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Spatial distribution of clinical computer systems in primary care in England: implications for primary care electronic medical record databases

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2017-020738
Article Type:	Research
Date Submitted by the Author:	20-Nov-2017
Complete List of Authors:	Kontopantelis, Evangelos; University of Manchester, Division of Informatics, Imaging and Data Sciences; Faculty of Biology, Medicine and Health; NIHR School for Primary Care Research, Centre for Primary Care Stevens, Richard; University of Oxford, Nuffield Dept Primary Care Health Sciences Helms, Peter; University of Aberdeen, The Institute of Applied Health Sciences Edwards, Duncan; University of Cambridge, Department of Public Health and Primary Care Doran, Tim; University of York, Department of Health Sciences Ashcroft, Darren; University of Manchester, Division of Pharmacy & Optometry; Faculty of Biology, Medicine and Health
Primary Subject Heading:	General practice / Family practice
Secondary Subject Heading:	Epidemiology, Health informatics, Health services research, Research methods
Keywords:	Electronic Health Records, Primary Care Databases, clinical computer systems, EMIS, Vision, CPRD

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3 **Spatial distribution of clinical computer systems in primary care in England: implications for**
4 **primary care electronic medical record databases**
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Abstract

Objectives

UK Primary Care Databases (PCDs) are used by researchers worldwide to inform clinical practice. These databases have been primarily tied to single clinical computer systems, but little is known about the adoption of these systems by primary care practices or their geographical representativeness. We explore the spatial distribution of clinical computing systems and discuss the implications for the longevity and regional representativeness of these resources.

Design

Cross-sectional study.

Setting

English primary care clinical computer systems.

Participants

7,526 general practices in August 2016.

Methods

Spatial mapping of family practices in England in 2016 by clinical computer system at two geographical levels: the lower Clinical Commissioning Group (CCG, 209 units) and the higher NHS regions (14 units). Data for practices included: numbers of doctors, nurses, and patients; and area deprivation.

Results

Of 7,526 practices, EMIS was used in 4,199 (56%), SystemOne in 2,552 (34%) and Vision in 636 (9%). Great regional variability was observed for all systems, with EMIS having a stronger presence in the West of England, London and the South; SystemOne in the East and some regions in the South; and Vision in London, the South, Greater Manchester and Birmingham.

Conclusions

PCDs based on single clinical computer systems are geographically clustered in England. For example, CPRD and THIN, the most popular primary care databases in terms of research outputs, are based on the Vision clinical computer system, used by less than 10% of practices and heavily concentrated in three major conurbations and the South. Researchers need to be aware of the analytical challenges posed by clustering, and barriers to accessing alternative PCDs need to be removed.

Keywords

Electronic Health Records; Primary Care Databases; clinical computer systems; representativeness; EMIS; Vision; SystemOne; CPRD; THIN; QRESEARCH; ResearchOne.

Strengths and limitations of the study

- Cross-sectional analysis of all clinical computer systems used in English primary care, in August 2016.
- Data allowed a detailed description of regional use of each clinical computer system at the Clinical Commissioning Group (CCG) level, and the discussion of implications for UK Primary Care Databases (PCDs).
- Although regional presence of a clinical computer system cannot be equated to contribution to a PCD, since contributing practices are anonymised, inferences on the regional representativeness of UK PCDs are still possible.

Introduction

Primary care in the UK has been almost fully computerised since the early 1990s.¹ Following the introduction of partial subsidies for the purchase of clinical computer systems in 1998 and full subsidies in 2003 (in anticipation of the implementation of a national pay-for-performance programme) UK primary care became fully computerised.^{2 3} Interoperability requirements of the National Health Service led to the universal adoption of a loosely hierarchical clinical coding system, known as Read codes,⁴ which is due to be replaced in April 2018 by a multi-hierarchical coding system (SNOMED CT).⁵ Various commercial providers were permitted to enter the market for clinical computer systems, resulting in numerous different systems with varying interfaces, mechanisms and implementations of Read code usage.⁶ By 2010-11, seven clinical computer systems were consistently active in England, holding 99% of the market share: EMIS systems (LV and PC) were active in 54.7% of practices, followed by Vision v3 (18.1%) and SystemOne (17.8%), with the remaining 9.4% held by other systems (Synergy, Practice Manager, Premiere and the then newly launched EMIS Web).²

The uniformity and interoperability standards have facilitated the creation of large repositories of primary care electronic health records (EHRs), which contain the complete primary care records of patients attending general practices in the UK. The secondary use of these EHRs by researchers – both within and outside the UK – has been increasing exponentially,⁷ and they have provided insights in numerous research areas, including: real-world effectiveness, adverse events, resource utilisation, condition prevalence and incidence, quality of care, and policy interventions.⁸ Several EHR databases exist, maintained by the different clinical computer system providers, drawing data from practices using their systems that have agreed to make patient data available for secondary use. The four largest EHR databases (hereafter primary care databases, or PCDs) in terms of numbers of patient records are the Clinical Practice Research Datalink (CPRD), The Health Improvement Network (THIN), QResearch and ResearchOne.

The CPRD (formally General Practice Research Database, GPRD) was established in 1987 and has been owned by the Secretary of State for Health since 1994. In May 2017, the CPRD covered approximately 8% of the UK population, with 718 contributing general practices and over 17 million total patients (historical and current). The CPRD primarily collects data from Vision practices, although it is currently undergoing an expansion to include EMIS practices, and a future expansion to cover SystemOne practices is planned. THIN was established in 2003 as a collaboration between the company owning Vision (In Practice Systems Ltd) and the CSD Medical Research Group (now Quintiles IMS). In April 2015, THIN reported covering 6% of the UK population, with 562 practices and 11 million total patients. There is a considerable overlap (around 60%) between CPRD and THIN practices, which has implications for studies wishing to

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3 replicate findings between different databases.⁹ QResearch collects data from practices using
4 EMIS systems and is the biggest PCD, with approximately 1500 practices in 2017, covering a
5 population of more than 22 million patients.¹⁰ ResearchOne is a collaboration between the
6 provider of SystmOne (TPP) and the University of Leeds, reporting 28 million (primary and
7 secondary care) records and 423 practices in 2017.
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11 The geographical coverage of PCDs is dependent on the location of practices using the parent
12 clinical computer system, which is in turn dependent on historical patterns of market
13 penetration by the software suppliers and system uptake by general practices. Geographical
14 representativeness is an important prerequisite if analysts are to generalise PCD findings to the
15 whole of England and the UK, which is what routinely happens in practice. This is due to great
16 regional variability across England in terms of population characteristics (primarily, age,
17 ethnicity and deprivation),¹¹ or even regional variation in hard outcomes. For example, a
18 persistent mortality divide between North and the South of England has existed since the
19 middle of the previous century,¹² while, more recently, much higher mortality rates were
20 observed for young adults in the North of England.¹³ There is also regional variation in the
21 organisation and productivity of health services in England,^{14 15} which could have important
22 implications for the generalisability of health services research with the use of regionally
23 unrepresentative PCDs. Therefore, the aim of this paper is to describe the regional distribution
24 of clinical computer systems in English primary care, evaluate the implications of the current
25 picture of representativeness and provide some insight into the sustainability of existing PCDs.
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36 **Methods**

37 **Data**

38 Clinical computer system information was obtained from NHS Digital after direct
39 communication, for August 2016. Primary care workforce and patient information as of 30
40 September 2016 was downloaded from the NHS Digital website.¹⁶ At the practice level,
41 information was available on geography (Clinical Commissioning Group and NHS region),
42 patient list size by age groups, and numbers and full-time equivalent (FTE) for GPs and nurses.
43 Deprivation was quantified using the 2015 release of the Index of Multiple Deprivation (IMD), a
44 complete aggregate measure widely used to quantify area deprivation, attributed to the
45 practice location.¹⁷ Spatial coordinates for NHS organisational units in 2016 were obtained from
46 the ONS open geography portal.¹⁸ We focused on two organisational levels, the lower Clinical
47 Commissioning Groups (CCGs) with 209 units, and the higher NHS regions with 14 units.
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Analyses

For all aspects of data manipulation and analysis we used Stata v14.1. Whenever medians are reported, we also report the 25th and 75th centiles. Spatial maps were plotted using the *spmap* command.¹⁹ Practice-level data were aggregated by clinical computer system, to provide information on all patients, patients aged 75 or over, GPs and nurses, practice location deprivation and list size. Counts for each clinical computer system, by NHS region, were also calculated. Spatial graphs at the CCG level, with additional information on NHS regions, were plotted for the three most popular clinical computer systems, to provide a visual guide in regional distribution and representativeness.

