Using funnel plots to explore variation in cancer mortality across primary care trusts in South-East England

Elizabeth Davies¹, Vivian Mak¹, Jamie Ferguson², Stephen Conaty³, Henrik Møller¹

¹King’s College London, Thames Cancer Registry, 42 Weston Street, London SE1 3QD, UK
²Lambeth Primary Care Trust, Department of Public Health, 1 Lower Marsh, London SE1 7NT, UK
³Islington Primary Care Trust, 338-346 Goswell Road, London EC1V 7LQ, UK

Address correspondence to E. A. Davies, E-mail: elizabeth.davies@kcl.ac.uk

ABSTRACT

Background  In 2004, the English government set a target to reduce the difference in cancer mortality in those aged under 75 between spearhead primary care trusts (PCTs) and all others by 6% in 2010.

Methods  We used mortality data for 2002–04 to calculate the age-standardized cancer mortality rates in 11 spearhead and 65 non-spearhead PCTs in South-East England. We calculated the ratio of each rate to that for England and Wales overall, and plotted these within funnel plots.

Results  Age-standardized cancer mortality ratios for males varied widely. The 11 spearhead PCTs had the highest mortality and six fell outside three standard deviations of the distribution of the funnel. Removing mortality due to lung cancer greatly reduced this variation and caused the outliers to shift down within the normal range. Ratios for females showed less variation, although those for spearheads were higher. One high outlier was unaffected by removing mortality due to lung cancer, other smoking-related cancers or breast cancer.

Conclusion  Current variation in PCT cancer mortality is materially influenced by past patterns of smoking in men but less so in women. Effective smoking cessation policies should decrease inequalities in male cancer mortality, but will take time and be less effective in decreasing female inequalities.

Keywords  cancer, epidemiology, statistics

Introduction

It is now well-recognized that socio-economic inequalities in cancer mortality exist across UK. Areas defined using a range of measures and scores as more deprived have higher death rates from cancer than areas defined as more affluent.¹ This appears to be partly because people living in these areas suffer a higher incidence of some common cancers, and partly because they have a worse survival after diagnosis. For example, a recent national study by the UK Association of Cancer Registries shows that lung cancer is more common among people living in deprived areas (L.G. Shack, C. Jordan, C.S. Thomson et al., submitted for publication). Although other cancers, such as breast cancer and melanoma, of the skin were more common among those living in affluent areas, these individuals tend to have a better survival after diagnosis.²

Recent health policy in England has set out to reduce inequalities in mortality between populations living in different areas. In 2002, 303 primary care trusts (PCTs) were created as organizations responsible for implementing public health initiatives and commissioning health services for populations of around 100 000. In 2004, 88 spearhead PCTs were defined for particular attention by the Department of Health³ on the basis that they fell in the bottom fifth nationally for three or more of the following five indicators: male life expectancy at birth, female life expectancy at birth, cancer mortality rate in the under 75s, cardiovascular disease mortality rate in the under 75s and average score on the Index of Multiple deprivation 2004.⁴ The specific inequality target set for cancer was to reduce the difference in cancer mortality in those aged <75 between these spearhead PCTs and all others by 6% by 2010.⁵ Alongside, this
target setting has been a movement to feed data on cancer mortality into annual performance monitoring of each PCT. In September 2006, the Minister of State for Public Health announced that health inequalities would be a mandatory indicator within Local Area Agreements from April 2007 for Spearhead PCTs. The choice of measures for performance management of public services has been a subject of some debate. One question for PCTs has been whether their populations are large enough to detect significant differences in cancer outcomes between them and over time. Following the merger of PCTs into 152 organizations, many of these populations are now larger. Another problem, however, is that the organizations will tend to concentrate on their position within any ranking of performance measures, even if the confidence intervals and the point estimates for observations of any two adjacent organizations overlap.

