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Data visualisation: funnel plots and maps for small-area cancer survival

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LONDON SCHOOL of HYGIENE &TROPICAL MEDICINE

Background

Describing geographic inequalities in cancer survival

- Different levels of geography, in particular at small-area level

1. Obtain robust estimates of cancer survival at small-area level
2. Effective communication of cancer survival research

- Defining users (patients, service providers, policy makers)
- Defining needs (information, policy change, monitoring)

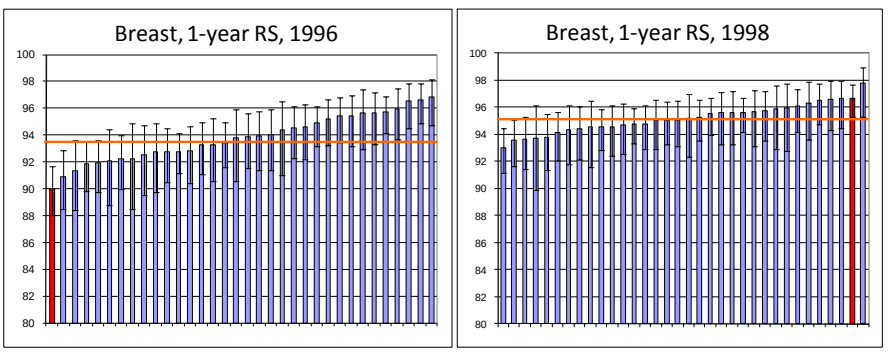
How are cancer survival statistics typically presented?

	Year of diagnosis													
Region	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
A	67	67	68	68	69	69	70	70	71	71	71	72	73	73
B	69	68	69	70	69	70	70	71	71	72	71	72	72	72
C	64	65	66	67	68	69	70	71	71	72	73	73	74	75
D	66	66	67	67	68	68	69	69	70	71	70	71	72	72
E	67	67	68	68	68	69	69	70	70	70	71	71	72	72
F	66	67	67	68	69	69	69	70	71	71	71	72	72	73
G	67	67	68	69	69	70	71	71	72	73	73	73	74	74
H	65	67	68	69	70	71	71	72	73	74	74	74	75	75

Point estimates + some measure of variability such as 95% CI

150 regions over **10** years of diagnosis = **1,500** estimates of survival in one table!

League tables or ranked bar charts



Ellis L, Rachet B, Coleman MP. Cancer survival indicators by Cancer Network.

- Spurious ranking between Cancer Networks
  - Visual misleading indication of "worst"/"best" outcomes
- Instability of estimates (large 95% confidence intervals)
  - big jumps in ranking

How can we improve the dissemination of these results?

Demonstrate geographic and temporal patterns in survival for National surveillance

↓

Smoothed maps

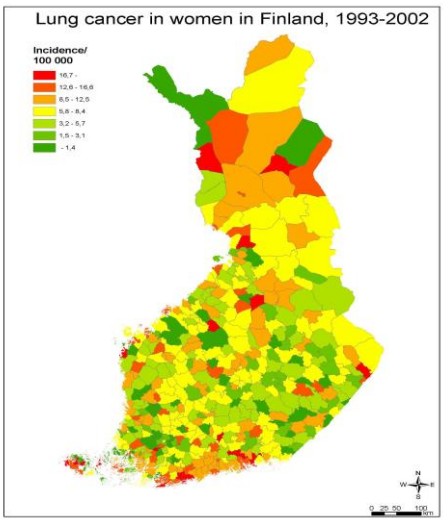
Distribution of individual survival and identifying outliers for local services

↓

Funnel plots

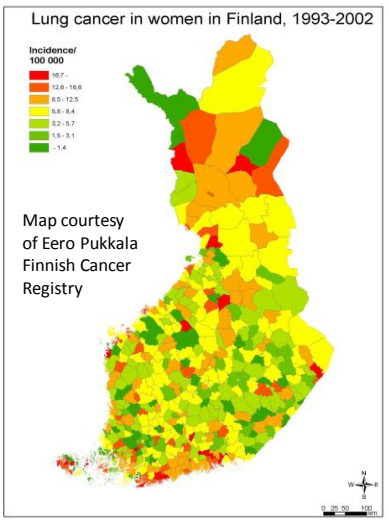
Problems with traditional maps

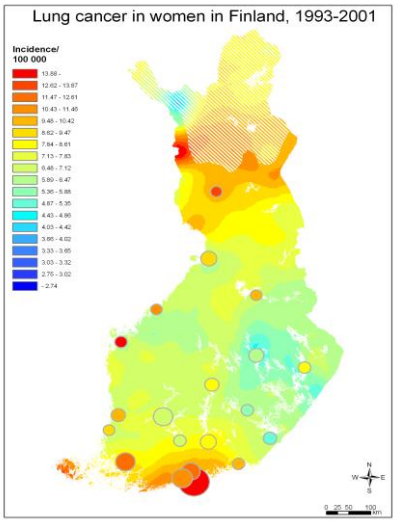
- Large populations may live in small regions and vice versa
- No information about *reliability* of estimates
- Does not reflecting the **uncertainty** of small area statistics
- Difficult to read due to excessive random variation
- Mask true geographic patterns in survival



Map courtesy of Eero Pukkala
Finnish Cancer Registry

Smoothed maps





Moving weighted average

Weights are defined as a function of the inverse of the distance
The radius is defined based on population density and cancer prevalence

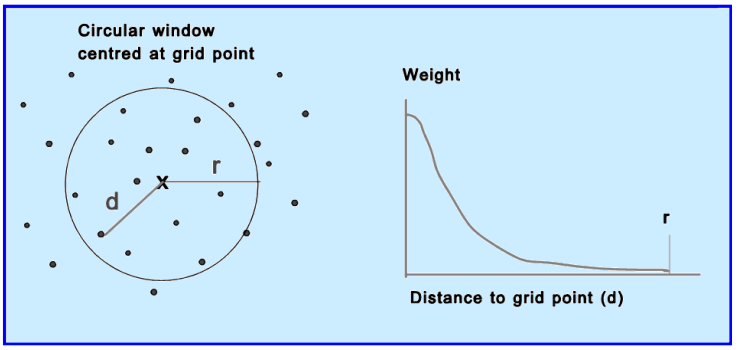
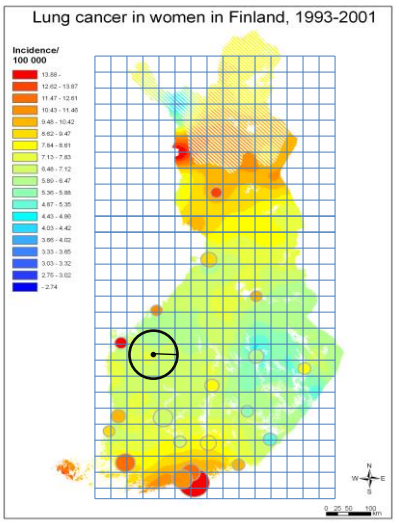


