Cancer Networks are responsible for the management of cancer services in England. They are, in principle, logical units for the analysis of cancer survival, since for most patients, the entire pathway of referral, diagnosis and treatment is likely to be contained within the territory of a Cancer Network.

This study investigates the implications of using each patient’s Cancer Network of residence as the geographic basis of cancer survival indicators for the Department of Health and the National Health Service. Incidence data from the National Cancer Registry were used to estimate survival from cancers of the breast and colon diagnosed in adults during 1996–98.

Survival estimates varied little between Cancer Networks. They were generally stable over time. We conclude that Cancer Networks are suitable geographic units for the analysis of cancer survival as a NHS performance indicator.

Introduction
Cancer survival statistics provide useful information about the local performance of the National Health Service (NHS) for the resident populations of the various health and administrative geographies in England. In the last few years, Government Office Regions (GOR) and Strategic Health Authorities (SHA) have been the main geographic basis for cancer survival indicators requested by the Department of Health and the National Health Service.

Until the most recent changes to NHS boundaries in April 2006, the 28 SHAs had overall strategic responsibility for the delivery of health care to their resident populations, averaging around two million. From April 2006, the 28 SHAs merged to form ten new SHAs, which resemble, at least in terms of size and boundary, the nine Government Office Regions.

The ten much larger SHAs that arose from these boundary changes are too large to demonstrate geographical variations in cancer survival to the requisite level of detail. The resident populations of the new SHAs range from about 2.5 to 7.5 million. The 152 newly configured Primary Care Trusts (PCTs), although much larger than the previous 302, are still too small to be used as geographic units for monitoring cancer survival. The smallest PCT has a resident population of just 90,000, and the statistical stability of survival estimates for such small areas is not adequate for reliable monitoring of performance.

As a consequence of this re-organisation, Cancer Networks have been proposed as an alternative geographic unit for the comparison of cancer survival statistics.

In principle, Cancer Networks are more logical units of analysis for cancer survival than SHAs, since for the vast majority of cancer patients,
the entire patient pathway of referral, diagnosis and treatment will be contained within the territory of the Cancer Network in which they reside. There are currently 34 Cancer Networks, each serving a population of around one to two million people. Cancer Networks were established in 2001 under the NHS Cancer Plan. They bring together health service commissioners and providers, the voluntary sector and local authorities in a defined territory, and they are responsible for the entire range of cancer management services for the population of that territory.

Despite reconfiguration of a few boundaries in October 2002, Cancer Networks have been more or less stable since their creation in 2001. In a climate of frequently changing NHS administrative geography, comparison of cancer survival estimates with previous years can become meaningless when the geographical units of analysis no longer refer to the same population. The recent and likely future stability of the Cancer Networks should permit more reliable and more useful monitoring of geographical comparisons and temporal trends in cancer survival. (Note: a few mergers have in fact occurred among the 34 Cancer Networks in existence when this article was written.) In contrast to SHAs however, Cancer Network boundaries are not always coterminous with GORs and do not easily aggregate to them, or indeed to any other health or administrative geography.

The populations covered by Cancer Networks are large (1–2 million people), and comparable with those covered by population-based cancer registries in many other countries. Statistical stability of cancer survival indicators will be greater than for smaller geographic units, such as PCTs.

Although the number of Cancer Networks in England today (34) is similar to the number of SHAs up to 2006 (28), the range of resident population sizes differs significantly. The smallest SHA had a resident population of approximately 1.15 million, but seven of the 34 Cancer Networks have a resident population of fewer than one million (Table 1). Cancer Networks have a five-fold range in population size.

Given the comparatively small population in some Cancer Networks, this article explores the stability of one- and five-year survival estimates for two common cancers, and examines the extent to which the Cancer Network of residence can be reliably used as the geographic basis for NHS cancer survival indicators.

### Methods and data

The incidence data used in this article are taken from the National Cancer Registry at the Office for National Statistics (the National Cancer Intelligence Centre). The analysis included adults (15–99 years) resident in each of the 34 Cancer Networks in England who were diagnosed with cancer of the breast (women only, ICD-10 code C50) or colon (men and women, ICD-10 code C18) during 1996–98, and were followed up until 31 December 2003. Data on at least five years of follow-up were available for all patients included in the analyses.

