NDRS
NATIONAL DISEASE REGISTRATION SERVICE

NHS England

Methodology: Case-mix adjusted percentage of cancers diagnosed at stages 1 and 2 in England

For publications August 2025 onwards

About the NDRS

The National Disease Registration Service (NDRS) is part of NHS England. Its purpose is to collect, collate and analyse data on patients with cancer, congenital anomalies, and rare diseases. It provides robust surveillance to monitor and detect changes in health and disease in the population. NDRS is a vital resource that helps researchers, healthcare professionals and policy makers make decisions about NHS services and the treatments people receive.

The NDRS includes:

- the National Cancer Registration and Analysis Service (NCRAS) and
- the National Congenital Anomaly and Rare Disease Registration Service (NCARDRS)

Healthcare professionals, researchers and policy makers use data to better understand population health and disease. The data is provided by patients and collected by the NHS as part of their care and support. The NDRS uses the data to help:

- understand cancer, rare diseases, and congenital anomalies
- improve diagnosis
- plan NHS services
- improve treatment
- evaluate policy
- improve genetic counselling

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Methodological changes

The methodology for the Case-mix adjusted percentage of cancers diagnosed at stages 1 and 2 in England publication has had several updates. The first publication to be affected by these changes will be the August 2025 release and will cover the period 2013 to 2022.

- Cancer groups: To better reflect the variety of cancers that patients are diagnosed and treated with, this publication now uses the National Disease Registration Service (NDRS) standard cancer definitions. The groups are defined using either ICD-O-2, ICD-O-3, or ICD-10 dependent on the cancer group. See section 'Cancer groups'.
- Geography: Integrated Care Systems were legally established on 1 July 2022, covering all of England. Each ICS has an Integrated care board (ICB) which are NHS organisations responsible for planning health services for their local population. ICBs, NHS trusts and NHS foundation trusts are working in collaboration with Cancer Alliances to deliver approaches to help achieve the NHS Long Term Plan ambition of diagnosing 75% of patients at stage 1 or 2 by 2029. To help ICBs monitor cancer activity and groups facing inequalities, this publication will now present the Case-mix adjusted percentage of cancers diagnosed at stages 1 and 2 (CMA) indicator at ICB level.
- Inclusion criteria: Due to an increase in geographical size, cancer groups will be included in the CMA indicator if 1,000 people are diagnosed with that cancer each year in England (this was previously 1,500 people).
- Statistical software: To comply with Reproducible Analytical Pipeline guidance, we have updated our analysis to use the open-source software, R. The code will be published on Github.

Introduction

Stage at diagnosis is a measure of the anatomical extent of a cancer at diagnosis. For solid tumours, a higher stage number means the cancer has extended further. As a cancer progresses through the stages of diseases, there are often fewer treatment options. 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 Integrated Care Boards (ICBs) 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, ICBs) delivering the highest quality of care and those that may need to improve quality. The National Institute for Health and Care Excellence (NICE) has an early cancer diagnosis strategy. The NICE 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.

Patients who are diagnosed with cancer at an earlier stage can typically be offered more effective treatment options, an improved quality of life and increased survival compared with patients diagnosed with the same cancer at a later stage. National public health interventions, such as screening programmes, information and educational campaigns (for example, Be Clear on Cancer and Help Us, Help You), 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. This has been replaced with the case-mix adjusted indicator which includes a back-series for diagnoses from 2013 onwards.

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.

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, significant characteristics recorded in our data. This facilitates fairer comparisons of outcomes between ICBs 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 an ICB if:

- cancers less likely to be diagnosed at stages 1 and 2 occur more frequently in the ICB than the national average, leading to the ICB's unadjusted performance indicator looking worse than it is
- cancers more likely to be diagnosed at stages 1 and 2 occur more frequently in the ICB than the national average, leading to the ICB's unadjusted performance indicator looking better than it 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, geographical areas with a higher than average occurrence of breast cancer will appear 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 earlier stage) and lung cancer (more common in more deprived areas and more frequently diagnosed at an advanced stage).

Statistical 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. Previous analyses using 12 months of data has shown that observed (apparent) variability of a crude indicator is dominated by chance. This reflects insufficient sample size, in addition to variability between ICBs. An indicator that is unreliable will more frequently classify ICBs into high or low ranks by chance.

