNM classification can be found here. However, the impact on the case-mix adjusted percentage is minimal. Minor differences in the site definition are required, as shown in Table 1. Further details will be included in the Statistical Commentary. In the 2023 review, an assessment will also be made as to whether the TNM version should be included as a case-mix variable.

Table 1. Cancer sites included in the case-mix adjusted indicator

Site	Site (ICD-10) for TNMv7	Site (ICD-10) for TNMv8
Bladder	C67	C67
Breast (females only, excluding Paget's disease)	C50	C50
Cervix (females only)	C53	C53
Colon	C18	C18
Hodgkin lymphoma	C81	C81
Kidney	C64	C64
Larynx (including anterior surface of epiglottis)	C10.1, C32	C10.1, C32
Lung	C34	C34
Melanoma of skin	C43	C43
Non-Hodgkin lymphoma	C82, C83, C84, C85	C82, C83, C84, C85
Oesophagus (including oesophagogastric junction)	C15, C16.0	C15, C16.0
Oral cavity, hard palate and lip (inner aspect)	C00.3, C00.4, C00.5, C02, C03, C04, C05.0, C06.	C00.3, C00.4, C00.5, C02.0,C02.1, C02.2, C02.3, C02.8, C02.9, C03, C04, C05.0, C06
Oropharynx, base of tongue, tonsil, soft palate and uvula	C01, C05.1, C05.2, C09, C10.0, C10.2, C10.3, C10.4, C10.8, C10.9	C01, C02.4, C05.1, C05.2, C09, C10.0, C10.2, C10.3, C10.4, C10.8, C10.9
Ovary, fallopian tube and primary peritoneal carcinomas (females only)	C56, C57 excluding C57.7-57.9, C48*	C56, C57 excluding C57.7-57.9, C48*
Pancreas	C25	C25
Prostate (males only)	C61	C61
Rectum	C19, C20	C19, C20
Stomach (excluding oesophagogastric junction)	C16 excluding C16.0	C16 excluding C16.0
Testis (males only)	C62	C62
Thyroid	C73	C73
Uterus (females only)	C54, C55	C54, C55

* Sarcomas in site C48 are excluded, defined as ICD-O-2 codes 8693, 8800, 8801, 8802, 8803, 8804, 8805, 8806, 8963, 8990, 8991, 9040, 9041, 9042, 9043, 9044, 8810, 8811 – 8921, 9120 – 9373, 9490, 9500, 9530 – 9582

The included sites have changed from previous stage at diagnosis publications (see Similar existing indicators). The changes and rationale for each are provided below:

- colon and rectum cancer have distinct stage distributions and clinical management so should be treated separately
- Paget's disease is excluded from breast cancer as it is considered a pre-malignancy and this is staged as in situ in TNM
- the mesenchymal uterine cancer site code (C55) is included with uterine cancers (C54)
- neither prostate and testicular cancer in people whose recorded sex is female nor gynaecological cancers in people whose recorded sex is male are considered for inclusion to ensure individuals are not identifiable in publications

- breast cancer in men is considered separately from breast cancer in women (that is, would only be included if there were more than 1,500 cases per year in men)
- oesophagogastric junction cancer (C16.0) is combined with oesophagus cancer (C15), rather than stomach cancer (C16) as the oesophagus and oesophagogastric junction are staged using the same TNM staging system
- staging groups for oral cavity and oropharynx cancers have been chosen to align with Union for International Cancer Control (UICC) and TNM definitions
- ovary cancers now are combined with fallopian tube and primary peritoneal carcinomas (excluding sarcomas and non-specific sites to ensure exclusion of non-ovarian sites) More information about specific ICD codes for this site grouping can be found on the CancerData website

Stage 1 and 2 cancers

The metric uses stage 1 and 2 uniformly across all sites as the numerator as an indication of the proportion of cancers diagnosed at an early stage, rather than a more advanced one. However, uniformly using stages 1 and 2 this way does not reflect differences in stage-specific management, outcomes, and patterns of declining survival with later stage of diagnosis across cancer sites.

For example, 5-year survival from prostate cancer is high and similar for patients diagnosed at stage 1 through to stage 3, with considerable declines observed for patients diagnosed at stage 4. For bladder cancer, considerable differences in survival between stages 1 and 2 are observed.