Diagram courtesy of Eero Pukkala, Finnish Cancer Registry

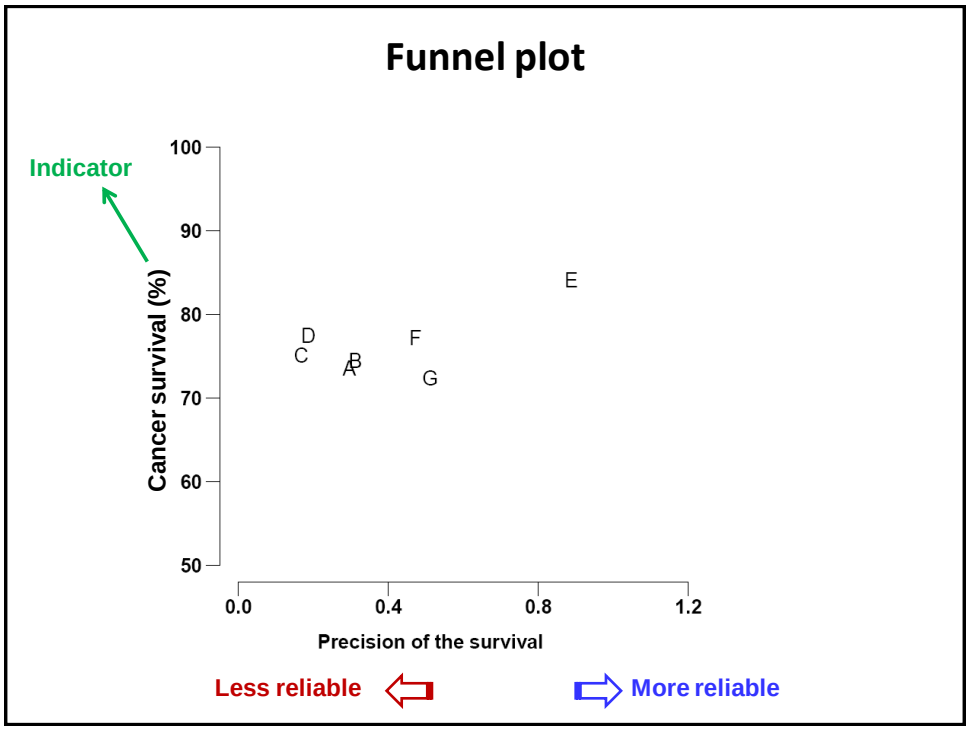
Smoothed maps

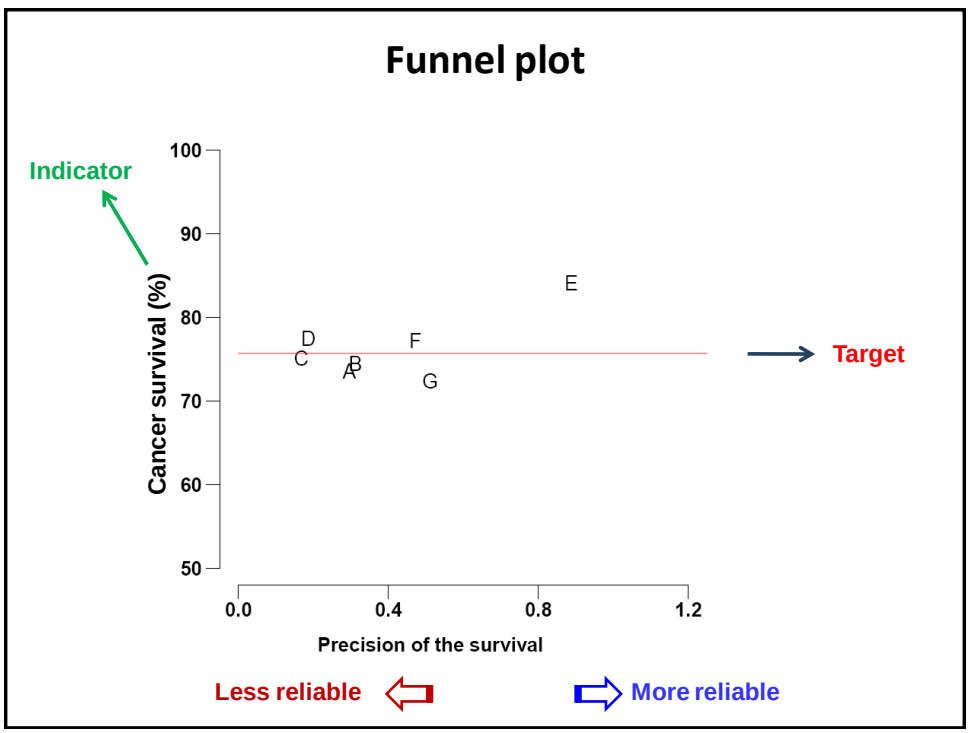


Map courtesy of Eero Pukkala
Finnish Cancer Registry

Funnel plots

- Graphical tools implemented within industrial settings to visualize the limits between two categories of variation :
  - "Common cause variation": expected in any stable process
    - ('good performance') (random variation/ expected by chance)
  - "Special cause variation": divergent from what is expected, due to systematic deviation - 'bad performance'
- Identify "*out of control*" processes.
- Widely used in meta-analysis to check for publication bias
- Suggested for institutional comparisons (D. Spiegelhalter)
- Avoid inappropriate ranking of results while providing a strong visual indication of "special cause variation" by statistically defining control limits around measurable outcomes
- Emphasis on the increased variability expected from less precise estimates (based on small data sets)


Funnel plot
Indicator
Cancer survival (%)
100
90
80
70
60
50
D
C
A
B
E
F
G
0.0
0.4
0.8
1.2
Precision of the survival
Less reliable
More reliable


Funnel plot
Indicator
Cancer survival (%)
100
90
80
70
60
50
D
C
A
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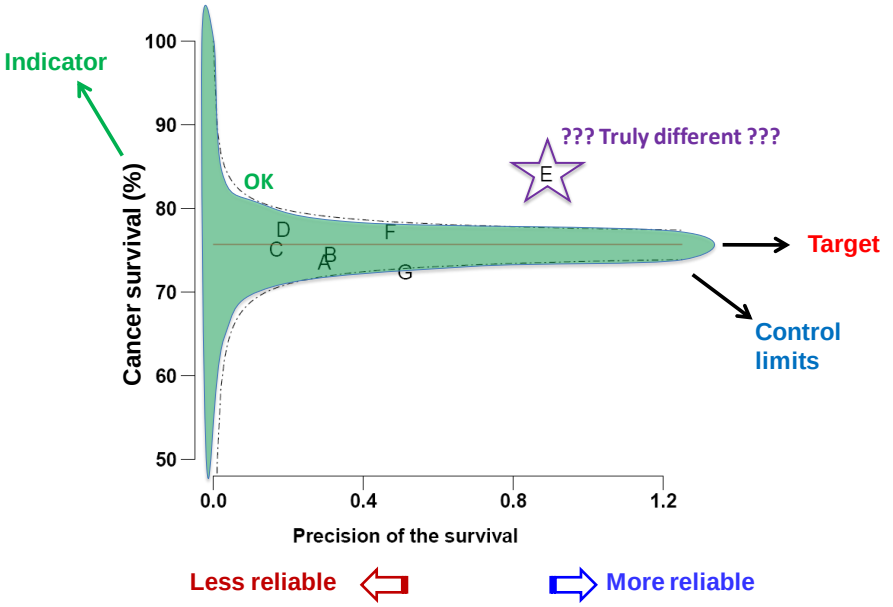
E
F
G
Target
0.0
0.4
0.8
1.2
Precision of the survival
Less reliable
More reliable

Funnel plot



The four components of a funnel plot

1) **Indicator** variable plotted on a scatter plot (y-axis)

2) **Target θ** specifies the desired expectation (overall *mean)* for institutions considered "in control" (horizontal line)

3) **Precision p** parameter determining the accuracy with which the indicator is being measured (x-axis)
   1) precision=1/variance
   2) Interpretable axis: study size=N

4) **Control limits** typically represent 2 and 3 standard deviations from the overall *mean* (target): 95% and 99.8% control limits, respectively.

Control limits

- Superimposed on the funnel plot and indicate thresholds for "alert" and "alarm". Indications have no formal relation to the multiple comparisons implicit in the funnel plot!
- *Key*: correct formulation of control limits depends on the data distribution and requires careful consideration to identify the appropriate distribution!
- The smaller the precision the wider the control limits become, thus reflecting the greater variability due to chance (corresponds to the wider part of the *funnel*)
- Majority of data points sitting outside the control limits: over-dispersion. Causes may include insufficient risk adjustment, individuals being plotted do not come from a homogeneous population.

Example

All-cancers survival index by Primary Care Trust

Objective

Produce an index of cancer survival at one year after diagnosis for all cancers combined for each of the 151 Primary Care Trusts

Requirements

1. Local measure of outcome (effectiveness of cancer services)

2. National tool for surveillance and health strategy

   - Responsive measure
   - Statistically robust (sparse data)
   - Comparable over time and across PCTs
   - Fair representation...

Data and methods

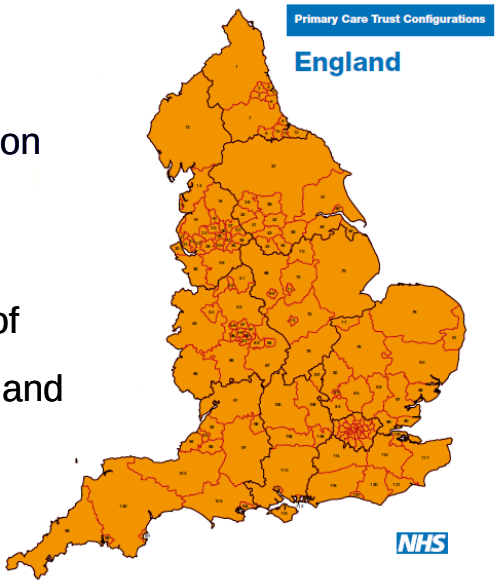
- National Cancer Registry in England
- All adults (15-99 years) diagnosed in 1996-2006 with a first, primary, invasive malignancy
- Follow-up until December 2007
- PCT boundaries attributed retrospectively for period 1996-2006

- Generating a one-year survival index for each PCT and year of diagnosis
- Adjustment for differences in the distribution of age, sex and type of cancer
- Flexible parametric regression models for relative survival