Strengths and limitations

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

- users can make fairer comparisons between ICBs 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 stageable 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 further cases may be added after registration years are published. 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

Methodology

Data source

The indicator uses information routinely collected by the National Disease Registration Service (NDRS), NHS England. 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 87% of all cases of cancer. Although some exceptions by cancer group exist, data quality had continued to improve in terms of completeness. Cancer registrations are usually just over 1-year behind real time, so 2019 cancer registrations would normally have been published in early 2021. Due to the impact of the COVID-19 pandemic on both clinical and data quality arrangements, the ability to obtain stage data for cancer registrations was reduced for the 2019 to 2022 diagnosis years. In 2019, the proportion of stageable cancer diagnoses with a registered stage fell from 85% in 2018 to 76%. For the 2020 diagnosis year, this increased to 80% then fell to 78% in 2021 and 75% in 2022.

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. Typically, 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 some cancers, a site/group-specific staging system is used instead of TNM:

- International Federation of Gynaecology and Obstetrics (FIGO) staging for gynaecological (ovary, cervical and uterus) cancers
- Ann Arbor staging for non-Hodgkin lymphomas
- International Staging System (ISS) for myelomas
- Binet staging for chronic lymphocytic leukaemia (CLL)
- Chang staging for Medulloblastoma
- International Neuroblastoma Risk Group staging system (INRGSS) for neuroblastoma
- National Wilms Tumour Study staging for Wilms tumours.

For these cancer sites/groups, TNM stage has been used where the site/group-specific stage was unknown. Cervical cancer is the exception, whereby a cancer is only considered staged if a FIGO staging value is available.

These site/group-specific staging systems can be mapped to TNM as follows:

- Stage 1 = TNM stage 1, FIGO stage 1, Ann Arbor stage 1
- Stage 2 = TNM stage 2, FIGO stage 2, Ann Arbor stage 2
- Stage 3 = TNM stage 3, FIGO stage 3, Ann Arbor stage 3
- Stage 4 = TNM stage 4, FIGO stage 4, Ann Arbor stage 4

For this publication, cancers that have been staged in an alternate system (Binet; ISS; Chang; INRGSS; NWTS) and cannot be mapped to TNM, have been included as two separate categories

- Staged – other early = Binet A-B; ISS 1-2; Chang M0; INRGSS L1-L2; NWTS 1-2
- Staged – other advanced = Binet C; ISS 3-4; Chang M1-M4; INRGSS M&MS; NWTS 3-5

Both TNM staging system and site/group-specific staging systems can be mapped to early (referred to as stages 1 & 2) or advanced stage (referred to as stages 3 & 4) as follows:

- Stages 1 & 2 = Stage 1, Stage 2, Staged – other early
- Stages 3 & 4 = Stage 3, Stage 4, Staged – other advanced

Cases where staging information was unknown or not available, or unstageable 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 Clinical Commissioning Groups (CCGs).

The staging classification system (TNM) was updated to version 8 and introduced for all cancers (except head and neck) registered since January 2018 and for head and neck cancers registered since January 2019. 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.

Table 1. Cancer sites with changes to TNM classification

Site	Site (ICD-10) for TNMv7	Site (ICD-10) for TNMv8
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

Cancer groups

From 2013, cancers have been registered by the National Disease Registration Service using ICD-O-3, these were previously coded in ICD-10 and ICD-O2. The ICD-O-3 coding system allows for better reporting by type of cancer. To better reflect the variety of cancers that patients are diagnosed and treated with, this publication introduces new cancer groupings. The standard cancer groupings used by NDRS are available on our website and are regularly reviewed. For definitions used in a specific publication, please see the data download corresponding to the years of interest. The first 'Case-mix adjusted percentage of cancers diagnosed at stages 1 and 2 in England' publication to be affected by this change will be the August 2025 release, which will cover the period 2013 to 2022.

Cancer groups are chosen for the CMA indicator based on two main criteria:

- An average of 70% of cases have a recorded stage at diagnosis over the latest three years
- At least 1,000 people are diagnosed with that cancer each year in England (based on data from 2013)

Only cancers that can be staged using a recognised system are included in the CMA indicator. These are cancers that have a valid staging system and are part of the UKIACR stage performance indicator. Currently, only malignant tumours are included,

but we are reviewing non-malignant tumours with valid staging systems for possible inclusion.

We review these criteria—and the definitions of which cancers are stageable—each year. The full list of included cancer groups and stageable cancers is published annually with the release of the 'Case-mix adjusted percentage of cancers diagnosed at stages 1 and 2 in England'.

In addition to the CMA indicator, this publication also presents the unadjusted 1-year rolling percentage of cancers diagnosed at stages 1 and 2 — also known as the 75% ambition indicator — at a national level and by Cancer Alliance. This indicator uses the same cancer groups as the CMA indicator.