Cancer registration in England is conducted by eight regional registries which collect and collate data on cancers resident in their area, and submit a standard dataset on these registrations to the National Cancer Intelligence Centre. All adults resident in England who were diagnosed during 1996–98 with breast or colon cancer as a first, primary, invasive, malignant neoplasm were eligible for inclusion in the analysis. Records of benign and in situ tumours, and those of uncertain behaviour, were considered ineligible. Patients known to have had a previous invasive primary malignancy at any site (except non-melanoma skin cancer) at any time since 1971 were excluded.

### Relative survival

One- and five-year relative survival estimates for England by age and calendar year of diagnosis were estimated. Relative survival is the ratio of the observed (absolute) survival of the cancer patients and the survival that would have been expected if those patients had experienced only the same age- and sex-specific mortality rates (background mortality) as the general population from which they are drawn. It provides a measure of patient survival corrected for the effect of independent causes of death, other than the cancer of interest. The background mortality is derived from life tables. Since background mortality varies substantially between regions of the country, and in certain age ranges such variations are wide, we used separate life tables for each region in our survival analysis.

Complete life tables by single year of age (up to 99 years), sex and region (GOR) were derived from the numbers of deaths in England during the period 1997–99 and from mid-year population estimates for 1998. These life tables were used to represent background mortality in England during the period 1996–2003.

The maximum likelihood approach for individual records was applied to estimate both observed and relative survival, using an algorithm.

### Table 1

<table>
<thead>
<tr>
<th>Rank</th>
<th>Cancer Network</th>
<th>Population</th>
<th>Rank</th>
<th>Strategic Health Authority</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Greater Manchester &amp; Cheshire</td>
<td>3.0</td>
<td>1</td>
<td>Trent</td>
<td>2.7</td>
</tr>
<tr>
<td>2</td>
<td>Mount Vernon</td>
<td>2.8</td>
<td>2</td>
<td>Greater Manchester</td>
<td>2.5</td>
</tr>
<tr>
<td>3</td>
<td>Pan Birmingham</td>
<td>2.5</td>
<td>3</td>
<td>Surrey &amp; Sussex</td>
<td>2.5</td>
</tr>
<tr>
<td>4</td>
<td>Yorkshire</td>
<td>2.5</td>
<td>4</td>
<td>Cheshire &amp; Merseyside</td>
<td>2.3</td>
</tr>
<tr>
<td>5</td>
<td>Northern</td>
<td>2.2</td>
<td>5</td>
<td>Birmingham &amp; the Black Country</td>
<td>2.3</td>
</tr>
</tbody>
</table>

**Largest populations**

**Smallest populations**

1. SHA boundaries before the reconfiguration in 2006.
2. 2002.

Sources: Cancer Services Catchment Population Data, National Cancer Services Analysis Team; Office for National Statistics mid-year population estimates.
Relative survival is the ratio of the survival actually observed in the cancer patients, and the survival that would have been expected if they had only experienced the same mortality rates, in the calendar period in question, at each age and for each sex, as those observed in the general population from which they are drawn. It is usually expressed as a percentage (for example, 0.6/0.8=75 per cent). It can be interpreted as the proportion of survivors after correction for other causes of death. The general population (background) mortality rates are taken from life tables. Cancer Survival Trends should be consulted for further details of the methods. The proportion of survivors who have a normal life expectancy (the proportion 'cured') would be the ideal outcome measure, but methods remain under development, and relative survival estimates at one and five years have become the conventional measures of short- and medium-term outcome of cancer treatment.

Statistical reliability

The statistical precision of survival estimates depends on the number of events (deaths) that contribute to the estimate. This depends in turn both on the number of patients diagnosed (which depends on the incidence rate and the size and age-sex structure of the underlying population) and on the lethality of the tumour, which changes with time since diagnosis, but also varies with age and sex, and over calendar time, as well as between geographic areas. We explored the range and variability between Cancer Networks in the number of deaths for each cancer included in the analysis (those occurring within five years of diagnosis) as a guide to the reliability of the survival estimates.