Presentation of results with relevance for health policy

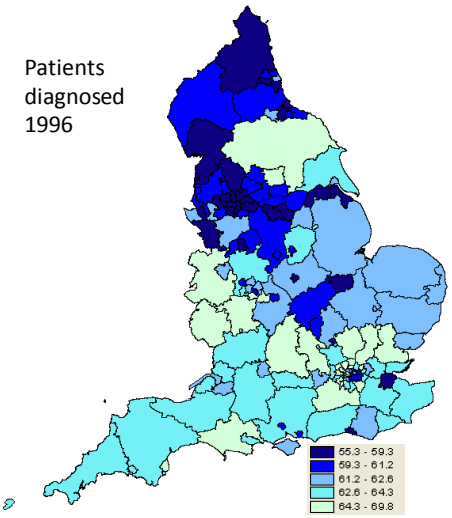
Maps: Regional variation and changes over time

Funnel plots: Spread of individual PCT survival and deviating PCTs

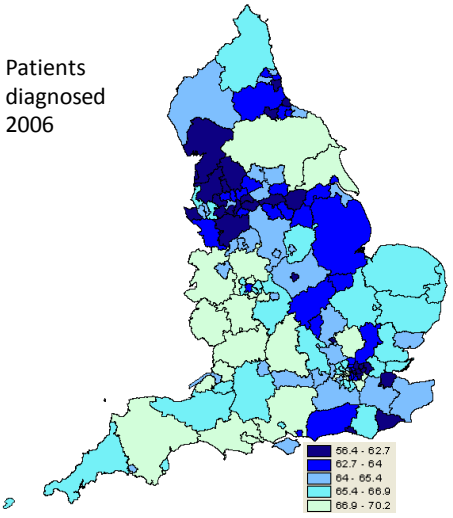


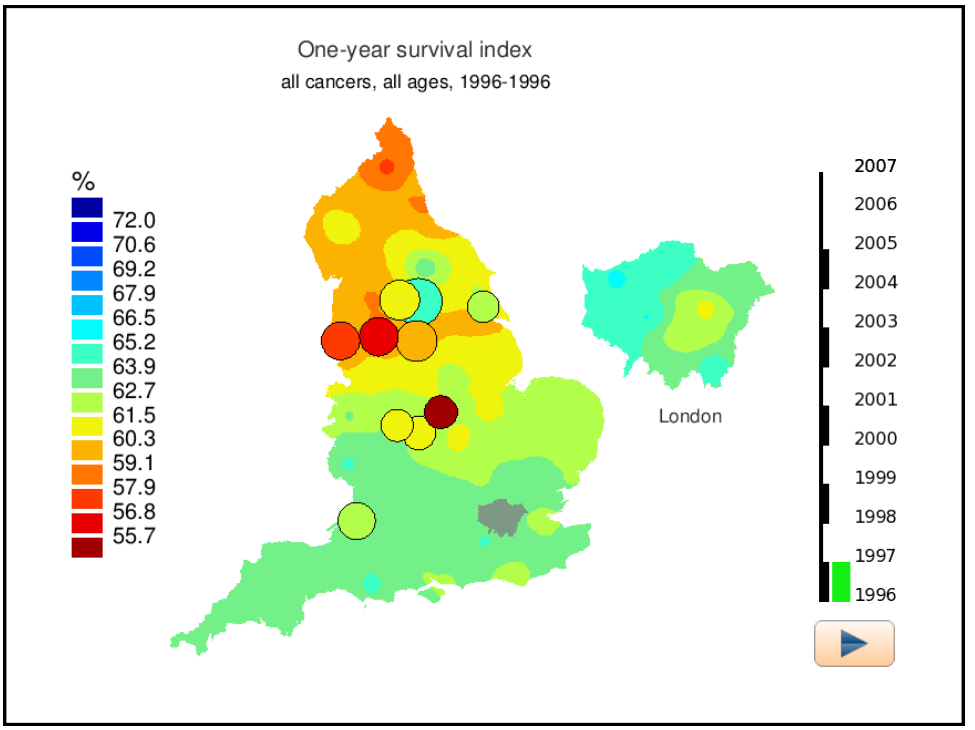
All-cancers index, one-year survival, by PCT