Results

System information was missing for 49 (0.7%) of 7,526 general practices. EMIS systems were used in 4,199 practices (56%), with all but 23 of these using EMIS Web. SystmOne was used in 2,552 (34%), Vision in 636 (9%) and Evolution in 90 (1%) practices. Patterns of area deprivation, based on the locations of general practices, were similar across all systems. SystmOne practices tended to be larger (median of 7,080 patients), followed by EMIS (6,833), Vision (6,279) and Evolution (6,222).

Great regional variability in system usage was observed both at the NHS Region level (Table 1) and CCG level (Figures 1-3). EMIS is present in all but 18 of the 209 CCGs (91.4%), with a much stronger presence in the West of England, London and the South. SystmOne is present in 120 CCGs (57.4%), and is mainly active in the East and some regions in the South. Vision, although with a much lower market share than SystmOne, is still used in 96 CCGs (45.9%), mainly in London, the South, Greater Manchester and Birmingham. Evolution is only present in 18 CCGs (8.6%) and is primarily used in the South West.

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Discussion

High regional variability exists in the use of different clinical computer systems in English primary care, which should be a consideration when utilising primary care electronic health databases based on this population in the future, especially if effect heterogeneity (or other forms of heterogeneity) is context relevant. For example, drawing nationwide conclusions in health services organisation would be more problematic than identifying medication side-

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3 effects. EMIS Web is by far the most widely used clinical computer system and therefore
4 QResearch is the most nationally representative single database – potentially able to collect
5 data from almost all English CCGs. SystmOne has a very strong presence in many parts of
6 England, but no presence in many CCGs in the North West, West Midlands, London and South
7 East. The ResearchOne database is therefore unable to capture data from many regions. Finally,
8 Vision is the most geographically restricted of the three major clinical computer systems, with
9 relatively few practices heavily concentrated in three conurbations and the South. The CPRD
10 and THIN databases are therefore currently unable to provide comprehensive coverage of large
11 parts of the country, particularly in the North and East of England.
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17 **Strengths and limitations of the study**

18 The main strength of this study is the use of numerous national administrative datasets of high
19 data quality, allowing us to obtain a complete picture for the whole of England. The main
20 weakness of the work is the fact we cannot equate the regional presence of a clinical system to
21 active contribution to a primary care database – not all practices contribute data and
22 contributing practices are anonymised – and we have therefore discussed potential
23 contribution instead.
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29 **Findings and implications**

30 The current picture of clinical system usage in English primary care is very different to what was
31 reported for 2011.² Although EMIS is still the biggest provider and has retained its market share
32 (56% in both 2011 and 2016), its LV and PCS systems which dominated the market in 2011 are
33 hardly used anymore, with almost all practices having transitioned to the Web system. The use
34 of TPP's SystmOne has increased from 18% to 34%, while that of Vision by In Practice System
35 has halved (from 18% to 9%). Many providers that were present in 2011 have subsequently
36 withdrawn from primary care, with the exception of Microtest's Evolution (transitioned from
37 Practice Manager). If the current trend continues, English primary care will be completely
38 dominated by EMIS Web and SystmOne in the next 5 to 10 years, and access to both of these
39 systems would ensure almost complete coverage for England.
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45 The trend for primary care convergence to two clinical systems has implications for the future
46 of PCDs and the research findings based on them. CPRD and THIN will need to adapt very
47 quickly and include EMIS and/or SystmOne practices in their processes. Given that the CPRD
48 and THIN are the two most widely used primary care databases in clinical research, losing them
49 altogether – as happened with the DIN-LINK database²⁰ – would be a severe setback for the
50 research community. As of 20 July 2017, a PubMed search identified 1,782 published papers
51 linked to the CPRD (886 in the last 5 years), 471 linked to THIN (303 in the last 5 years), 71
52 linked to QRESEARCH (32 in the last 5 years) and 2 to ResearchOne (both in the last 5 years).
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3 Although not exhaustive, this search indicates the large variability across databases in terms of
4 scientific contribution, demonstrating that the most accessible and productive databases are
5 the ones at immediate risk.
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9 Within the CPRD, there are clear actions towards future-proofing the resource, in light of the
10 deterioration of the Vision market share. A large number of EMIS practices are already
11 contributing data to the resource, but differences in the data format (compared to the standard
12 Vision format) has prevented their immediate release along with Vision data, while it was not
13 possible to link the EMIS data to other data sets. Nevertheless, a major transformation in
14 processes is being undertaken which will allow the release of both Vision and EMIS data as
15 standard, within 2018. In addition, the recruitment of EMIS practices continues, with over 150
16 practices having joined the CPRD in the last 12 months.
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21 Users of the UK PCDs need to be aware of the generalisability issues we described, and consider
22 if there are any risks relevant to their studies. Generalisability (external validity) should be
23 discussed as standard in such work and is listed as an item (#21) in both the STROBE and
24 RECORD statements.^{21 22} The context is important here, and regional representativeness may be
25 less relevant for clinical questions but more relevant for health services research. Sensitivity
26 analyses on a more representative group of practices, obtained through deterministic sampling
27 and existing software,²³ can also be used to strengthen findings.²⁴ However, the strong
28 clustering of clinical systems within CCGs, largely driven top-down from CCGs to general
29 practices, limits the usefulness of such sampling approaches.
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37 Conclusions

38 The geographical representativeness of primary care databases varies enormously, and the two
39 most used databases in the UK, the CPRD and THIN, were in 2016 the least representative of
40 the major databases due to the quickly diminishing market share of the clinical computer
41 system providing their data (Vision). The existence of these databases is under threat, and
42 urgent action is required to allow data collection from at least one of the two dominant clinical
43 systems (EMIS Web and SystemOne). CPRD has recognized this, and has recently negotiated
44 access to data held by EMIS practices, and is due to operationalise this data by 2018. In
45 addition, development and access barriers that have restricted publication outputs from data
46 drawn from EMIS (QRESEARCH) and SystemOne (ResearchOne) practices urgently need to be
47 overcome if the confidential use of NHS patient data is to continue driving research that directly
48 informs patient safety, management, and health services policy.
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Acknowledgments

We would like to thank the Office of National Statistics and NHS Digital for the wealth of information they have collected and systematically organised, which made this study possible.

Funding

MRC Health eResearch Centre Grant MR/K006665/1 supported the time and facilities of EK. The views expressed are those of the authors and not necessarily those of the MRC.

Declaration of competing interests

EK, RS, PH and DE are members of the Independent Scientific Advisory Committee (ISAC) for MHRA database research: <https://www.gov.uk/government/groups/independent-scientific-advisory-committee-for-mhra-database-research>

Ethical approval

Not applicable

Patient involvement

Not applicable

Authorship & contributions

EK designed the study, extracted the data from all sources, performed the analyses and drafted the first version of the manuscript. RS, PH, DE, TD and DA critically edited the manuscript. EK is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Transparency declaration

EK affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Data sharing

The data used in this study are freely available and the authors are happy to share an organised and cleaned final dataset.