Funnel plots are one method of presenting data from organizations that draws attention to the influence that the numbers of events occurring has on the variation observed between them, and to results that fall outside the expected limits despite this. Essentially, they are a form of control chart in which the observed outcome measure is plotted against a measure of its precision so that the control limits form a funnel around the target outcome. These plots were first used within meta-analyses to determine the extent to which the size of trials influenced the range of their results and whether it appeared likely that both small and large trials results had been published. More recently Spiegelhalter has used funnel plots to investigate hospital outcomes, such as risk-adjusted post-operative mortality rates, and public health issues such as teenage pregnancy rates in health authority areas. Funnel plots can equally be applied to data from smaller PCT populations and used to compare cancer incidence and mortality. In 2004, the Thames Cancer Registry covered a population of 14 million living in the area of South-East England including London, Essex, Hertfordshire, Surrey, Kent and Sussex, a region spanning a wide range of deprivation and affluence and including 11 spearhead PCTS and 65 non-spearhead PCTs. We aimed to use funnel plots to explore the variation in cancer mortality between them, the influence that deaths from the most common cancers had upon this and to suggest the implications for spearhead PCTs.

**Materials and methods**

Cancer registries in England receive an annual mortality data file from the Office for National Statistics, since 2002 in electronic form. This data set is anonymized, derived from information from death certificates and includes date of death, postcode of residence and the underlying cause of death. Registries use this data to calculate cancer mortality rates for their resident populations and report these alongside information from data, they collect themselves on cancers diagnosed and treated in their resident population. The registration process involves the use of information from individual death certificates received routinely from the Office of National Statistics via the NHS Central Register.

We used data from the three annual mortality files 2002–04 to calculate the age-standardized mortality rate from all malignant neoplasms (ICD10 C00–C97) in those aged <75 for each PCT, considering males and females separately. We then calculated the ratio of each PCT mortality rate to that for England and Wales overall. Using spreadsheets developed by Eastern Public Health Observatory, we plotted these ratios within funnel plots. These plots show the second and third standard deviation of distribution compared with the mortality rate for England and Wales. We first examined the plots visually for evidence of over-dispersion. We then identified the 11 spearhead PCTs (Hammersmith and Fulham, Haringey Teaching, Islington, Barking and Dagenham, City and Hackney Teaching, Newham, Tower Hamlets, Greenwich Teaching, Lambeth, Lewisham and Southwark) and highlighted these within the plots. Funnel plots and other statistical control process measures identify variation outside a control limit, which is generally known as ‘special cause variation’. This is the variation beyond that which is inherent in a system under control, implying that the process has changed. Rates that fall outside the funnel of the plot are significantly different from the norm but more importantly, exhibit different behaviour and therefore require further investigation. An ‘outlier’ is the term commonly given to such rates that require investigation. We identified outliers and then explored possible reasons for their position, first excluding deaths due to lung cancer in males and then due to breast cancer in females. In females, we then explored removing deaths due to other cancers including lung cancer where the population attributable risk (PAR) due to smoking is high. The PAR is the proportion (or percent) of the disease in any population that can be attributable to a given risk factor. Such PAR estimates are published for US populations and initial estimates have been made for a European Study (Ester de Vries, EUROCADET Study, personal communication, 2006) but not for the UK. We therefore chose to exclude the mortality from cancers where the PAR due to smoking was consistent between the US and European estimates and at least 30% for European populations. Our aim was to determine if this would reduce
the variation in age-standardized mortality ratios and therefore whether mortality from these diseases had been contributing to the prior variation.

Results

Fig. 1 shows the wide variation between PCTs in age-standardized cancer mortality for males in 2002 and 2004 and the higher mortality for the spearhead PCTs. Six of the 11 ‘spearhead’ PCTs fell above the upper limit of three standard deviations of the distribution of the funnel and three fell above the second standard deviation. In contrast, nine non-spearhead PCTs fell below the lower limit of three standard deviations. However, removing mortality due to lung cancer greatly reduced this variation, causing all the spearhead outliers to shift down within the normal range and seven of the non-spearhead PCTs to move up. The variability among the PCTs was greatly reduced, showing that it has been previously dominated by the variation among PCTs in lung cancer mortality.