Patients diagnosed 1996



Patients diagnosed 2006




One-year survival index
all cancers, all ages, 1996-1996
%
72.0
70.6
69.2
67.9
66.5
65.2
63.9
62.7
61.5
60.3
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56.8
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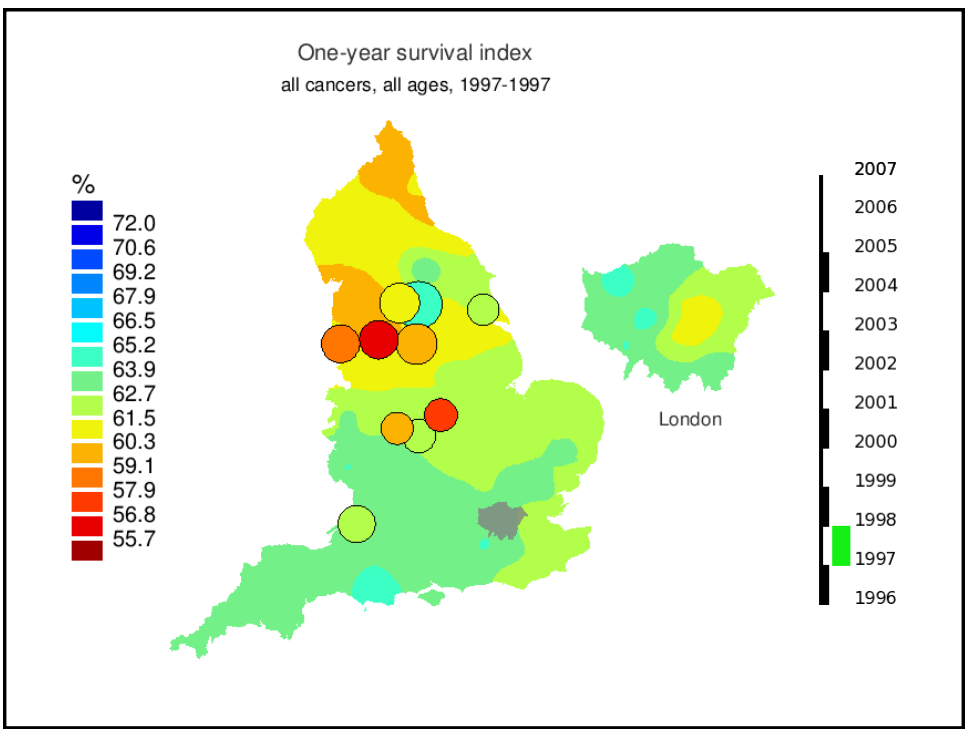
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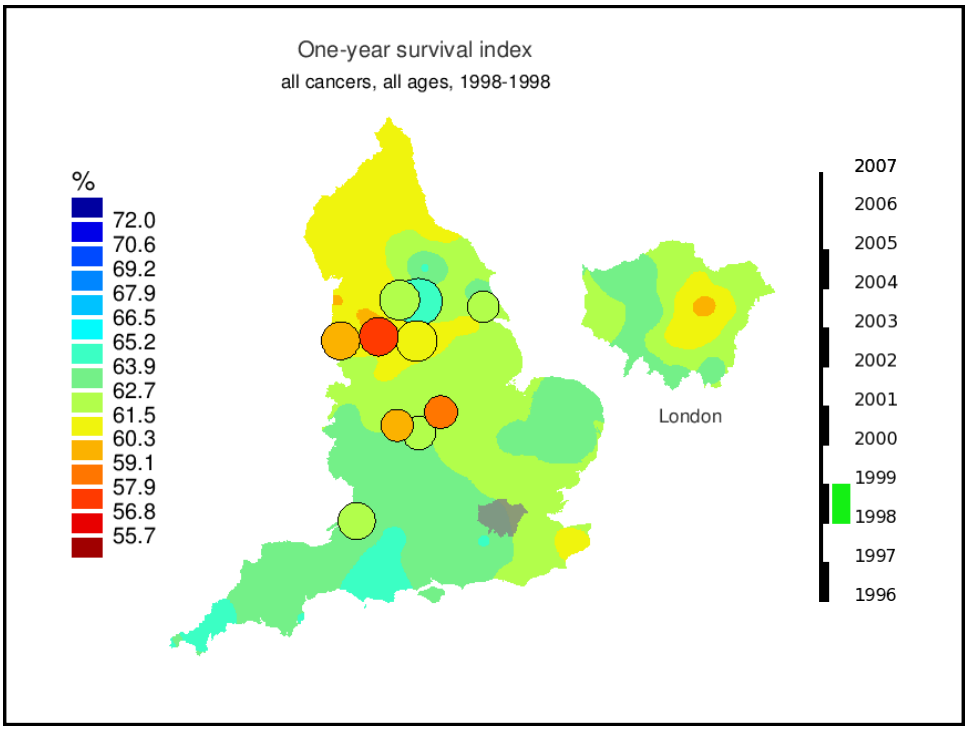
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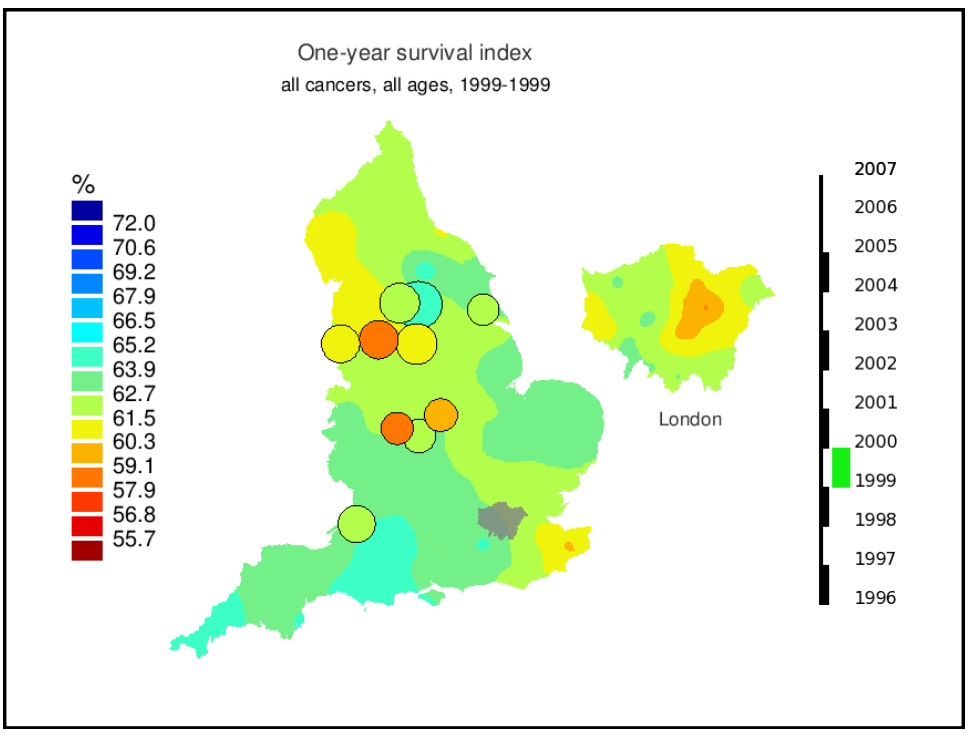
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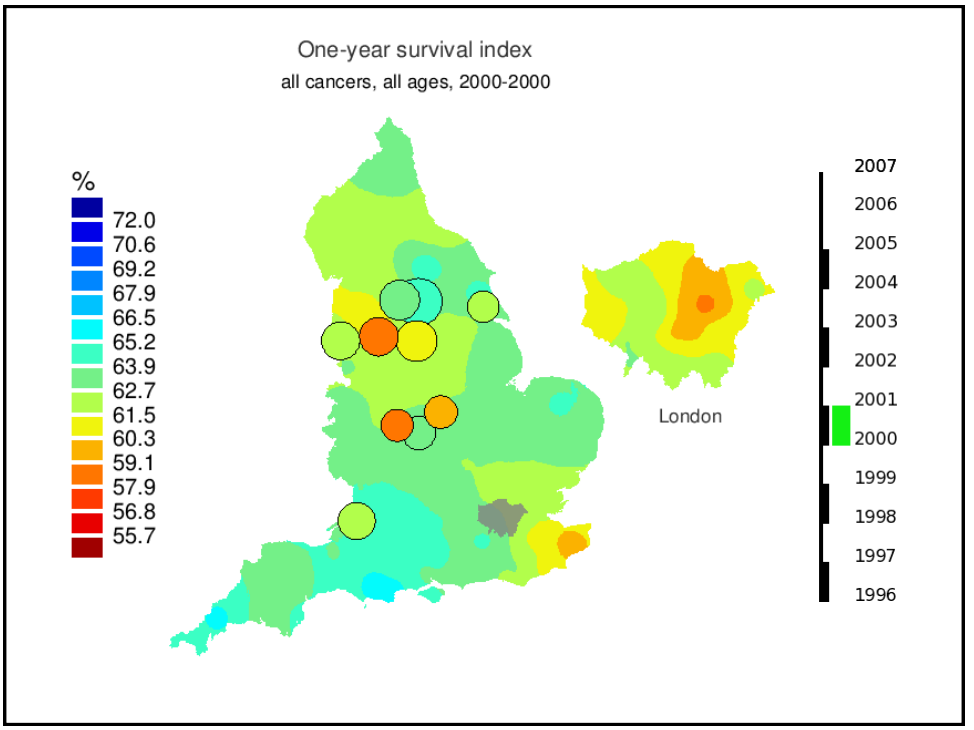
One-year survival index
all cancers, all ages, 2000-2000
%
72.0
70.6
69.2
67.9
66.5