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Table 1: Regional distributions of systems and the characteristics of their respective general practices*†‡§

	EMIS [¶]	SystmOne	Vision v3	Evolution
<i>Aggregates (%)</i>				
Number of practices	4199(56%)	2552(34%)	636(9%)	90(1%)
Number of patients	32191392(56%)	20199414(35%)	4601205(8%)	629166(1%)
Number of GPs	18675(57%)	11160(34%)	2433(7%)	393(1%)
<i>Medians (25th and 75th centiles)</i>				
IMD 2015 [#]	22.2 (12.1,37.4)	22.5 (12.8,36.8)	22.4 (12.3,37.0)	22.7 (14.4,31.0)
List size	6833 (4257,10094)	7080 (4214,10553)	6279 (3988,9759)	6222 (4743,9121)
Patients aged 75 or over	476 (240,823)	524 (256,895)	455 (225,710)	592 (400,924)
<i>Means (SD)</i>				
All GPs	5.1(3.4)	5.1(3.7)	4.5(3.1)	5.5(2.9)
Female GPs	2.8(2.4)	2.7(2.5)	2.3(2.1)	2.7(2.1)
GPs aged under 40	1.7(1.9)	1.6(2.0)	1.4(1.7)	1.5(1.6)
GPs aged 40 to 54	2.3(1.9)	2.4(2.1)	2.0(1.8)	2.8(1.9)
GPs aged 55 or over	1.0(1.0)	1.0(1.0)	1.1(1.0)	1.2(1.1)
All Nurses	3.1(2.3)	3.6(2.6)	2.8(1.9)	3.4(1.6)
<i>Regional counts, NHS regions (%)</i>				
Wessex	164(55%)	113(38%)	17(6%)	4(1%)
London	917(68%)	254(19%)	182(13%)	1(0%)
Yorkshire & the Humber	186(25%)	544(74%)	5(1%)	0(0%)
Cumbria & the North East	270(59%)	172(38%)	12(3%)	0(0%)
Cheshire & Merseyside	353(92%)	19(5%)	8(2%)	2(1%)
North Midlands	260(54%)	216(45%)	2(0%)	2(0%)
West Midlands	496(76%)	96(15%)	58(9%)	0(0%)
Central Midlands	156(28%)	378(69%)	16(3%)	0(0%)
East	112(21%)	413(77%)	4(1%)	4(1%)
South West	225(59%)	86(22%)	7(2%)	65(17%)
South East	303(56%)	96(18%)	145(27%)	1(0%)
South Central	227(55%)	129(31%)	57(14%)	3(1%)
Greater Manchester	310(65%)	36(8%)	123(26%)	8(2%)
Lancashire	220(100%)	0(0%)	0(0%)	0(0%)

* Data for Aug 2016 (clinical system) and Sep 2016 (GMS data)

† System information not available for 49 (0.65%) of 7,526 practices

‡ All GP numbers exclude locums

§ SystmOne provided by TPP, Vision (version 3) provided by In Practice Systems, Evolution provided by Microtest

¶ EMIS includes Web (4,176 practices), LV (19 practices) and PCS (4 practices)

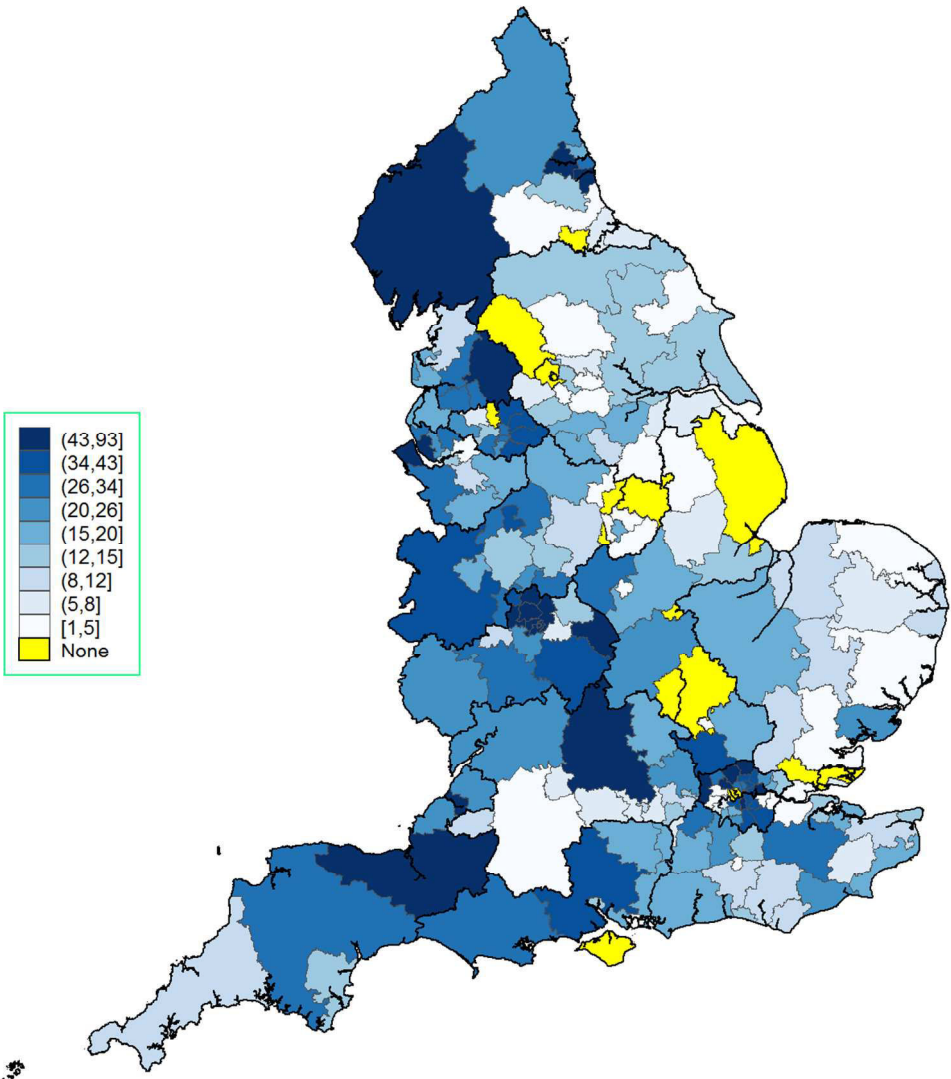
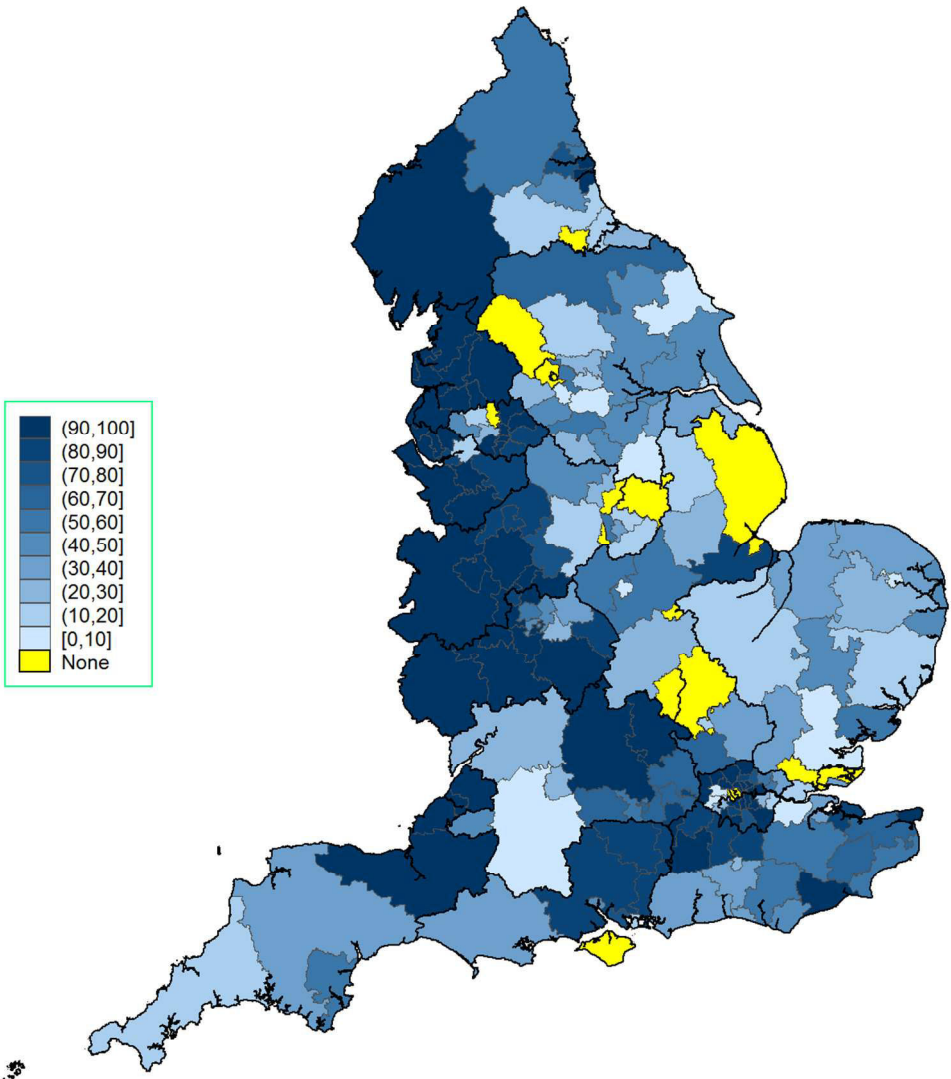
Index of Multiple Deprivation, details available in the 2015 technical report of the English Indices of Deprivation¹⁷