The age-standardized cancer mortality ratios for females showed less variation between PCTs (Fig. 2a), although those for spearhead PCTs were higher. Removing mortality due to lung cancer (Fig. 2b) or breast cancer (Fig. 2c) had little effect on this variation and one outlier (Islington PCT) remained. When we removed all smoking-related cancers with a PAR for females of >30% (lung, oesophagus and larynx), we were not able to bring the outlier down within the funnel.

Discussion

Main findings of this study

Presenting age-standardized cancer mortality ratios for PCTs in South-East England within funnel plots confirmed that the 11 spearhead PCTs have the highest mortality for male residents aged <75 years and identified six of these as significant outliers. This exercise also showed that removing the mortality due to lung cancer in males greatly reduced the variation between PCTs and caused the outliers to shift down within the normal range. There was less variation in cancer mortality between PCTs in females, and despite removing mortality due to lung cancer, other smoking-related cancers and breast cancer, one PCT had a high outlying mortality. The ratio plots did not show evidence of over-dispersion as discussed by Spiegelhalter, which occurs when the measure is not a good indicator of the underlying process of interest. This suggests that the drivers of the indicator of cancer mortality are common across all the organizations being observed. Since lung cancer is caused primarily by smoking, these findings show how current variation in cancer mortality is materially influenced by past patterns of smoking in males but less so in females.

What is already known on this topic

We are not aware of any published research using funnel plots to explore influences upon cancer mortality in the way that we have described. The South-West Public Health Observatory has presented overall and specific cancer-standardized mortality ratios for the 42 PCTs in the South-West Region, Hampshire and the Isle of Wight for 2001–03 in funnel plots, but this showed fewer outliers. In 2004, the Thames Cancer Registry area included 76 PCTs and covered a wider range of deprivation including 11 spearhead PCTs in London. This makes it more likely that the variation in cancer mortality due to lung cancer in males would emerge. The outlying PCT for male and female cancer mortality identified in this analysis has already published an investigation finding that its lung cancer incidence and mortality in males and females has been consistently higher than that for England and Wales, since 1985. Although both rates have declined that there was a suggestion that the lung cancer rates for men had stopped falling in the decade up to 2002. An analysis by the London Health Observatory predicted that London spearhead PCTs as a whole were on course to meet the target for a 6% reduction in inequalities in cancer mortality by 2010, although three individual PCTs (Islington, Haringey and Greenwich) were not.

It has long been established that there are significant differences in the mortality for males from different socioeconomic groups. Jha et al. recently used mortality data from England and Wales, Canada, the USA and Poland to show that there was at least a 2-fold difference in the risk of dying from smoking-related diseases between the richest and the poorest social groups in those aged 35–69 years. Presenting overall age-standardized cancer mortality ratios for all PCTs in England within one funnel plot would show the range of variation that exists for males, and determine whether this is driven by that due to lung cancer in the same way as in South-East England.

What this study adds

These findings underline that to decrease inequality in cancer mortality for males spearhead PCTs in South-East England need to focus on preventing lung cancer by a sustained reduction in smoking. As a result of its analysis of cancer mortality, Islington PCT recommended support of a maximum voluntary ban ahead of the ban on smoking in public places in July 2007 and an investment in smoking
Fig. 1. Funnel plots of age-standardized mortality ratios for men dying from cancer aged <75 by primary care trusts in South-East England, 2002–04. (a) All malignant neoplasms and (b) excluding lung cancer deaths.
Fig. 2. Funnel plots of age-standardized mortality ratios for women dying from cancer aged <75 by primary care trusts in South-East England, 2002–04. (a) All malignant neoplasms, (b) excluding lung cancer deaths, (c) excluding breast cancer deaths and (d) excluding oesophageal, larynx and lung cancer deaths.
Excluding breast cancer deaths