65.2
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60.3
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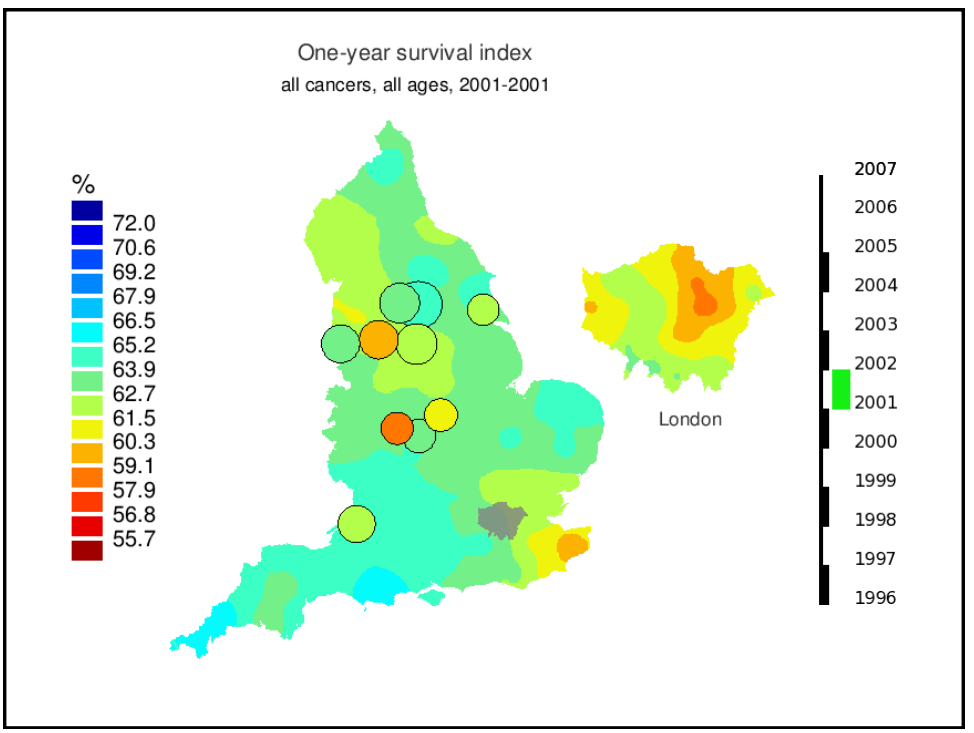
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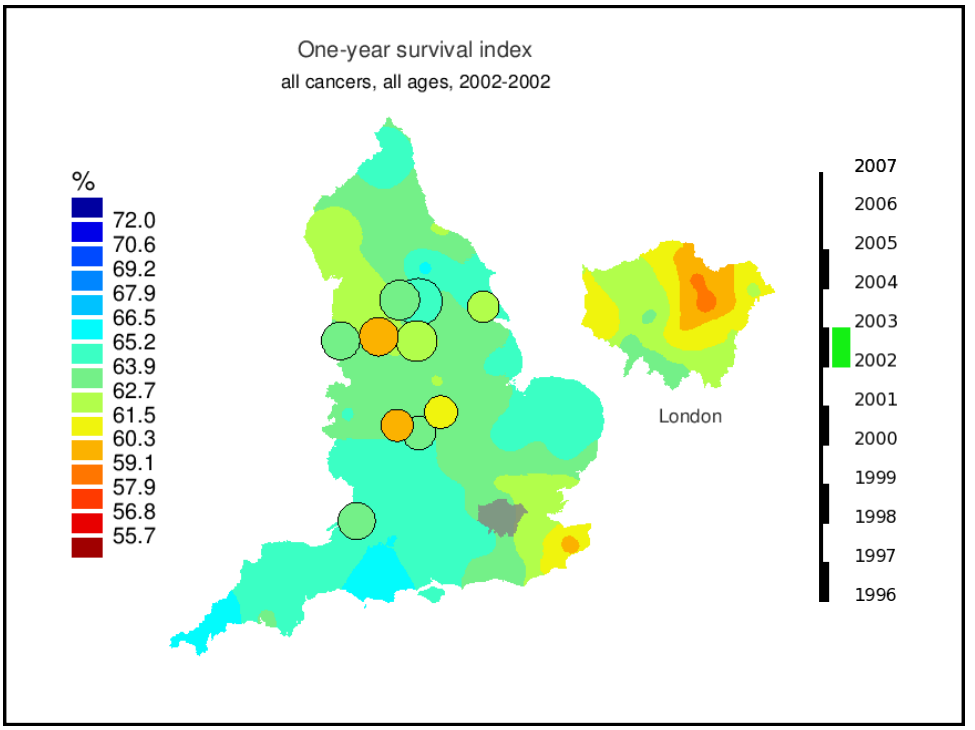
One-year survival index
all cancers, all ages, 2002-2002
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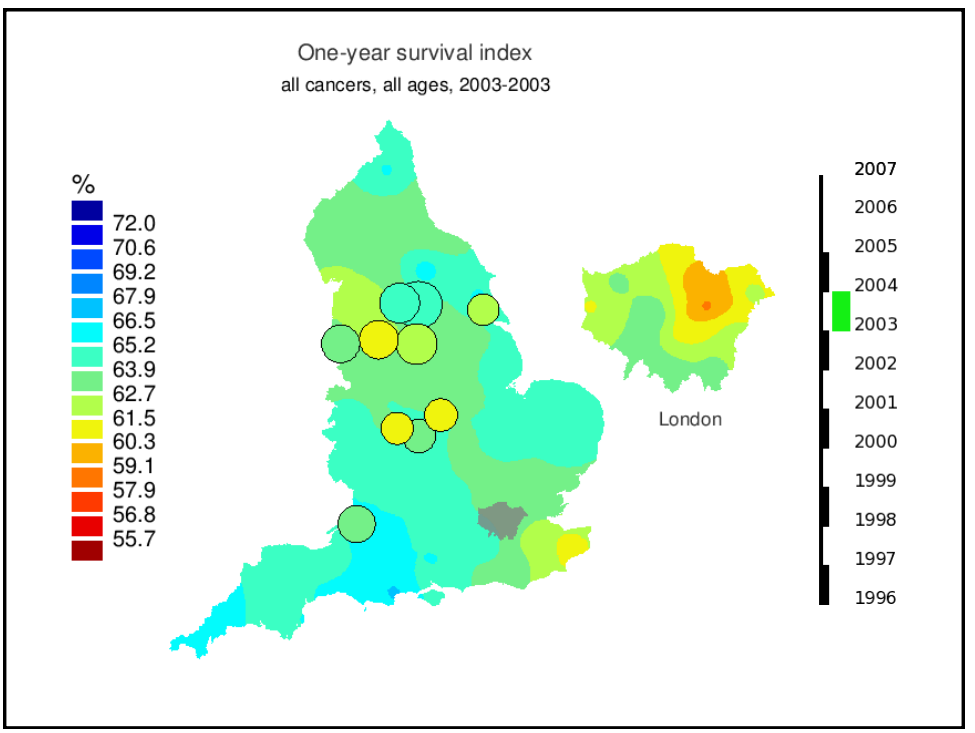
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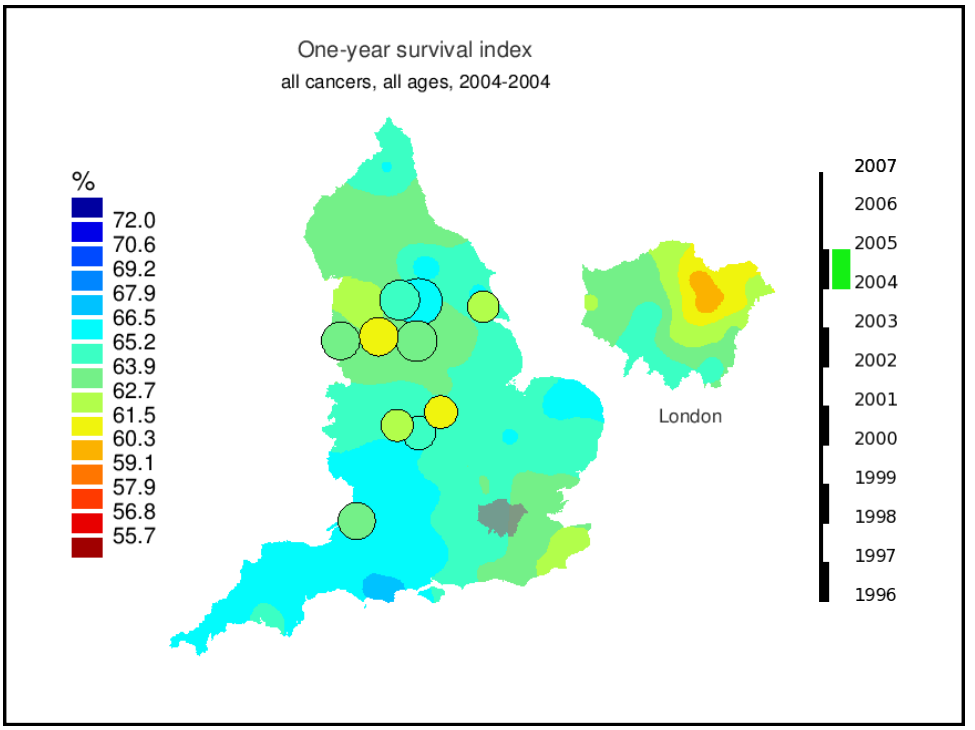
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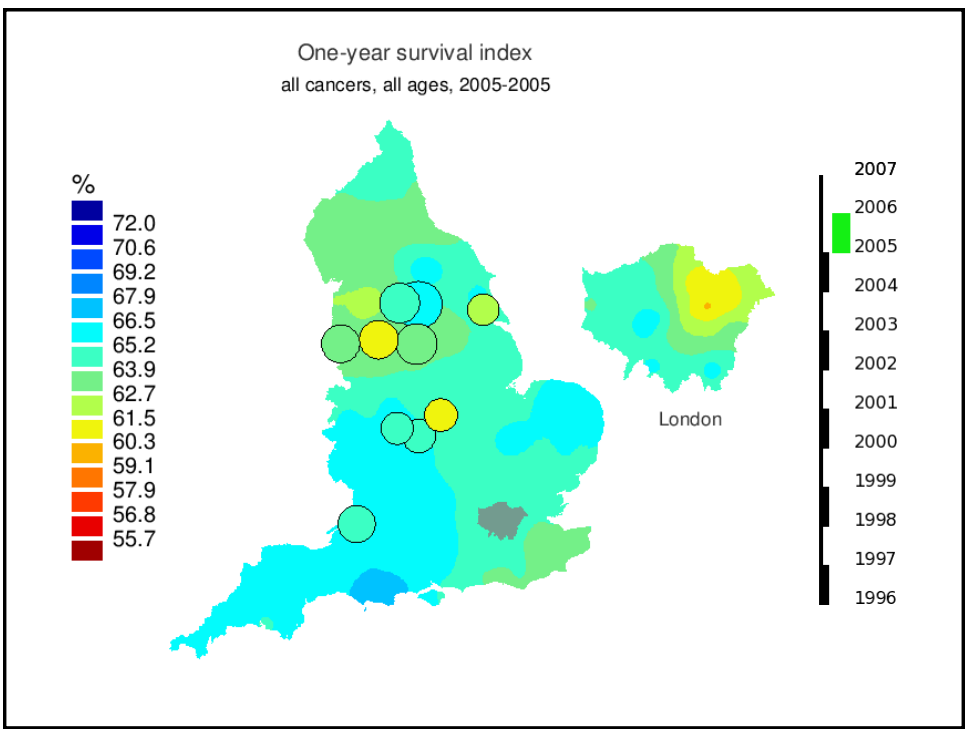
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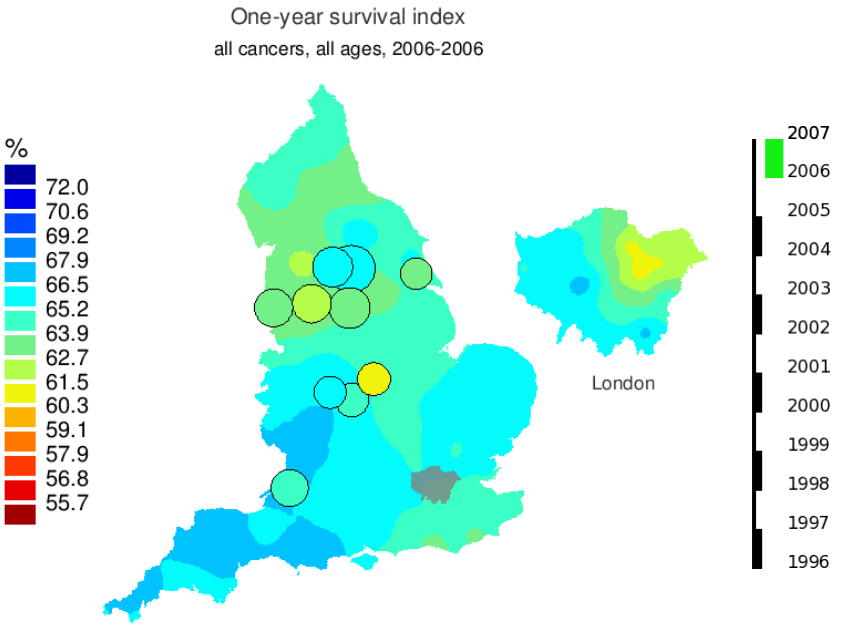