Figure 1: Spatial map at the Clinical Commissioning Group (CCG) level, September 2016: EMIS*†

Percentage of patient population share

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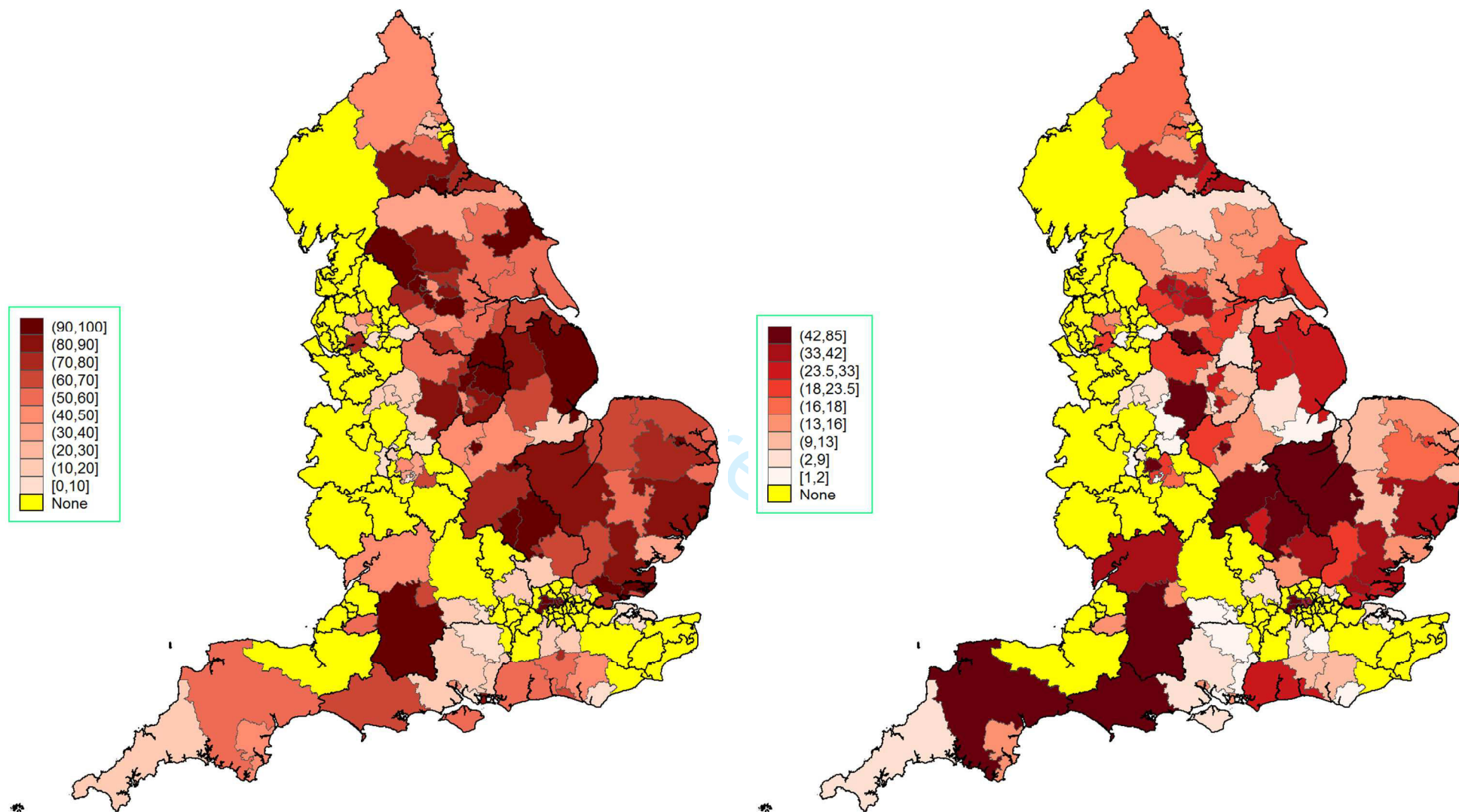


* thicker border lines correspond to the 14 NHS regions
 † left graph uses equidistant class breaks; right graph uses class breaks based on distribution of variable of interest, with each class having approximately the same number of spatial polygons (CCGs)

Figure 2: Spatial map at the Clinical Commissioning Group (CCG) level, September 2016: SystemOne*†