Therfore, alternatives to using stages 1 and 2 as the numerator were considered during the development of this indicator. The following grouping to represent ‘early’ stage at diagnosis was proposed following a review of survival by stage data (Table 2). This was discussed by a group of expert cancer clinicians from Cancer Research UK’s Clinical Advisory Panel and Public Health NDRS’s Clinical Advisors at Public Health England.

Table 2. Grouping cancer sites according to survival by stage data

Early as stage 1 only	Early as stage 1 and 2	Early as stage 1, 2, 3	
Bladder	Lung *	Breast	Cervical
Oesophageal	Ovarian *	Laryngeal	Thyroid
Stomach	Hodgkin lymphoma	Prostate	Uterine*
		Colorectal	Kidney
		Melanoma	

* These sites could also be considered in another group as they are less clear-cut to categorise from survival by stage data alone; No survival by stage data available for testicular, pancreatic, oropharyngeal and oral cavity cancers.

Overall, the expert group raised concerns that the work to define early stage in this way could be misleading and clinically irrelevant. Some of the main issues raised generic to all cancer sites, briefly described as:

- the implication of 'early' stage of disease and the associated outcomes are heavily influenced by treatment decisions and responses, rather than a cut-off in stage
- creating a more complex way to define 'early' stage for each cancer site based on stage data alone could imply greater clinical accuracy than is justified
- through inclusion of stage 3 as an 'early' stage of diagnosis, the acceptability of this diagnosis may be increased to commissioners and policy-makers, consequentially reducing the impetus to diagnose more cases at stages 1 and 2

Site-specific considerations included, for example, within gynaecological cancers tumour biology is a very important consideration regarding likely disease progression rate and clinical parameters. There is not a clear distinction between 'good' and 'bad' prognosis using stage alone.

Therefore, overall the Operational Group took the pragmatic decision to maintain the use of stage 1 and 2 as the numerator or the stage at diagnosis indicator.

Inclusion criteria

The following eligibility criteria were used to select tumour records from the Cancer Analysis System for inclusion in the analysis:

- unique tumour identifier
- unique patient identifier
- recorded postcode at diagnosis in England
- finalised registration status
- complete and valid date of birth
- known sex
- neither prostate and testicular cancer in people whose recorded sex is female nor gynaecological cancers in people whose recorded sex is male are not considered for inclusion to prevent the identification of individuals
- breast cancer in men is considered separately from breast cancer in women
- complete and known stage at diagnosis
- recorded diagnosis in years 2013 to 2018
- cancer site as defined by the UKIACR Performance Indicators selection criteria [3], in addition to at least 1,500 cancers are diagnosed in England per year during the 2013 to 2017 period

[3] The selection criteria is a pragmatic definition of which topographical and morphological combinations are considered stageable

Crude measures

Numerator

Cases of cancer diagnosed at stages 1 and 2 for the following collective cancer sites: lung, oesophagus, stomach, colorectal, pancreas, melanomas of the skin, breast, cervix, uterus, ovary, prostate, testis, kidney, bladder, Hodgkin lymphoma, thyroid, larynx, oropharynx, oral cavity and non-Hodgkin lymphoma (as defined in Table 1).

Denominator

Cases of cancer diagnosed at any known stage (1, 2, 3, and 4) for the following cancer sites: lung, oesophagus, stomach, colorectal, pancreas, melanomas of the skin, breast, cervix, uterus, ovary, prostate, testis, kidney, bladder, Hodgkin lymphoma, thyroid, larynx, oropharynx, oral cavity and non-Hodgkin lymphoma (as defined in Table 1).

Percentage

New cases of cancer diagnosed at stages 1 and 2 is calculated as a percentage of all new cases of cancer diagnosed at any known stage (1, 2, 3, and 4) for the following cancer sites: lung, oesophagus, stomach, colorectal, pancreas, melanomas of the skin, breast, cervix, uterus, ovary, prostate, testis, kidney, bladder, Hodgkin lymphoma, thyroid, larynx, oropharynx, oral cavity and non-Hodgkin lymphoma (as defined in Table 1).