What is the main message from maps?

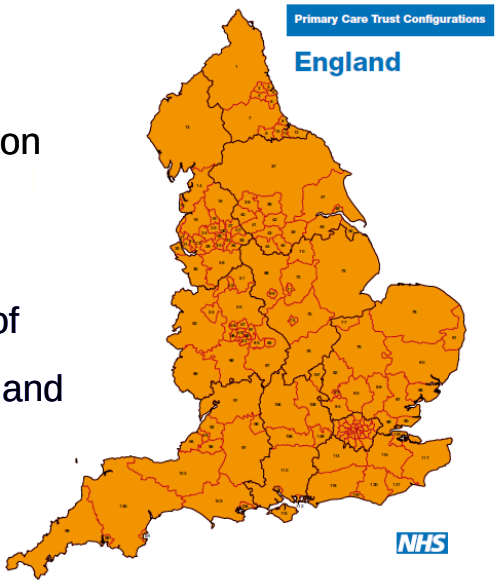
- General improvement in survival during 1996-2009
- North-South gradient in England persistent during the whole period but reduced in more recent years
- London: - Lower survival in NW-SE in 1996-1997
  - Lower survival in NE in more recent years

++ National overview of geographic inequalities in cancer survival and their evolution with time

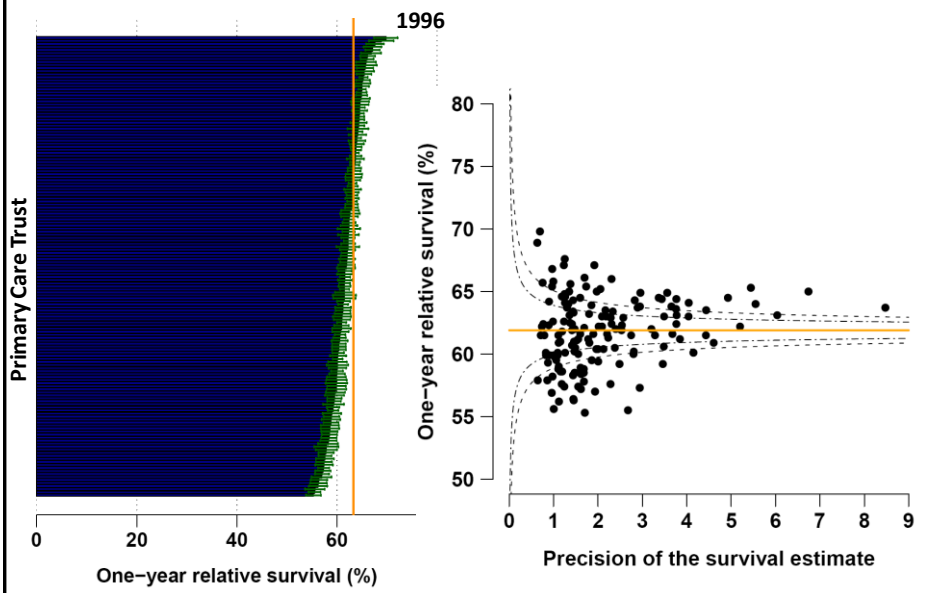
Presentation of results with relevance for health policy

Maps: Regional variation and changes over time

Funnel plots: Spread of individual PCT survival and deviating PCTs



Bar chart with funnel-plot lower outliers marked in light blue and upper outliers in green



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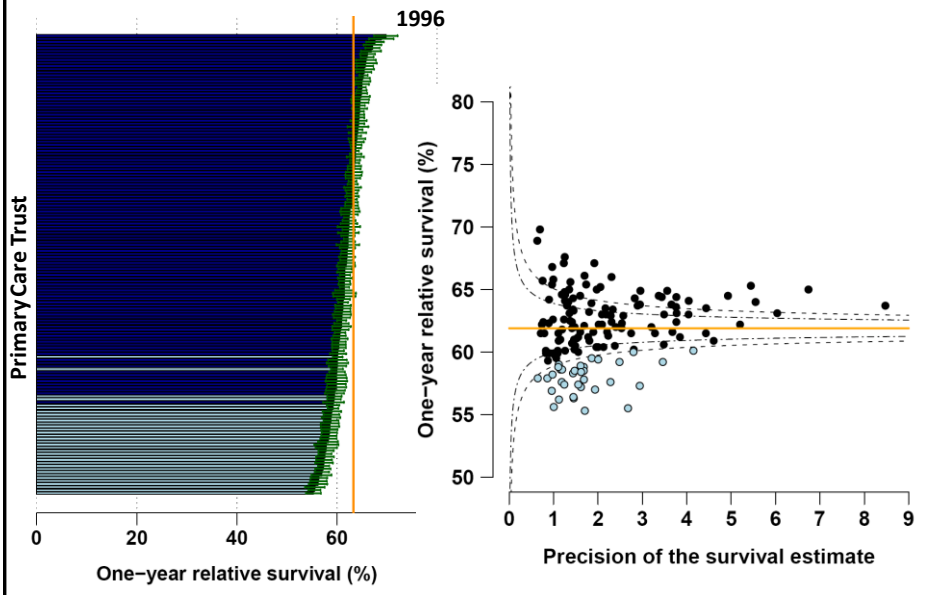

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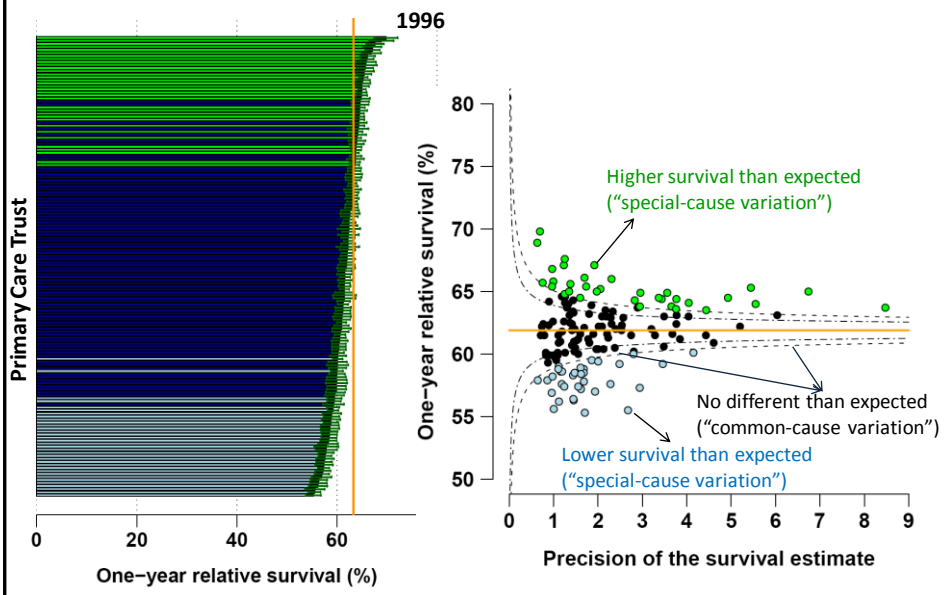
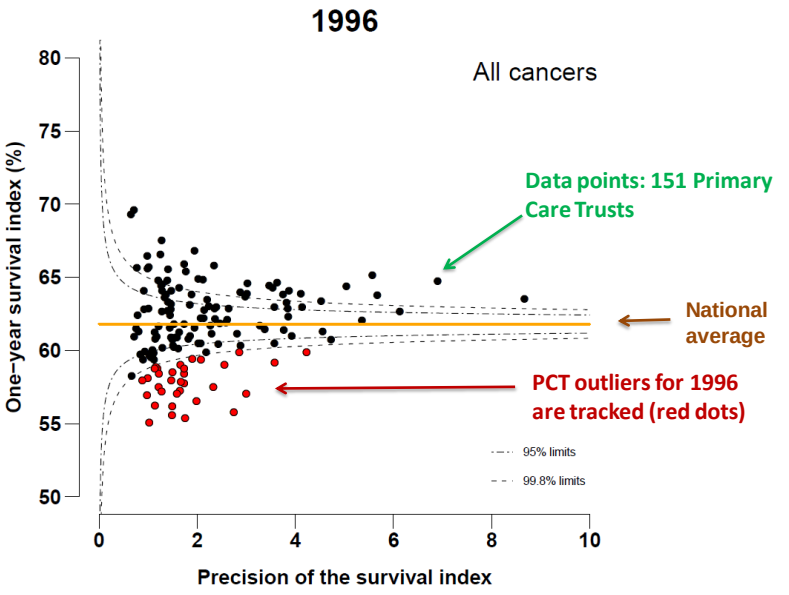