Percentage of patient population share

Number of general practices



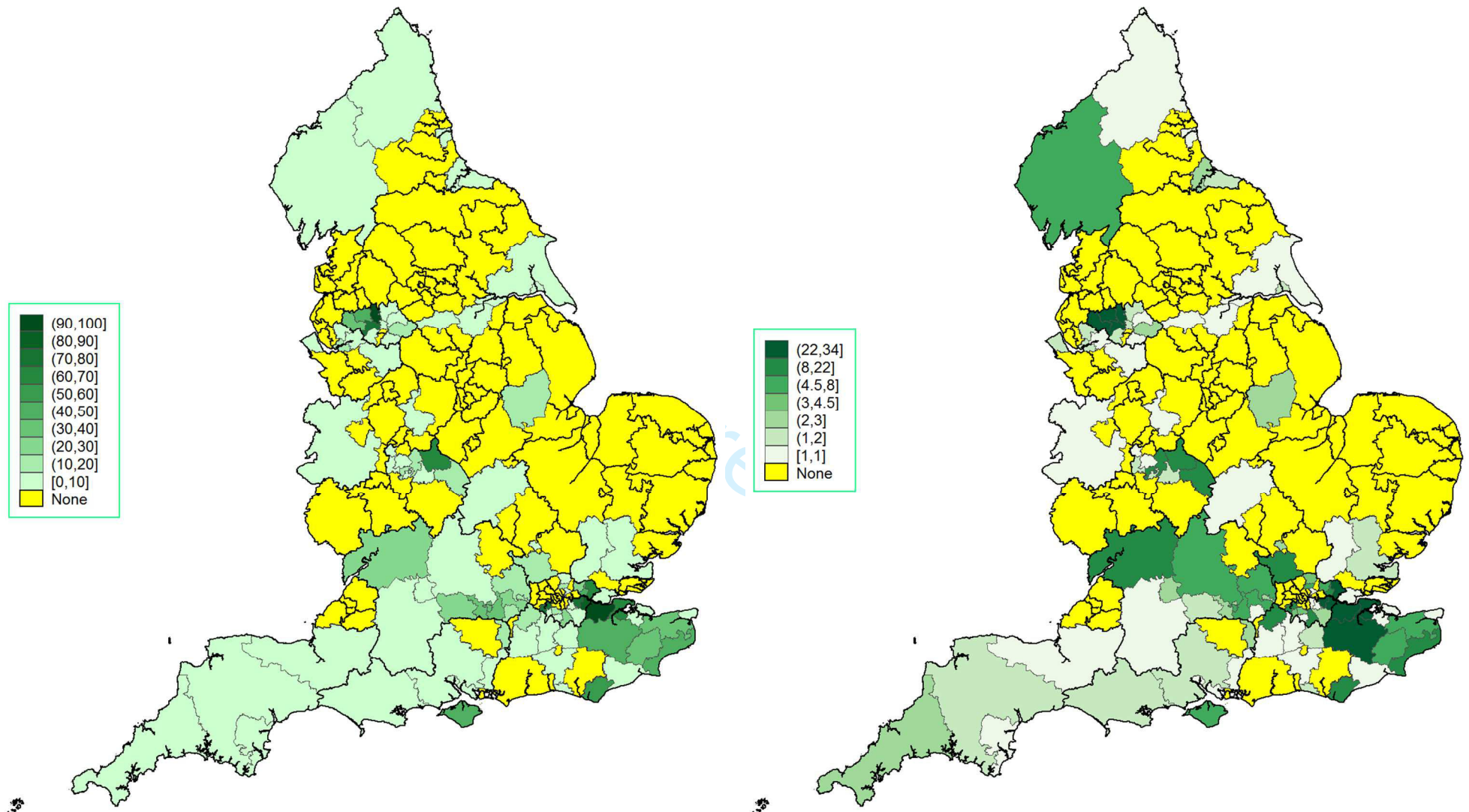
* thicker border lines correspond to the 14 NHS regions

† left graph uses equidistant class breaks; right graph uses class breaks based on distribution of variable of interest, with each class having approximately the same number of spatial polygons (CCGs)

Figure 3: Spatial map at the Clinical Commissioning Group (CCG) level, September 2016: Vision*†

Percentage of patient population share

Number of general practices



* thicker border lines correspond to the 14 NHS regions

† left graph uses equidistant class breaks; right graph uses class breaks based on distribution of variable of interest, with each class having approximately the same number of spatial polygons (CCGs)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	5-6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5-6
Bias	9	Describe any efforts to address potential sources of bias	NA
Study size	10	Explain how the study size was arrived at	5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	NA
		(b) Describe any methods used to examine subgroups and interactions	NA
		(c) Explain how missing data were addressed	NA
		(d) If applicable, describe analytical methods taking account of sampling strategy	NA
		(e) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6 and 12
		(b) Indicate number of participants with missing data for each variable of interest	6
Outcome data	15*	Report numbers of outcome events or summary measures	6 and 12
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	NA
		(b) Report category boundaries when continuous variables were categorized	12
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	6-7
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	7
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	7-8
Generalisability	21	Discuss the generalisability (external validity) of the study results	7-8
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	9

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Spatial distribution of clinical computer systems in primary care in England in 2016 and implications for primary care electronic medical record databases: a cross sectional population study

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2017-020738.R1
Article Type:	Research
Date Submitted by the Author:	30-Nov-2017
Complete List of Authors:	Kontopantelis, Evangelos; University of Manchester, Division of Informatics, Imaging and Data Sciences; Faculty of Biology, Medicine and Health; NIHR School for Primary Care Research, Centre for Primary Care Stevens, Richard; University of Oxford, Nuffield Dept Primary Care Health Sciences Helms, Peter; University of Aberdeen, The Institute of Applied Health Sciences Edwards, Duncan; University of Cambridge, Department of Public Health and Primary Care Doran, Tim; University of York, Department of Health Sciences Ashcroft, Darren; University of Manchester, Division of Pharmacy & Optometry; Faculty of Biology, Medicine and Health
Primary Subject Heading:	General practice / Family practice
Secondary Subject Heading:	Epidemiology, Health informatics, Health services research, Research methods
Keywords:	Electronic Health Records, Primary Care Databases, clinical computer systems, EMIS, Vision, CPRD

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3 **Spatial distribution of clinical computer systems in primary care in England in 2016 and**
4 **implications for primary care electronic medical record databases: a cross sectional**
5 **population study**
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44 Keywords
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Abstract

Objectives

UK Primary Care Databases (PCDs) are used by researchers worldwide to inform clinical practice. These databases have been primarily tied to single clinical computer systems, but little is known about the adoption of these systems by primary care practices or their geographical representativeness. We explore the spatial distribution of clinical computing systems and discuss the implications for the longevity and regional representativeness of these resources.

Design

Cross-sectional study.

Setting

English primary care clinical computer systems.

Participants

7,526 general practices in August 2016.

Methods

Spatial mapping of family practices in England in 2016 by clinical computer system at two geographical levels, the lower Clinical Commissioning Group (CCG, 209 units) and the higher NHS regions (14 units). Data for practices included, numbers of doctors, nurses, and patients; and area deprivation.

Results

Of 7,526 practices, EMIS was used in 4,199 (56%), SystemOne in 2,552 (34%) and Vision in 636 (9%). Great regional variability was observed for all systems, with EMIS having a stronger presence in the West of England, London and the South; SystemOne in the East and some regions in the South; and Vision in London, the South, Greater Manchester and Birmingham.

Conclusions

PCDs based on single clinical computer systems are geographically clustered in England. For example, CPRD and THIN, the most popular primary care databases in terms of research outputs, are based on the Vision clinical computer system, used by less than 10% of practices and heavily concentrated in three major conurbations and the South. Researchers need to be aware of the analytical challenges posed by clustering, and barriers to accessing alternative PCDs need to be removed.

Keywords

Electronic Health Records; Primary Care Databases; clinical computer systems; representativeness; EMIS; Vision; SystemOne; CPRD; THIN; QRESEARCH; ResearchOne.

Strengths and limitations of the study

- Cross-sectional analysis of all clinical computer systems used in English primary care, in August 2016.
- Data allowed a detailed description of regional use of each clinical computer system at the Clinical Commissioning Group (CCG) level, and the discussion of implications for UK Primary Care Databases (PCDs).
- Although regional presence of a clinical computer system cannot be equated to contribution to a PCD, since contributing practices are anonymised, inferences on the regional representativeness of UK PCDs are still possible.

Introduction

Primary care in the UK has been almost fully computerised since the early 1990s.¹ Following the introduction of partial subsidies for the purchase of clinical computer systems in 1998 and full subsidies in 2003 (in anticipation of the implementation of a national pay-for-performance programme) UK primary care became fully computerised.^{2 3} Interoperability requirements of the National Health Service led to the universal adoption of a loosely hierarchical clinical coding system, known as Read codes,⁴ which is due to be replaced in April 2018 by a multi-hierarchical coding system (SNOMED CT).⁵ Various commercial providers were permitted to enter the market for clinical computer systems, resulting in numerous different systems with varying interfaces, mechanisms and implementations of Read code usage.⁶ By 2010-11, seven clinical computer systems were consistently active in England, holding 99% of the market share: EMIS systems (LV and PC) were active in 54.7% of practices, followed by Vision v3 (18.1%) and SystemOne (17.8%), with the remaining 9.4% held by other systems (Synergy, Practice Manager, Premiere and the then newly launched EMIS Web).²

The uniformity and interoperability standards have facilitated the creation of large repositories of primary care electronic health records (EHRs), which contain the complete primary care records of patients attending general practices in the UK. The secondary use of these EHRs by researchers – both within and outside the UK – has been increasing exponentially,⁷ and they have provided insights in numerous research areas, including real-world effectiveness, adverse events, resource utilisation, condition prevalence and incidence, quality of care, and policy interventions.^{8 9} Several EHR databases exist, maintained by the different clinical computer system providers, drawing data from practices using their systems that have agreed to make patient data available for secondary use. The four largest EHR databases (hereafter primary care databases, or PCDs) in terms of numbers of patient records are the Clinical Practice Research Datalink (CPRD), The Health Improvement Network (THIN), QResearch and ResearchOne.