We estimated the relative survival for each calendar year as well as for the three-year period 1996–98 for each cancer. The stability of the survival estimates across the three years of incidence was assessed as a measure of ‘external’ reliability. We used the median value as a measure of central tendency among the 34 estimates of survival, and the survival that would have been expected if they had only experienced the same mortality rates, in the calendar period in question, at each age and for each sex, as those observed in the general population from which they are drawn. It is usually expressed as a percentage (for example, 0.6/0.8=75 per cent). It can be interpreted as the proportion of survivors after correction for other causes of death. The general population (background) mortality rates are taken from life tables. Cancer Survival Trends should be consulted for further details of the methods. The proportion of survivors who have a normal life expectancy (the proportion 'cured') would be the ideal outcome measure, but methods remain under development, and relative survival estimates at one and five years have become the conventional measures of short- and medium-term outcome of cancer treatment.

The difference in the number of deaths within five years of diagnosis between Cancer Networks (n=34) and Strategic Health Authorities (n=28) is a consequence of the different resident population sizes.

### Table 2

<table>
<thead>
<tr>
<th>Year</th>
<th>Median</th>
<th>Interquartile range</th>
<th>Cancer Network</th>
<th>Median</th>
<th>Interquartile range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>239</td>
<td>196</td>
<td>333</td>
<td>302</td>
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<tr>
<td>1997</td>
<td>252</td>
<td>196</td>
<td>335</td>
<td>324</td>
<td>261</td>
</tr>
<tr>
<td>1998</td>
<td>238</td>
<td>186</td>
<td>333</td>
<td>285</td>
<td>250</td>
</tr>
<tr>
<td>1996–98</td>
<td>725</td>
<td>574</td>
<td>976</td>
<td>989</td>
<td>751</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Median</th>
<th>Interquartile range</th>
<th>Cancer Network</th>
<th>Median</th>
<th>Interquartile range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>128</td>
<td>96</td>
<td>175</td>
<td>165</td>
<td>121</td>
</tr>
<tr>
<td>1997</td>
<td>127</td>
<td>98</td>
<td>174</td>
<td>163</td>
<td>126</td>
</tr>
<tr>
<td>1998</td>
<td>120</td>
<td>95</td>
<td>175</td>
<td>150</td>
<td>128</td>
</tr>
<tr>
<td>1996–98</td>
<td>369</td>
<td>293</td>
<td>515</td>
<td>472</td>
<td>380</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Median</th>
<th>Interquartile range</th>
<th>Cancer Network</th>
<th>Median</th>
<th>Interquartile range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>113</td>
<td>94</td>
<td>178</td>
<td>165</td>
<td>120</td>
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<tr>
<td>1997</td>
<td>120</td>
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<tr>
<td>1998</td>
<td>125</td>
<td>96</td>
<td>166</td>
<td>158</td>
<td>126</td>
</tr>
<tr>
<td>1996–98</td>
<td>364</td>
<td>294</td>
<td>517</td>
<td>477</td>
<td>393</td>
</tr>
</tbody>
</table>

To summarise the variability of a set of survival estimates, we divide the entire range of values, from highest to lowest, into centiles (one-hundredths). The median is the value at the middle of the distribution (the central tendency) and is thus the 50 centile value. The interquartile range is one measure of the dispersion of the estimates (how widely they range around the median), and is the range between the 25 and 75 centiles of the distribution. The standard error is another measure of the dispersion of the observed values around the central value (mean, or average). The coefficient of variation is a standardised measure of this dispersion, expressed as a percentage, which does not depend on the actual value of the average.
For breast cancer in women, the median one- and five-year relative survival estimates among the 34 Cancer Networks improved steadily by approximately 1.0–1.5 percentage points between successive years of incidence 1996, 1997 and 1998. Median one-year survival estimates increased by 0.7 percentage point (from 93.8 per cent to 94.5 per cent) between 1996 and 1997, and by 0.6 percentage point (from 94.3 per cent to 95.1 per cent) between 1997 and 1998. For five-year survival, estimates increased by 1.6 percentage points (from 78.8 per cent to 80.4 per cent) between 1996 and 1997, and by 1.0 percentage point (from 80.4 per cent to 81.4 per cent) between 1997 and 1998 (Table 3). This steady pattern of improvement of survival estimates is consistent with the national picture.