All-cancers survival index: one year since diagnosis, PCT



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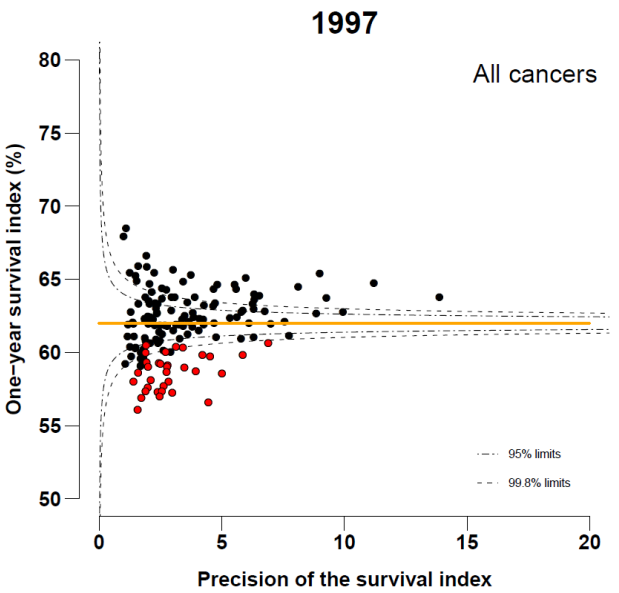

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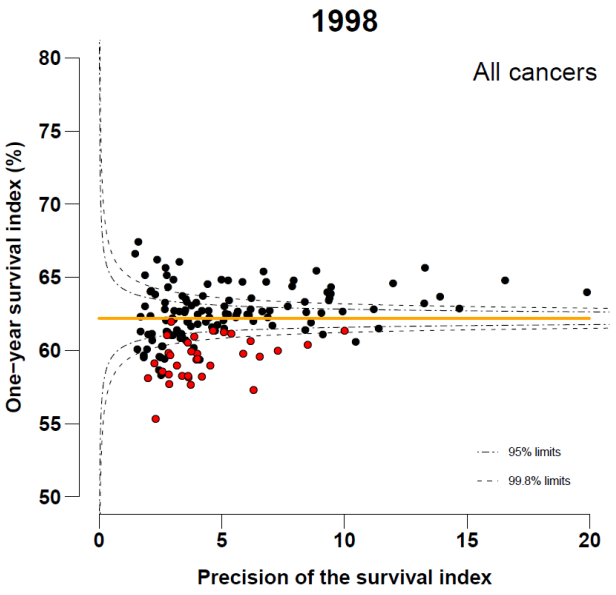

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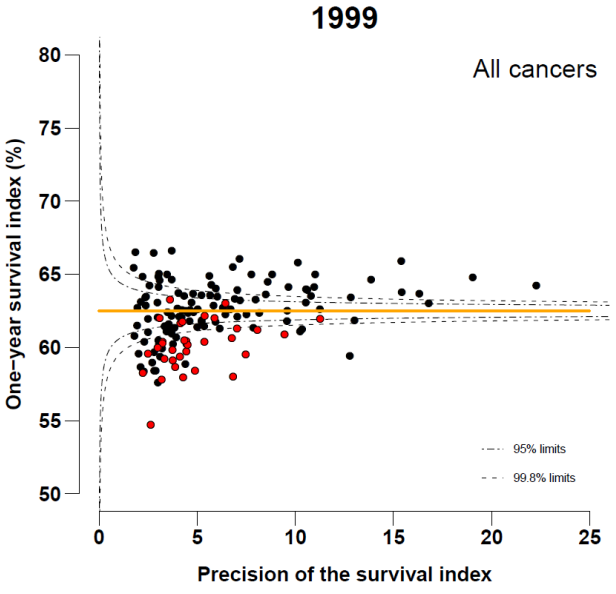

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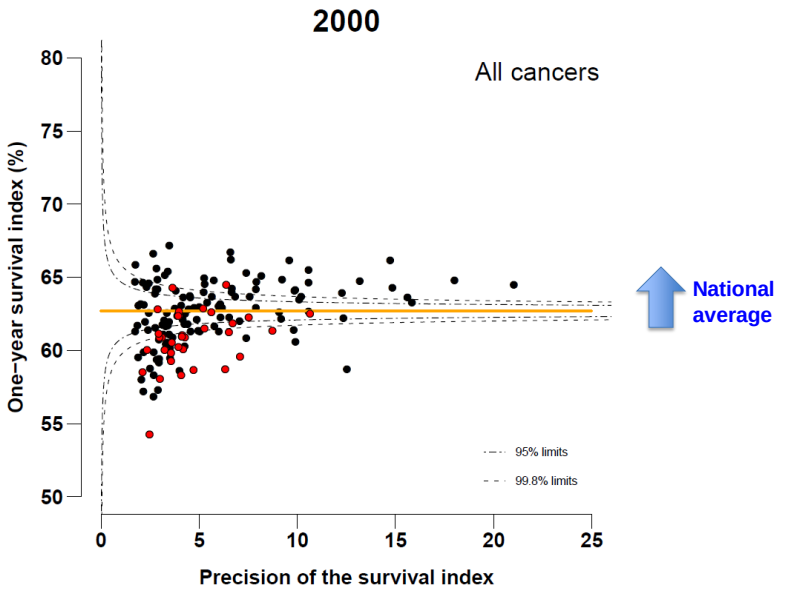

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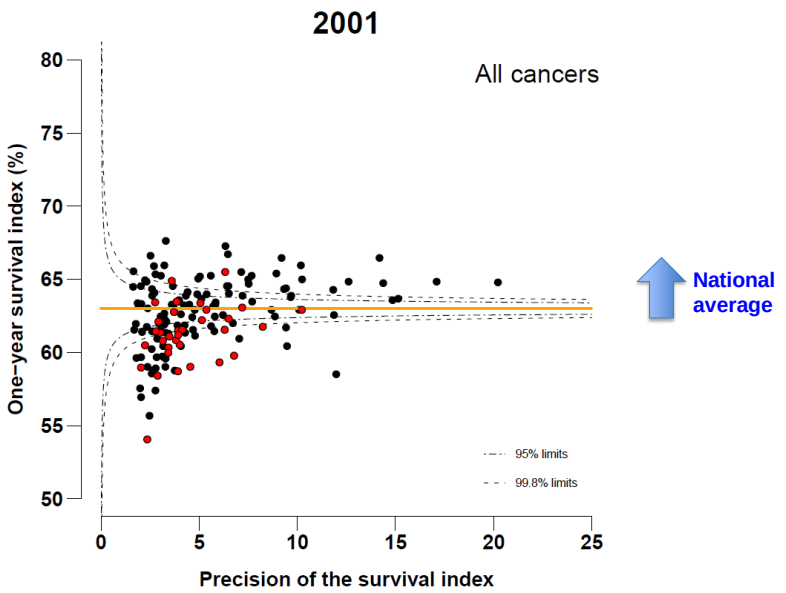