Excluding oesophageal, larynx and lung cancer deaths

Fig. 2. Continued.
cessation services.\textsuperscript{15} It also modelled a 1% annual reduction in smoking prevalence in male adult smokers aged 35–74 (using estimates of risk reduction developed by Peto et al.\textsuperscript{16}) could reduce lung cancer mortality by 12% by 2010 from 2002 levels. This major reduction in smoking may be optimistic, but it is clear that spearhead PCTs need to work more intensively than others on these activities. Although an individual’s risk of lung cancer begins to decrease shortly after they stop smoking, and it is possible for those in middle age to avoid most of their excess risk, some risk does persist for many years.\textsuperscript{18}

The 5-year survival for men diagnosed with lung cancer in 1999–2003 was only 6.5% in England relative to those without the disease.\textsuperscript{19} There is little variation in survival after the diagnosis of lung cancer by the countries of the UK and the regions of England.\textsuperscript{1} A recent analysis for London found that the survival of men with lung cancer was lower in two of the most deprived cancer networks.\textsuperscript{20} However, since most patients present with advanced disease and are not eligible for curative surgery, there is limited scope for decreasing mortality due to lung cancer by improving survival after the diagnosis.

Funnel plots appear an attractive method of presenting data on cancer mortality to decision-makers in PCTs and local authorities. They appear useful because they identify outlying positions more clearly than tables, bar charts and ranking and, by prompting an organization to reflect on their position, may trigger action. Funnel plots have been incorporated into the Cancer Information System currently being developed by the UK Association of Cancer Registries. They may also be useful for policy makers and commissioners in different ways in clarifying the distinction between measures useful for monitoring population health, deciding on action and assessing organizational performance. For cancer mortality, monitoring is best done using long-term trends rather than by exploring the significance of yearly changes in figures. The effectiveness of an organization’s smoking cessation policies may be better assessed by more direct measures, such as overall smoking rates, the sign-up for individuals from more deprived areas in cessation programmes and their success in quitting. Public health practitioners are often most interested in the initial presentation of data and of understanding variation within it before a more complex adjustment for all possible influences.\textsuperscript{13} The creative use of funnel plots is a one way to explore variation in disease rates such as cancer and present findings in a readily understandable way.

Our findings therefore underline that focusing on smoking cessation is the right action to decrease inequalities in male mortality, but it is a long-term project. PCTs can clearly not yet be held responsible for events set in train very many years before. Our findings also suggest that these policies will be less effective in decreasing inequalities in cancer mortality for females and that further work is required to understand their cause.

\textbf{Limitations of this study}

Although funnel plots appear an attractive method of presenting performance measures so that attention is focused on outliers rather than on the order of ranking, these plots have several limitations. First, they do not take account of the multiple comparisons that are made. Second, crossing a threshold of three standard deviations does not in itself indicate poor or good organizational performance, but is simply a trigger for the investigation of possible reasons for this. Spiegelhalter has therefore suggested the term ‘warning’ zone for the area above the second standard deviation and ‘alarm zone’ for that above the third.\textsuperscript{12} Third, funnel plots present data from one point in time rather than trends over time. We summed 3 years of data to decrease possible variability in year to year observations, but further investigation could explore whether those falling outside the funnel do so consistently in previous and in future years.

In this study, the funnel plots were less useful for explaining variation in cancer mortality for females because this is not being driven by lung cancer, but possibly by a number of factors that influence different cancers. The next step will be to plot PCT mortality rates for each of the main cancer sites individually within funnel plots to identify in which of these there is most variation. This exercise could then be extended to plot incidence rates following work carried out by the South-West Public Health Observatory.\textsuperscript{9}

\textbf{Acknowledgments}

We thank Christine Harling of South-West Public Health Observatory for her advice, John Rodrigues and John Hamm for their feedback on initial presentations and the Eastern Region Public Health Observatory for making the funnel plot software available.

\textbf{References}