The lower and upper 95% confidence intervals are published with the percentage of cancers diagnosed at stages 1 and 2. Confidence intervals are used to determine whether any differences in the figures are likely to be real, or due to natural variation. A wider confidence interval shows a larger degree of uncertainty that the interval contains the true underlying value.

Confidence intervals were calculated using the Wilson Score method, described in detail in the following document: Public Health England: Technical Guide Confidence Intervals.

Selection of case-mix variables

The National Quality Forum in the United States of America advise the following conditions are met for a variable to be used in case-mix adjustment:

- proven reliability and validity
- outside the control or influence of healthcare-related organisations
- varies between healthcare-related organisations
- established or theoretical relationship to performance indicator
- makes a difference to final performance interpretations
- does not disadvantage vulnerable groups

The variables selected as case-mix adjusters were age, sex, cancer site, and deprivation. These were chosen *a priori* using expert advice and research evidence that showed they have an important bearing on the adjustment applied to the stage at diagnosis performance indicator.

During methodological development, further discussions were undertaken in relation to whether deprivation should be included as a case-mix adjuster. The outcome is discussed in more detail below.

In 2014, the US National Quality Forum published specific guidance as to whether performance indicators should be adjusted for deprivation. The overall recommendation from the panel was that decisions should be made on a case-by-case basis. The decision should be informed by using scientific evidence, plausible conceptual and theoretical models, and statistical relationships. The panel also recommends that publication of case-mix adjusted performance measures are accompanied by a rationale which provides supporting evidence for the decision to adjust for sociodemographic variables. Performance incentives may have unintended consequences, including widening of existing disparities in access to high-quality care if they increase the resource gap between high- and low-performing healthcare-related organisations.

A summary of arguments for and against accounting for socio-demographic risk factors in proposed case-mix adjusted performance measures is provided below. More detail can be found here.

Supporters advocate that social risk (for example, English or health literacy, poor living conditions, homelessness, job insecurity) may predispose individuals to poorer health outcomes in ways that are unrelated to quality of care of the healthcare-related organisation. If the relative deprivation of a population is ignored, the performance indicator may lead to unfair conclusions about comparative performance between healthcare-related organisations. Healthcare-related organisations serving more socioeconomically disadvantaged populations may appear to provide lower quality of

healthcare than is true, and those serving more affluent populations may appear to provide higher quality of healthcare than is true.

Opponents of adjusting performance indicators for sociodemographic factors argue against on the basis that worse quality of care provided to more disadvantaged populations may be hidden through that statistical adjustment. This may lead to lower standards of care for more disadvantaged populations. A further concern is that adjustment for deprivation could mask meaningful differences in performance. This is based on the belief that differences in the outcome reflect the degree to which healthcare-related organisations mitigate the effects of 'social risk' (for example, provision of language and interpreting services, flexible appointment systems). The final argument made against inclusion is that adjustment for deprivation risks normalising the expectation that more disadvantaged populations have poorer health outcomes.

Analysis of the data showed independent associations of diagnosis at stages 1 and 2 with deprivation, overall and across most of the cancer sites (data not shown). There was evidence that the inclusion of deprivation in the case-mix variables impacted on the output by CCG for 'percentage of cancers diagnosed at stages 1 and 2' indicator.

The income domain score from the Index of Multiple Deprivation was included as a case-mix adjuster variable on the basis that:

- the income domain score from the Index of Multiple Deprivation is a reliable measure of deprivation
- a theoretical and empirical relationship between deprivation and stage at diagnosis exists
- as the indicator is used to measure performance, failing to adjust for deprivation would mean CCGs serving more deprived populations being at an unfair disadvantage
- it would be consistent with other official statistics that account for deprivation (for example, survival analyses)
- the crude measure would be published alongside the case-mix adjusted measure. This will avoid 'masking' inequalities as the crude measure of CCGs can be compared with other CCGs with similar deprivation profiles

Methodologies for case-mix adjustment

Methodologies for case-mix adjustment include direct standardisation, indirect standardisation, and multivariable regression-based approaches. In direct standardisation, the probability of an outcome for the healthcare-related organisation is calculated for every combination of the case-mix variables. The specific probability of an outcome of the

study population is then applied to a standard population. Indirect standardisation involves comparing the number of observed events against the number expected if a set of standard case-mix specific event rates is 'weighted' by the local population case-mix.