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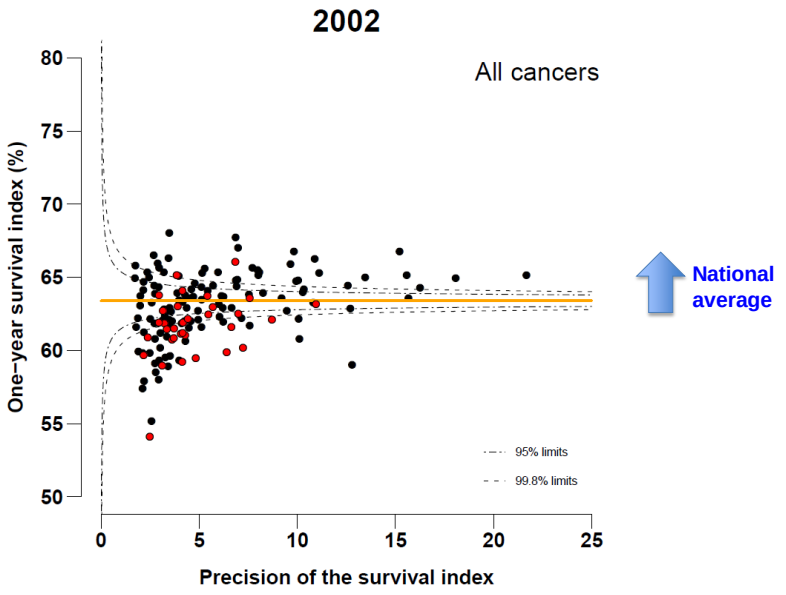

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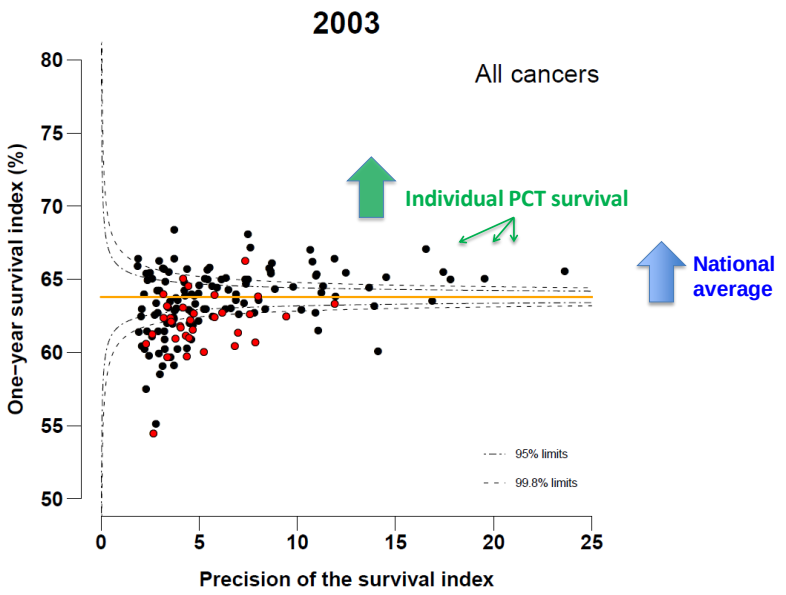

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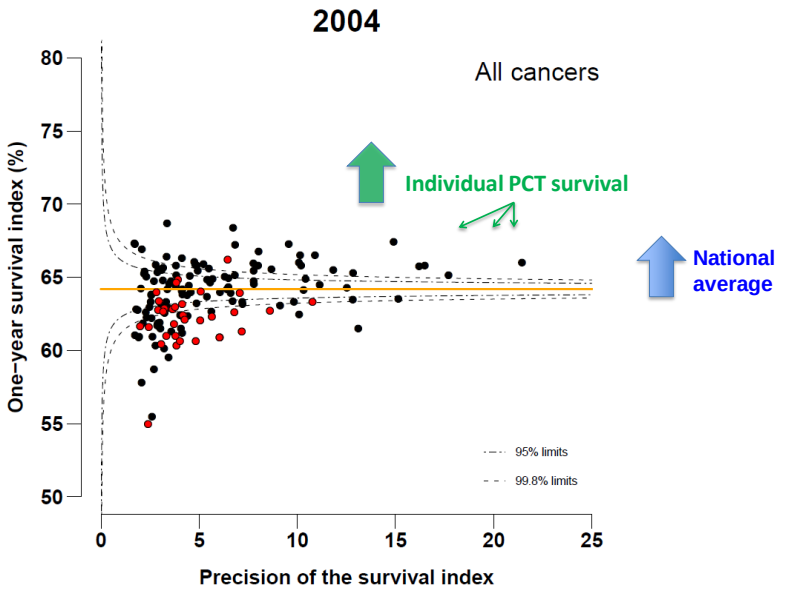

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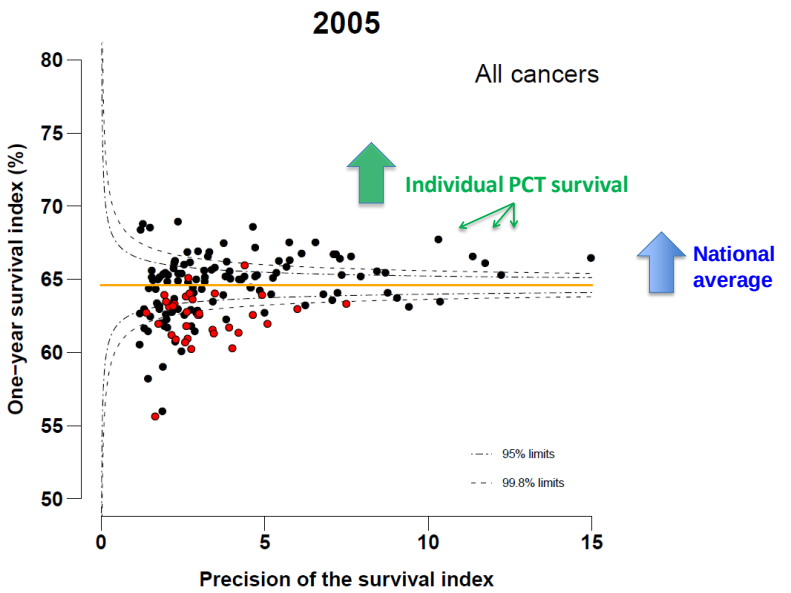
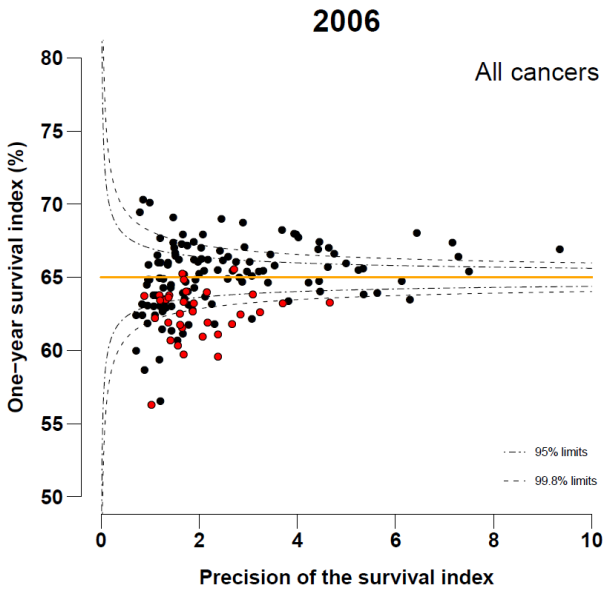


All-cancers survival index: one year since diagnosis, PCT



What is the main messages from funnel plots?

- Increasing national average survival during 1996-2009
- Increasing survival for individual PCT
- Less divergent PCTs in more recent years

++ Easy to identify PCTs with consistently different survival over several years

Applicability

- Generalised to different settings:
  - Geographies
  - Outcome indicators
- Feasible to use the standard set of variables collected by population-based cancer registries:
  - Age at diagnosis
  - Sex
  - Cancer site
  - Dates of diagnosis and end of follow-up, and vital status
  - Geographic information

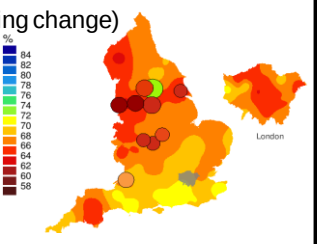
Summary

Effective communication of cancer survival research:

- Defining users (patients, service providers, policy makers)
- Defining purpose (information, influencing policy, monitoring change)
- Clear principles (statistically robust)

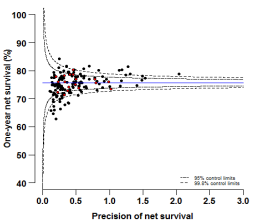
Maps:

- Regional variation and changes in time
- National tool for surveillance and strategy
- Visually pleasing and accessible – influencing policy



Funnel plots:

- Spread and divergence from national average
- Defining outliers
- Local measure of outcome (effectiveness)
- Avoid spurious ranking



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