We also show the unadjusted percentage of cancers diagnosed at each stage, broken down by cancer group and deprivation quintile. This includes the cancer groups used in the CMA indicator, as well as an 'Other' group. The 'Other' group includes cancers that are part of the NDRS standard cancer groupings but did not meet the criteria for inclusion in the CMA indicator.

Some cancer groups are excluded from the 'Other' group because they contain very few stageable cancers. These excluded groups are:

- Registrable non-invasive skin
- Keratinocyte tumours
- Ungrouped uncertain/unknown tumours
- Ungrouped in situ tumours
- Other malignant tumours
- Sarcomas

The change to use NDRS standard cancer groups results in an increase in the number of unstageable cancers for some cancer groups due to the inclusion of non-malignant cancers. Particularly notable cancer groups are 'Bladder', 'Renal pelvis' and 'Other'. This does not affect the CMA indicator as only stageable cancers are included.

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.

Therefore, 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 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 as in Table 2 could be misleading and clinically irrelevant. Some of the main issues raised were generic to all cancer sites, and can be briefly described as:

- the associated outcomes of 'early' stage disease are heavily influenced by treatment decisions and responses, rather than by a stage cut-off
- 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, the Operational Group took the pragmatic decision to maintain the use of stage 1 and 2 as the numerator for the stage at diagnosis indicator.

Inclusion criteria

The following eligibility criteria were used to select tumour records from the National Cancer Registration Dataset 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 gender at diagnosis
- neither prostate and testicular cancer in people whose recorded gender is female nor gynaecological cancers in people whose recorded gender is male areconsidered for inclusion to prevent the identification of individuals
- complete and known stage at diagnosis
- recorded diagnosis in years 2013 onwards
- stageable cancers as defined by the UKIACR Performance Indicators selection criteria, in addition to at least 1,000 cancers are diagnosed in England per year from 2013 onwards (the selection criteria utilises 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 cancer sites defined in Table 1.

Denominator

Cases of cancer diagnosed at any known stage (TNM 1-4, site-specific systems) for the cancer sites defined in Table 1.

Percentage

This is the numerator divided by the denominator as defined above.

Confidence intervals

The lower and upper 95% confidence intervals are published along 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 that the indicator value presented is likely to be a less precise estimate of 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 ICB for 'percentage of cancers diagnosed at stages 1 and 2' indicator. Deprivation is a suitable case-mix adjuster variable on the basis that:

- 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 ICBs 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 ICBs can be compared with other ICBs with similar deprivation profiles

The Index of Multiple Deprivation (IMD) is the official measure of relative deprivation for small areas in England and is based on the postcode of residence at diagnosis. The IMD was grouped into quintiles, which were weighted so that the quintiles were equal in terms of the number of Lower-layer Super Output Areas (LSOAs).

The income domain score from the IMD was previously used as a case-mix adjuster variable. Deprivation defined solely by the income domain may not truly reflect the deprivation experienced by individuals who may suffer from other forms of deprivation measured by the other six domains (employment deprivation; education, skills and training deprivation; health deprivation and disability; crime; barriers to housing and services; living environment deprivation). Therefore, for publications using 2019 cancer registrations onwards, the full Index of Multiple Deprivation has been used.

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 ICB. Clustered data arises when the records (in our case patients) comprising the dataset can be classified into several different groups (in our case ICBs). 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 ICB. The steps undertaken are:

1. Estimation of ICB 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 ICB 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 ICB.
4. Estimation of reliability for the estimates of 'percentage of cancers diagnosed at stages 1 and 2' for each ICB 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.

Step 1. Estimation of healthcare-related organisation effect

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 (i.e. '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 (gender, age, cancer site, and deprivation). The ICB was included as a fixed effect as this remains constant across individuals.

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 ICB, had the mix of patients in that ICB 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 R function 'Prediction' from the 'Prediction' package was used to obtain predicted 'percentage of cancers diagnosed at stages 1 and 2' for each ICB 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 ICB 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 ICBs, as opposed to random variation.

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

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

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

Reliability of binary indicators depends on 3 factors:

Unit sample size, with a higher sample size leading to more precise unit score estimates and thus increasing reliability.

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.
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 ICB the following steps were taken:

A logistic model was run which contained the case-mix variables and the ICB as a random-effect in the model. The post-estimation R function 'Prediction' from the 'Prediction' package was used to estimate the empirical-Bayes prediction for each ICB 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
Maximum likelihood provider estimates were calculated from a case-mix adjusted model with the ICB 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.

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