For colon cancer in each sex, the year-on-year survival estimates were slightly more variable. For example, median one-year survival estimates in men decreased by 1 percentage point (from 68.5 per cent to 67.5 per cent) between 1996 and 1997, and then increased by 2.7 percentage points (from 67.5 per cent to 70.2 per cent) between 1997 and 1998. The interquartile ranges also reflect this variability: they were wider for colon cancer than for breast cancer (Table 3).

Survival estimates based on a three-year period (1996–98) were more precise than the annual estimates, with median standard errors of 0.6 or 1.0 for women with breast cancer (for one- and five-year survival respectively), and of 2.0 and 2.5 for colon cancer in each sex. Variability between Cancer Networks was about half that observed for annual estimates, with very narrow interquartile ranges (Table 4). Variability in the annual estimates of one- and five-year survival in the 34 Cancer Networks was small, with a coefficient of variation of 1 per cent and 2 per cent for breast cancer, and of 5 per cent and 9 per cent for colon cancer. The use of three years of data reduces this variability still further. For breast cancer, the coefficient of variation falls from 1 per cent to 0.6 per cent for one-year survival and from 2 per cent to 1 per cent for five-year survival. For colon cancer, the coefficient of variation falls from 5 per cent to 3 per cent for one-year survival and from 9 per cent to 5 per cent for five-year survival (Table 4).

For survival estimates based on a single year of diagnosis, the median standard error of the estimates among the 34 Cancer Networks for one-year survival for women with breast cancer was around 2 per cent for breast cancer in women and around 3 per cent for colon cancer in each sex (Table 4).

For survival estimates based on a single year of diagnosis, the median standard error of the estimates among the 34 Cancer Networks for one-year survival for women with breast cancer was around 2 per cent for breast cancer in women and around 3 per cent for colon cancer in each sex (Table 4).
Table 5

<table>
<thead>
<tr>
<th>Time since diagnosis</th>
<th>Breast cancer (women)</th>
<th>Colon cancer (men)</th>
<th>Colon cancer (women)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>1.4</td>
<td>5.5</td>
<td>0.7</td>
</tr>
<tr>
<td>Interquartile range</td>
<td>1.8</td>
<td>2.9</td>
<td>7.1</td>
</tr>
<tr>
<td>Mean</td>
<td>4.7</td>
<td>3.4</td>
<td>7.9</td>
</tr>
<tr>
<td>Interquartile range</td>
<td>3.1</td>
<td>9.2</td>
<td>5.3</td>
</tr>
</tbody>
</table>

Note: Estimated as the average of the absolute difference (whether positive or negative) in the survival estimates for successive years for a given Cancer Network. For example, a change from 61.0 per cent (1996) to 62.0 per cent (1997) to 60.2 per cent (1998) would imply a change of +1 per cent and then −1.8 per cent, for which the mean annual change would be 1.4 per cent. The table shows the mean and interquartile range among the 34 estimates of this annual fluctuation, for both one- and five-year survival estimates.

5 per cent for colon cancer in both men and women (Table 5). Annual survival estimates for individual Cancer Networks, based on single years of diagnosis, fluctuate much more for colon cancer than for breast cancer. This instability of time trends in survival has implications for the use of annual survival estimates as performance indicators.

The national rankings of individual Cancer Networks on the basis of survival estimates derived from single years of diagnosis were not stable. Rankings fluctuate widely for a small year-on-year change in survival. For example, the annual change in rank for one-year breast cancer survival was dramatic (Figure 1), despite the fact that the example concerns the most steady trend. One Cancer Network, which had the lowest survival for breast cancer in 1996, was ranked second highest in 1998.

Discussion

As previously discussed, Cancer Networks are similar in number to the ‘old’ SHAs, and the survival estimates presented here, for patients diagnosed during 1996–98, are comparable to those published for the 28 Strategic Health Authorities for the same period. In the range of survival estimates for breast and colon cancer in the 34 Cancer Networks in existence at the time of these analyses is fairly narrow, but year-to-year fluctuation in survival estimates occurs within individual Cancer Networks for colon cancer, much more than for breast cancer. Since the annual number of new breast cancer cases is approximately twice that of colon cancer, it will be necessary to aggregate at least two years of colon cancer incidence data to obtain statistically stable results for individual Cancer Networks. Although annual indicators derived from data aggregated over two or more years will overlap in time coverage, which could mask recent changes in survival, it is far more important that reliable estimates of survival are used in the assessment of trends. This has important implications for the interpretation of time trends, especially as it is intended that cancer survival indicators will be updated annually.