The CPRD (formally General Practice Research Database, GPRD) was established in 1987 and has been owned by the Secretary of State for Health since 1994. In May 2017, the CPRD covered approximately 8% of the UK population, with 718 contributing general practices and over 17 million total patients (historical and current). The CPRD primarily collects data from Vision practices, although it is currently undergoing an expansion to include EMIS practices, and a future expansion to cover SystemOne practices is planned. THIN was established in 2003 as a collaboration between the company owning Vision (In Practice Systems Ltd) and the CSD Medical Research Group (now Quintiles IMS). In April 2015, THIN reported covering 6% of the UK population, with 562 practices and 11 million total patients. There is a considerable overlap (around 60%) between CPRD and THIN practices, which has implications for studies wishing to

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3 replicate findings between different databases.¹⁰ QResearch collects data from practices using
4 EMIS systems and is the biggest PCD, with approximately 1500 practices in 2017, covering a
5 population of more than 22 million patients.¹¹ ResearchOne is a collaboration between the
6 provider of SystmOne (TPP) and the University of Leeds, reporting 28 million (primary and
7 secondary care) records and 423 practices in 2017.
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11 The geographical coverage of PCDs is dependent on the location of practices using the parent
12 clinical computer system, which is in turn dependent on historical patterns of market
13 penetration by the software suppliers and system uptake by general practices. Geographical
14 representativeness is an important prerequisite if analysts are to generalise PCD findings to the
15 whole of England and the UK, which is what routinely happens in practice. This is due to great
16 regional variability across England in terms of population characteristics (primarily: age,
17 ethnicity and deprivation),¹² or even regional variation in hard outcomes. For example, a
18 persistent mortality divide between North and the South of England has existed since the
19 middle of the previous century,¹³ while, more recently, much higher mortality rates were
20 observed for young adults in the North of England.¹⁴ There is also regional variation in the
21 organisation and productivity of health services in England,^{15 16} which could have important
22 implications for the generalisability of health services research with the use of regionally
23 unrepresentative PCDs. The aim of this paper is to describe the regional distribution of clinical
24 computer systems in English primary care, evaluate the implications of the current picture of
25 representativeness and provide some insight into the sustainability of existing PCDs.
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36 **Methods**

37 **Data**

38 Clinical computer system information was obtained from NHS Digital after direct
39 communication, for August 2016. Primary care workforce and patient information as of 30
40 September 2016 was downloaded from the NHS Digital website.¹⁷ At the practice level,
41 information was available on geography (Clinical Commissioning Group and NHS region),
42 patient list size by age groups, and numbers and full-time equivalent (FTE) for GPs and nurses.
43 Deprivation was quantified using the 2015 release of the Index of Multiple Deprivation (IMD), a
44 complete aggregate measure widely used to quantify area deprivation, attributed to the
45 practice location.¹⁸ Spatial coordinates for NHS organisational units in 2016 were obtained from
46 the ONS open geography portal.¹⁹ We focused on two organisational levels, the lower Clinical
47 Commissioning Groups (CCGs) with 209 units, and the higher NHS regions with 14 units.
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Analyses

For all aspects of data manipulation and analysis we used Stata v14.1. Whenever medians are reported, we also report the 25th and 75th centiles. Spatial maps were plotted using the *spmap* command.²⁰ Practice-level data were aggregated by clinical computer system, to provide information on all patients, patients aged 75 or over, GPs and nurses, practice location deprivation and list size. Counts for each clinical computer system, by NHS region, were also calculated. Spatial graphs at the CCG level, with additional information on NHS regions, were plotted for the three most popular clinical computer systems, to provide a visual guide in regional distribution and representativeness.

Results

System information was missing for 49 (0.7%) of 7,526 general practices. EMIS systems were used in 4,199 practices (56%), with all but 23 of these using EMIS Web. SystmOne was used in 2,552 (34%), Vision in 636 (9%) and Evolution in 90 (1%) practices. Patterns of area deprivation, based on the locations of general practices, were similar across all systems. SystmOne practices tended to be larger (median of 7,080 patients), followed by EMIS (6,833), Vision (6,279) and Evolution (6,222).

Great regional variability in system usage was observed both at the NHS Region level (Table 1) and CCG level (Figures 1-3). EMIS is present in all but 18 of the 209 CCGs (91.4%), with a much stronger presence in the West of England, London and the South. SystmOne is present in 120 CCGs (57.4%), and is mainly active in the East and some regions in the South. Vision, although with a much lower market share than SystmOne, is still used in 96 CCGs (45.9%), mainly in London, the South, Greater Manchester and Birmingham. Evolution is only present in 18 CCGs (8.6%) and is primarily used in the South West.

<Please place Table 1 here>

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Discussion

High regional variability exists in the use of different clinical computer systems in English primary care, which should be a consideration when utilising primary care electronic health databases based on this population in the future, especially if effect heterogeneity (or other forms of heterogeneity) is context relevant. For example, drawing nationwide conclusions in health services organisation would be more problematic than identifying medication side-

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3 effects. EMIS Web is by far the most widely used clinical computer system and therefore
4 QResearch is the most nationally representative single database – potentially able to collect
5 data from almost all English CCGs. SystmOne has a very strong presence in many parts of
6 England, but no presence in many CCGs in the North West, West Midlands, London and South
7 East. The ResearchOne database is therefore unable to capture data from many regions. Finally,
8 Vision is the most geographically restricted of the three major clinical computer systems, with
9 relatively few practices heavily concentrated in three conurbations and the South. The CPRD
10 and THIN databases are therefore currently unable to provide comprehensive coverage of large
11 parts of the country, particularly in the North and East of England.
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16 17 **Strengths and limitations of the study**

18 The main strength of this study is the use of numerous national administrative datasets of high
19 data quality, allowing us to obtain a complete picture for the whole of England. The main
20 weakness of the work is the fact we cannot equate the regional presence of a clinical system to
21 active contribution to a primary care database – not all practices contribute data and
22 contributing practices are anonymised – and we have therefore discussed potential
23 contribution instead. Additional information on currently registered patients would have been
24 relevant, but is not routinely available for non-users of the resources (but can be deduced by
25 users).
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31 32 **Findings and implications**