Multivariable regression-based approaches can be advantageous as they overcome difficulties caused by lack of data within some case-mix combinations and difficulties in drawing comparisons between populations with very different population characteristics.

The data comprising the current analysis is clustered by CCG. Clustered data arises when the records (in our case patients) comprising the dataset can be classified into a number of different groups (in our case CCGs). Each cluster contains individual patients which gives the data a 'hierarchical' structure. A correlation between patients in the same cluster (intra-cluster correlation) exists as individuals within the same cluster are likely to have more similar characteristics than individuals from different clusters. Fixed- and random-effects models are statistical approaches developed to account for individual differences within clustered data.

Estimation of performance

Regression modelling was used to establish case-mix adjusted performance estimates for each CCG. The steps undertaken are:

1. Estimation of CCG effect for 'percentage of cancers diagnosed at stages 1 and 2' independent of population case-mix for each time period.
2. Generation of predicted case-mix adjusted estimates for 'percentage of cancers diagnosed at stages 1 and 2' for each CCG for each time period.
3. Generation of predicted case-mix adjusted estimates applied to the baseline population to allow direct comparisons over time for each CCG.
4. Estimation of reliability for the estimates of 'percentage of cancers diagnosed at stages 1 and 2' for each CCG and each time period.

Each of the steps undertaken to produce the case-mix adjusted 'percentage of cancers diagnosed at stages 1 and 2' indicator are based on a previously used methodology and described in more detail below.[4]

Step 1. Estimation of healthcare-related organisation effect

[4] Barclay M, *et al* (2019). The influence of patient case mix on public health area statistics for cancer stage at diagnosis: a cross-sectional study, *European Journal of Public Health*, https://doi.org/10.1093/eurpub/ckz024

Logistic regression is a class of regression where explanatory variables (or case-mix variables) are used to model the odds of an outcome occurring. This model can be used to predict the probability, or chance, of the outcome occurring for a person with specific case-mix characteristics. The logistic regression model was selected for this analysis as the outcome is binary (for example, ‘stages 1 and 2’ and ‘stages 3 and 4’. A multivariable logistic regression model was developed which included the indicator variable (cancer diagnosed at stages 1 and 2) and the case-mix variables (sex, age, cancer site, and deprivation). The CCG was included as a fixed-effect.

Step 2. Predicted scores

Previously fitted logistic regression models can be used to predict the probability of an event (diagnosis of cancer at stages 1 and 2) for individuals with different levels of each variable included in the model. By using the models developed in step 1, we can predict the percentage of patients that would be diagnosed with cancer at stages 1 and 2 in each CCG, had the mix of patients in that CCG been the same as the whole country. Metrics such as these can aid interpretation and create more tangible output from a regression model.

The postestimation Stata command ‘margins’ was used to obtain predicted ‘percentage of cancers diagnosed at stages 1 and 2’ for each CCG after adjusting for case-mix. The associated upper and lower 95% confidence intervals were also calculated using the Delta method which calculates the approximate probability distribution for a function of an asymptotically normal statistical estimator from knowledge of the limiting variance of that estimator.

Step 3. Applying estimates to baseline

Direct comparison of performance indicators across different time points can be misleading due to changes of population characteristics over time (cohort effects). Anchoring techniques can be used as a tool to facilitate comparisons over time. The estimates of the current population are applied to the patient characteristics of the nominated ‘baseline’ population. This allows demonstration of whether observable improvements are attributable to earlier diagnosis, rather than a different population case-mix over time. Unanchored estimates assume there is no population change over time. Although the absolute value of the indicator may change slightly through anchoring, the rank of the CCG does not change.

The following steps were undertaken to apply healthcare-related organisation estimates to the baseline:

1. Definition of ‘baseline’ population.
2. Definition of ‘current’ population.
3. Calculation of case-mix adjusted fixed-effects model using data related to ‘current’ population.

4. Estimates from ‘current’ population applied to ‘baseline’ population.
5. Calculation of case-mix adjusted percentage of cancers diagnosed at stages 1 and 2 by organisation applied to the baseline year (See: Step 2. Predicted scores).