This approach can be used with other common cancers but cannot be extended to every cancer, no matter how rare. It is not possible to give explicit guidance for every cancer. This is because the statistical robustness of cancer survival depends on the number of deaths included in the estimate, which depends in turn both on the number of cases (incidence) and the lethality of the tumour (survival), and both of those quantities are subject to geographic variation and to change over time. We chose to examine survival from breast and colon cancer in particular because they are common, but also in part because they may be considered as ‘sentinel’ cancers from the perspective of performance management, since the efficiency of the entire patient pathway from early diagnosis to prompt referral and rapid access to optimal treatment are all known to be of signal importance in achieving optimal outcomes.

The national rankings of individual Cancer Networks on the basis of survival estimates derived from single years of diagnosis were not stable. Rankings can fluctuate widely for a small year-on-year change in survival, because the range of survival estimates between the 34 Cancer Networks is relatively narrow.

Ranking of the Cancer Networks within each of the nine GORs would be even more problematic. There are only a few Cancer Networks in any GOR, and their boundaries are not always coterminous. Ranking of Cancer Networks within a Government Office Region is not advisable.
Previous recommendations that cancer survival indicators for NHS geographies should be ranked within their NHS region (or current equivalent), rather than on a national scale, were based on data for Health Authorities in the 1990s, when there were around 100 such areas. The instability of ranking the 34 Cancer Networks by survival estimates on a national scale is likely to be alleviated by the aggregation of several years of incidence data, because of improved statistical stability. The disadvantage is the interpretation of time trends in the indicator values.

Because survival may differ by age, and the age distribution of cancer patients may be dependant on both time and geography, the age-standardisation of cancer survival estimates is often necessary to enable comparisons to be made between different geographical areas (that is, Cancer Networks and SHAs), and over time. However, given the comparatively small population of some Cancer Networks, it was not possible to use conventional age standardisation as this requires an estimate of survival for each defined age group. Further work is in progress to explore the feasibility of age-adjusting relative survival estimates for Cancer Networks using Hermann Brenner’s alternative approach for less common cancers, or common cancers in small areas.

It should be clear from this discussion that the level and/or the ranking of cancer survival estimates for a given geographic area is not interpretable as a measure of performance in isolation. Persistently low ranking for survival from one cancer, or low ranking for several different cancers, should be used as a warning to seek explanations, and complementary information from other sources.

**Conclusion**

Cancer Networks are suitable as the geographic basis for cancer survival indicators to be used in NHS performance management.

**Key findings**

- Cancer Networks are logical units for the analysis of cancer survival. Survival estimates varied little between Cancer Networks and were stable over time. Cancer Networks should become the preferred geographic unit for the analysis of cancer survival as a NHS performance indicator.
- Within individual Cancer Networks, the year-to-year fluctuation in estimates of cancer survival requires aggregation of at least two years of incidence data to obtain statistically stable results. Such estimates can be used as a performance indicator to show improvement over time within a given Cancer Network.
- The national rankings of individual Cancer Networks on the basis of survival estimates using single years of diagnosis were not stable. For the purpose of bench-marking indicators, that is, to show the position of a given Cancer Network relative to other Cancer Networks, survival estimates should be based on at least three years of diagnosis, even for common cancers.
- Cancer Networks should not be identified as ‘poor performers’ solely on the basis of a low national rank in survival for one particular type of cancer in a given year or period.

**Acknowledgements**

This report, and more generally the utility of cancer survival data for performance management in the National Health Service, would not have been possible without the extraordinary dedication of cancer registry staff in all the regional cancer registries in England in ensuring complete and accurate data collection over many years, and we are happy to ensure due recognition of the importance of their work here.

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8. Cancer Research UK Cancer Survival Group. strel computer program version 5.8 for cancer survival analysis. London School of Hygiene and Tropical Medicine. Available at: www.lshtm.ac.uk/ncedu/cancersurvival/tools/index.htm