33 The current picture of clinical system usage in English primary care is very different to what was
34 reported for 2011.² Although EMIS is still the biggest provider and has retained its market share
35 (56% in both 2011 and 2016), its LV and PCS systems which dominated the market in 2011 are
36 hardly used anymore, with almost all practices having transitioned to the Web system. The use
37 of TPP's SystmOne has increased from 18% to 34%, while that of Vision by In Practice System
38 has halved (from 18% to 9%). Many providers that were present in 2011 have subsequently
39 withdrawn from primary care, with the exception of Microtest's Evolution (transitioned from
40 Practice Manager). If the current trend continues, English primary care will be completely
41 dominated by EMIS Web and SystmOne in the next 5 to 10 years, and access to both of these
42 systems would ensure almost complete coverage for England.
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48 The trend for primary care convergence to two clinical systems has implications for the future
49 of PCDs and the research findings based on them. CPRD and THIN will need to adapt very
50 quickly and include EMIS and/or SystmOne practices in their processes. Given that the CPRD
51 and THIN are the two most widely used primary care databases in clinical research, losing them
52 altogether – as happened with the DIN-LINK database²¹ – would be a severe setback for the
53 research community. As of 20 July 2017, a PubMed search identified 1,782 published papers
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3 linked to the CPRD (886 in the last 5 years), 471 linked to THIN (303 in the last 5 years), 71
4 linked to QRESEARCH (32 in the last 5 years) and 2 to ResearchOne (both in the last 5 years).
5 Although not exhaustive, this search indicates the large variability across databases in terms of
6 scientific contribution, demonstrating that the most accessible and productive databases are
7 the ones at immediate risk.
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11 Within the CPRD, there are clear actions towards future-proofing the resource, in light of the
12 deterioration of the Vision market share. A large number of EMIS practices are already
13 contributing data to the resource, but differences in the data format (compared to the standard
14 Vision format) has prevented their immediate release along with Vision data, while it was not
15 possible to link the EMIS data to other data sets. Nevertheless, a major transformation in
16 processes is being undertaken which will allow the release of both Vision and EMIS data as
17 standard, within 2018. In addition, the recruitment of EMIS practices continues, with over 150
18 practices having joined the CPRD in the last 12 months.
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24 Users of the UK PCDs need to be aware of the generalisability issues we described, and consider
25 if there are any risks relevant to their studies. Generalisability (external validity) should be
26 discussed as standard in such work and is listed as an item (#21) in both the STROBE and
27 RECORD statements.^{22 23} The context is important here, and regional representativeness may be
28 less relevant for clinical questions but more relevant for health services research. Sensitivity
29 analyses on a more representative group of practices, obtained through deterministic sampling
30 and existing software,²⁴ can also be used to strengthen findings.²⁵ However, the strong
31 clustering of clinical systems within CCGs, largely driven top-down from CCGs to general
32 practices, limits the usefulness of such sampling approaches.
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40 Conclusions

41 The geographical representativeness of primary care databases varies enormously, and the two
42 most used databases in the UK, the CPRD and THIN, were in 2016 the least representative of
43 the major databases due to the quickly diminishing market share of the clinical computer
44 system providing their data (Vision). The existence of these databases is under threat, and
45 urgent action is required to allow data collection from at least one of the two dominant clinical
46 systems (EMIS Web and SystemOne). CPRD has recognized this, and has recently negotiated
47 access to data held by EMIS practices, and is due to operationalise this data by 2018. In
48 addition, development and access barriers that have restricted publication outputs from data
49 drawn from EMIS (QRESEARCH) and SystemOne (ResearchOne) practices urgently need to be
50 overcome if the confidential use of NHS patient data is to continue driving research that directly
51 informs patient safety, management, and health services policy.
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For peer review only

Acknowledgments

We would like to thank the Office of National Statistics and NHS Digital for the wealth of information they have collected and systematically organised, which made this study possible.

Funding

MRC Health eResearch Centre Grant MR/K006665/1 supported the time and facilities of EK. The views expressed are those of the authors and not necessarily those of the MRC.

Declaration of competing interests

EK, RS, PH and DE are members of the Independent Scientific Advisory Committee (ISAC) for MHRA database research: <https://www.gov.uk/government/groups/independent-scientific-advisory-committee-for-mhra-database-research>

Ethical approval

Not applicable

Patient involvement

Not applicable

Authorship & contributions

EK designed the study, extracted the data from all sources, performed the analyses and drafted the first version of the manuscript. RS, PH, DE, TD and DA critically edited the manuscript. EK is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Transparency declaration

EK affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Data sharing

The data used in this study are freely available and the authors are happy to share an organised and cleaned final dataset.

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Table 1: Regional distributions of systems and the characteristics of their respective general practices*†‡§

	EMIS [¶]	SystmOne	Vision v3	Evolution
Aggregates (%)				
Number of practices	4199(56%)	2552(34%)	636(9%)	90(1%)
Number of patients	32191392(56%)	20199414(35%)	4601205(8%)	629166(1%)
Number of GPs	18675(57%)	11160(34%)	2433(7%)	393(1%)
Medians (25th and 75th centiles)				
IMD 2015 [#]	22.2 (12.1,37.4)	22.5 (12.8,36.8)	22.4 (12.3,37.0)	22.7 (14.4,31.0)
List size	6833 (4257,10094)	7080 (4214,10553)	6279 (3988,9759)	6222 (4743,9121)
Patients aged 75 or over	476 (240,823)	524 (256,895)	455 (225,710)	592 (400,924)
Means (SD)				
All GPs	5.1(3.4)	5.1(3.7)	4.5(3.1)	5.5(2.9)
Female GPs	2.8(2.4)	2.7(2.5)	2.3(2.1)	2.7(2.1)
GPs aged under 40	1.7(1.9)	1.6(2.0)	1.4(1.7)	1.5(1.6)
GPs aged 40 to 54	2.3(1.9)	2.4(2.1)	2.0(1.8)	2.8(1.9)
GPs aged 55 or over	1.0(1.0)	1.0(1.0)	1.1(1.0)	1.2(1.1)
All Nurses	3.1(2.3)	3.6(2.6)	2.8(1.9)	3.4(1.6)
Regional counts, NHS regions (%)				
Wessex	164(55%)	113(38%)	17(6%)	4(1%)
London	917(68%)	254(19%)	182(13%)	1(0%)
Yorkshire & the Humber	186(25%)	544(74%)	5(1%)	0(0%)
Cumbria & the North East	270(59%)	172(38%)	12(3%)	0(0%)
Cheshire & Merseyside	353(92%)	19(5%)	8(2%)	2(1%)
North Midlands	260(54%)	216(45%)	2(0%)	2(0%)
West Midlands	496(76%)	96(15%)	58(9%)	0(0%)
Central Midlands	156(28%)	378(69%)	16(3%)	0(0%)
East	112(21%)	413(77%)	4(1%)	4(1%)
South West	225(59%)	86(22%)	7(2%)	65(17%)
South East	303(56%)	96(18%)	145(27%)	1(0%)
South Central	227(55%)	129(31%)	57(14%)	3(1%)
Greater Manchester	310(65%)	36(8%)	123(26%)	8(2%)
Lancashire	220(100%)	0(0%)	0(0%)	0(0%)

* Data for Aug 2016 (clinical system) and Sep 2016 (GMS data)

† System information not available for 49 (0.65%) of 7,526 practices

‡ All GP numbers exclude locums

§ SystmOne provided by TPP, Vision (version 3) provided by In Practice Systems, Evolution provided by Microtest

¶ EMIS includes Web (4,176 practices), LV (19 practices) and PCS (4 practices)

Index of Multiple Deprivation (higher score implies higher levels of deprivation); details available in the 2015 technical report of the English Indices of Deprivation¹⁸

1 **Figure 1: Spatial map at the Clinical Commissioning Group (CCG) level, September 2016: [EMIS](#)*†**

2 * thicker border lines correspond to the 14 NHS regions

3 † left graph uses equidistant class breaks; right graph uses class breaks based on distribution of variable of interest, with each class having approximately the
4 same number of spatial polygons (CCGs)
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8 **Figure 2: Spatial map at the Clinical Commissioning Group (CCG) level, September 2016: [SystemOne](#)*†**

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10 * thicker border lines correspond to the 14 NHS regions

11 † left graph uses equidistant class breaks; right graph uses class breaks based on distribution of variable of interest, with each class having approximately the
12 same number of spatial polygons (CCGs)
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16 **Figure 3: Spatial map at the Clinical Commissioning Group (CCG) level, September 2016: [Vision](#)*†**

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18 * thicker border lines correspond to the 14 NHS regions