For annual estimates, the baseline population is defined as people being diagnosed with cancer in year 2014. The year 2014 was selected as this was the first year where staging completeness stabilised. For 3-year rolling average estimates, the baseline population is defined as people diagnosed in years 2014 to 2016. Although staging completeness was good enough to be included for the 2013 to 2016 rolling average estimates (median: 84.1%), the years 2014 to 2017 were selected to improve the reliability of the case-mix adjusted estimates as completeness was better (median: 87.8%).

Step 4. Organisational-level reliability

The statistical reliability of a measure indicates its reproducibility (consistency) in repeated measurement and robustness to random measurement error. Reliable indicators can help classify organisational performance and enable accurate targeting of improvement efforts. In this case, reliability can be used to indicate the extent to which the values of the case-mix adjusted ‘percentage of cancers diagnosed at stages 1 and 2’ indicator reflect true differences between CCGs, as opposed to random variation.

Spearman-Brown (organisational-level) reliability is calculated using the following equation:

$$\frac{\sigma^2\text{organisation–to–organisation}}{(\sigma^2\text{organisation–to–organisation}) + (\sigma^2\text{organisation–specific–error})}$$

- σ^2 organisation-to-organisation variance is a measure of the true variation in case-mix adjusted proportions between organisations in the cohort

- σ^2 organisation-specific-error reflects the uncertainty for an individual organisation due to the size of sample used to make an estimate

The observed variance in organisational scores include a contribution from both the true variation in proportions and the organisation-specific-errors. Further explanation is provided here.[5]

[5] Abel G, Elliott M (2019). Identifying and quantifying variation between healthcare organisations and geographical regions: using mixed-effects models. BMJ Quality & Safety doi: 10.1136/bmjqs-2018-009165

Reliability of binary indicators depends on 3 factors:

1. **Unit sample size**, with a higher sample size leading to more precise unit score estimates and thus increasing reliability.
2. **Unit score**, with percentage scores closer to 50% leading to smaller within-unit variances on the log odds scale for the same sample size, thus leading to more precise unit score estimates and thus increasing reliability.
3. **Between-unit variance**, with larger between-unit variances making it easier to distinguish units with the same absolute precision of estimated score, thus increasing reliability.

Reliability takes a value between 0 and 1, with higher values denoting more reliable indicators. Low reliability indicates that chance due to small numbers is having an unduly high influence on the observed performance measure. It has been reported that a reliability of 0.7 is often required for public reporting of indicators, while a reliability of 0.9 may be required for pay-for-performance use.

To calculate reliability for the 'percentage of cancers diagnosed at stages 1 and 2' value for each CCG the following steps were taken:

1. A logistic model was run which contained the case-mix variables and the CCG as a random-effect in the model
2. The post-estimation Stata command 'predict' was used to estimate the empirical-Bayes prediction for each CCG included within the random-effects model. Empirical Bayes approaches borrow information from the distribution of performance across all organisations to make more accurate inferences about the performance of individual organisations
3. Maximum likelihood provider estimates were calculated from a case-mix adjusted model with the CCG as a fixed-effects (see Step 2. Predicted scores)

Differences between the empirical Bayes estimates and the Maximum Likelihood estimates was used to estimate the reliability following previous work.[6]

[6] Abel G, Elliott M (2019). Identifying and quantifying variation between healthcare organisations and geographical regions: using mixed-effects models. BMJ Quality & Safety doi: 10.1136/bmjqs-2018-009165

Output

The ‘percentage of cancers diagnosed at stages 1 and 2’ indicator is presented for the eligible years as an interactive web application, with figures presented as percentages and an accompanying line graph to show variation over time (CancerData). The web application presents the overall percentage of 21 sites of cancers (Table 1) that are recorded as presenting at stages 1 or 2 (as opposed to stage 3 or 4) nationally, and by CCG level.

The output provides annual and 3-year rolling averages (which combines the result for the most recent year with those from the previous 2 years). The data are reported by different time periods to suit the needs of different stakeholders, but the reliability allows the user to understand the impact of choosing one timeframe or another.

The following data are presented in the worksheet for each CCG:

- annual count of cancer by cancer site and stage (stages 1, 2, 3, and 4)
- annual count of cancers diagnosed at stages 1 and 2
- annual count of cancers with a valid recorded stage (stages 1 to 4)
- annual percentage of all new cases of cancer diagnosed at stages 1 and 2 is calculated as a percentage of all new cases of cancer diagnosed at any stage (1, 2, 3 and 4)
- percentage for a rolling 3-year period (average of the last 3 years) (to account for chance variation due to small numbers in a time series)
- case-mix adjusted annual indicator applied to baseline population reported as an adjusted percentage
- reliability (between 0 and 1) for values of the case-mix adjusted annual indicator
- case-mix adjusted 3-year rolling indicator applied to baseline population
- reliability for case-mix adjusted 3-year rolling indicator values

The web-based application includes a tab with a brief description of the indicator, outline of cancer sites, time periods, and a summary of the methodology. This includes further contact details for more information, and a link to other relevant ‘stage at diagnosis’ related resources. Consistent with previous outputs, the data is hosted on the CancerData website.

Notes on data interpretation

Some cancer sites are excluded from the indicator due to higher levels of missing stage at diagnosis data. They were excluded on the basis that their inclusion would compromise the statistical robustness of the measure.

The grouping of stages 1 and 2 in the numerator is intended to be an indication of the proportion diagnosed at an earlier stage when there might be more effective treatment options, improved quality of life, and increased survival following diagnosis. However, treatment decisions and responses, and other factors, will influence outcomes, not just stage at diagnosis alone.

The definition of cancer sites included within this publication has been updated from previous definitions. For this reason, we are publishing a back-series for diagnoses from 2013 onwards. As a result, the crude percentages presented in the workbook are not directly comparable to previous publications related to the ‘percentage of cases of cancer diagnosed at stages 1 and 2’ indicator.

Case-mix adjusted ‘percentage of cancer diagnosed at stages 1 and 2’ indicator makes adjustments for the following patient-level characteristics: age, sex, cancer site and deprivation as defined by the income score of the Index of Multiple Deprivation.

The case-mix adjusted values of the ‘percentage of cancers diagnosed at stages 1 and 2’ are applied to the characteristics of the baseline population. This is to enable comparisons of changes to ‘percentage of cancers diagnosed at stages 1 and 2’ indicator which are unrelated to changes to the underlying patient characteristics over time.

Definition of cancer stage is agreed internationally by professional bodies. Although not anticipated, major changes to definitions could undermine meaningful comparisons over time.

Smaller populations when analysing at a Clinical Commissioning Group level creates wider confidence intervals. The reliability measure accompanying the output provides an indication of the robustness of the value.

Improvement in recording of stage continues to be part of the work programme for the National Cancer Registration and Analysis Service.

Similar existing indicators

The National Cancer Transformation Programme strategy and progress report for achieving world-class cancer outcomes cancer survival by stage at diagnosis for England.

Independent Cancer Taskforce Strategy set out 6 strategic priorities including reducing CCG variation and the ambition to increase 12 month survival to 75% by 2020 for all cancers combined.

Public Health Outcomes Framework (PHOF) currently publishes the cancers diagnosed at stages 1 and 2 at a variety of geographies (including local authority and regions). The definition currently comprises new cases of cancer diagnosed at stage 1 and 2 as a proportion of all new cases of cancer diagnosed (specific cancer sites, morphologies and behaviour: invasive malignancies of breast, prostate, colorectal, lung, bladder, kidney, ovary, uterus, non-Hodgkin lymphomas and invasive melanomas of skin). For publications including 2018 diagnoses onwards, the definition will be aligned to the complete case approach presented in the current document.

NHS Outcome Indicator Set publishes the following variables the percentage of all cases of cancer for which a valid stage is recorded by CCG, cancers detected at stage 1 or 2 (as defined as above), and record of lung cancer stage at decision to treat. By May 2020, the definition will be aligned to the complete case approach presented in the current document.

United Kingdom and Ireland Association of Cancer Registries (UKIACR) publishes data related to performance indicators, including stage complete by cancer site groups, for each of the cancer registries.