19 † left graph uses equidistant class breaks; right graph uses class breaks based on distribution of variable of interest, with each class having approximately the
20 same number of spatial polygons (CCGs)
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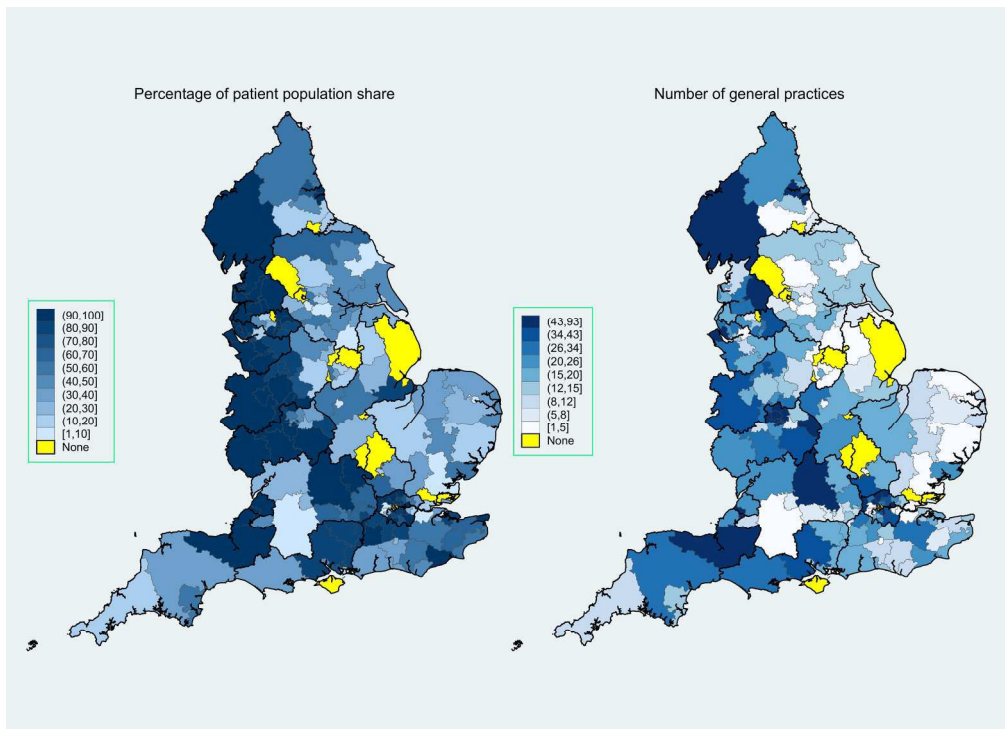


Figure 1: Spatial map at the Clinical Commissioning Group (CCG) level, September 2016: EMIS

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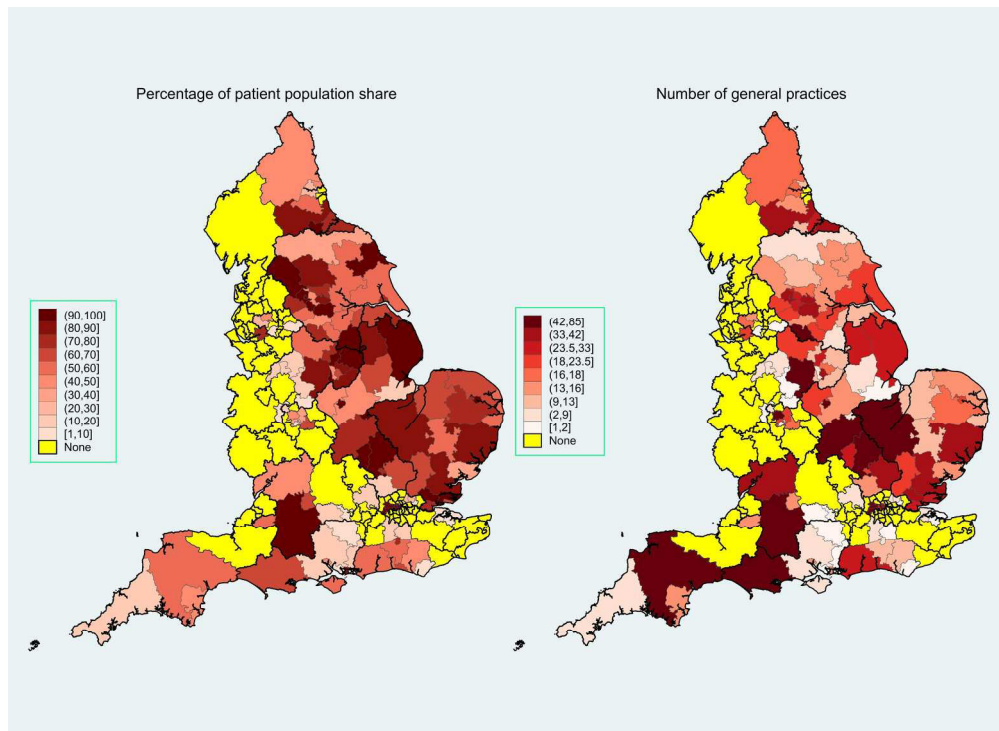


Figure 2: Spatial map at the Clinical Commissioning Group (CCG) level, September 2016: SystmOne

101x73mm (600 x 600 DPI)

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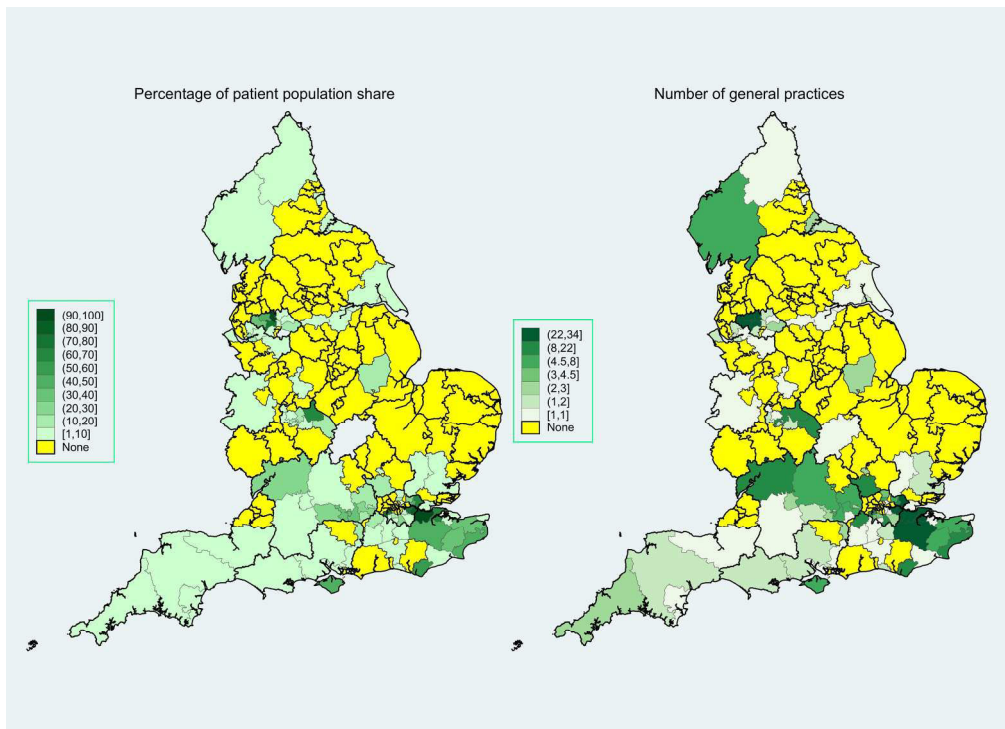


Figure 3: Spatial map at the Clinical Commissioning Group (CCG) level, September 2016: Vision

101x73mm (600 x 600 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	5-6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5-6
Bias	9	Describe any efforts to address potential sources of bias	NA
Study size	10	Explain how the study size was arrived at	5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	NA
		(b) Describe any methods used to examine subgroups and interactions	NA
		(c) Explain how missing data were addressed	NA
		(d) If applicable, describe analytical methods taking account of sampling strategy	NA
		(e) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6 and 12
		(b) Indicate number of participants with missing data for each variable of interest	6
Outcome data	15*	Report numbers of outcome events or summary measures	6 and 12
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	NA
		(b) Report category boundaries when continuous variables were categorized	12
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	6-7
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	7
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	7-8
Generalisability	21	Discuss the generalisability (external validity) of the study results	7-8
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	9

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.