Greater Manchester Connected Health City (GM CHC)

Building Rapid Interventions to reduce antimicrobial resisTance and over-prescribing of antibiotics: BRIT

CONNECTED
HEALTH CITIES
A nhsa project

Contents

ABSTRACT

The BRIT project aims to develop and implement at scale the infrastructure for collecting and analysing data on prescribing, clinical interventions and patient demographics in order to better understand the public drivers for antibiotic prescribing in the UK. The project team has developed and tested simple interventions to refine antibiotic prescribing in locations, facilities or sub-groups (of patients and/or clinicians). A web-based platform (dashboard) has been designed to help users develop a better understanding of how antibiotics are currently prescribed and where prescribing can be improved. The dashboard has two types of users, i.e. Practice level users and CCG level users

or policy makers. Features of the dashboard include benchmarking, so a practice can see their prescribing rates adjusted by STAR-PU, and compare to a regional average / national average. There is also information on the variability of prescribing across practices for each infectious condition, where users can see what antibiotic drugs are being prescribed for each condition. Practices will also be informed which of these antibiotic prescriptions are deviating from the guidelines with links to local prescribing recommendations. In addition, risk profiling where a patient's risk of an infection-related complication can be identified in a 30-day window. Over-prescribing to low-risk patients or under prescribing to high-risk patients can also be visualised.

The web-based platform has been designed to incorporate pertinent issues facing clinicians in Primary Care and can be tailored according to the user's requirements. For example, to explore drivers of antibiotic prescribing, complex models are fitted to national and local data to understand the factors that influence suboptimal prescribing.

INTRODUCTION

Background:

Antimicrobial resistance (AMR) is considered to be one of the major global public health challenges of the 21st Century, with projected significant impacts on morbidity and mortality and subsequent impacts on the global economy. [1] The discovery of novel antimicrobial medicines has stalled, and even though research is investigating increasingly innovative and collaborative ways of tackling the problem, no new class of antibiotics has been produced since the late 1980's and infection rates and resistance levels continue to increase. Research has found that the current use of antibiotics is highly variable across the NHS, resulting in the ineffective targeting of patients who are a high risk of infection-related complications and emergency hospital admission. This leads to longer stays in hospital, increased healthcare costs and increased mortality. In addition, overuse of antibiotics results in reduced effectiveness over time, increased risk of adverse events and the over-medicating of self-limiting conditions. [2]

The scale of the threat from AMR was set out in Chief Medical Officers (CMO) England's Annual report[3] (2013) with a subsequent Review of Antimicrobial Resistance[4] (2016). The UK Government recognises the significant and complex challenges of tackling the problem of antimicrobial resistance and have produced successive 5-year AMR strategies (2013-2018 and 2019-2024) with a 20-year vision for antimicrobial resistance. One of the key components of the strategy to reduce AMR is effective antimicrobial stewardship; that antibiotics are used appropriately and made available to those who need them most. Several interventions have supported this including revising the guidelines for appropriate antibiotic prescribing, the introduction of quality premiums (providing a financial incentive for Clinical Commissioning Groups to reduce antibiotic prescribing in primary care), and widespread public health campaigns with the introduction of antibiotic guardians to "keep antibiotics working". The Department of Health have highlighted the importance of behavioural change strategies in antibiotic prescribing, [5] but the effectiveness of these interventions has been varied and the need to reduce antibiotic prescribing remains.

The development of technologies in the second half of the 20th Century has revolutionised the way in which data is collected, processed, stored and transmitted and this is of particular importance in a healthcare setting where the power of information and technology can be used to improve health, wellbeing and care. [6,7] Clinicians, patients and citizens are in a position now to take full advantage of the digital opportunities available to them, such as the establishment of integrated electronic health records (EHR's). Having centralised and normalised data available through EHR's has produced a step change in health informatics, allowing analytical approaches to be applied to healthcare that could support predictive intelligence to determine healthcare risks, and the potential to develop the infrastructure that allows healthcare practitioners and researchers to test new interventions to support improvement and sustainability [8]. This has huge potential for the NHS and could establish the UK as a world leader in healthcare analytics.

Rationale:

In the UK, at least 72% of antibiotic prescribing occurs in primary care [9]. However, each GP practice faces different challenges and digital tools to support effective stewardship of antibiotics should be tailored to meet the challenges of those individual practices. By providing GP's with the tools to be able to understand aspects of antibiotic prescribing, they will be able to effectively apply, and analyse the impact of interventions that are relevant to their practice and their patient population.

The 'learning healthcare system' (LHS) has been proposed to deliver better outcomes for patients and communities by analysing routinely captured health information and feeding back results to clinical staff [10]. This approach was piloted in the Connected Health Cities programme in four regions in the North of England. With world-class expertise in data science, Greater Manchester CHC team (GM CHC) were well placed to develop digital tools that will give health care professionals all the data, information and knowledge they need to optimise their antibiotic prescribing behaviours. The impact of the BRIT project could be significant. The development of a comprehensive infrastructure for data analysis in an e-lab setting can be used to test simple interventions and be adaptive to accumulating evidence. Such infrastructure although initially developed here for antibiotic prescribing could be effective for use in multiple priority areas for the Department of Health.

Programme Aims and Objectives:

The GM CHC BRIT project in association with the University of Manchester, Public Health England and NHS Greater Manchester Medicines Optimisation Unit aims to reduce the burden of antimicrobial resistance (AMR) through the optimisation of antibiotic use in primary care by empowering healthcare professionals with clinically informative and actionable advanced analytics of their health data, by:

Understanding drivers of inappropriate antibiotic prescribing: By establishing a national DataLab (data repository) of patient level data on the treatment of common infections in primary care (including > 30 million records of antibiotics and common infections including hospital admission outcomes), thereby providing a comprehensive dataset for analysis to identify current prescribing trends at both practice and patient level.

Understanding stakeholder issues and requirements: Ensuring the maximum uptake and use of the Datalab, through effective engagement of clinical staff and policy makers and co-design and user feedback of the BRIT dashboards.

Developing the capability to use data: By developing mechanisms for a continuous flow of anonymised data into a Trustworthy Research Environment (TRE), and the development of a common data model to be able to transform data from multiple sources to be analysed at scale.

Developing BRIT DataLab: The delivery of dashboards to generate the feedback mechanism resulting from the data analytics and provide (i) tailored feedback to general practices on their antibiotic prescribing and clinical pathways for common infections and (ii) overall feedback to policy makers on regional patterns of antibiotic prescribing.

Supporting Industry engagement: which includes a 'Spin in' lab to provide companies with an opportunity to develop and validate products for the health care market. For BRIT this includes work with industry partners to deliver additional analytical tools or technology to support optimised prescribing practice.

Project Management:

Organisational Structure: GM CHC identified organisational structures that were critical in the delivery of the care pathways commitment. A CHC Advisory board meets quarterly and has oversight of all CHC Projects. The Project Management (PM) team provides technical oversight and coordination with the Steering committee in terms of policy development and standards setting. The PM team also coordination with the Trust Research Environment (TRE) operations team and the BRIT Project implementation team in terms of technical development, resource utilisation, capacity building, networking and communications. The BRIT Project implementation team consists of Data Analysts, Statisticians, Software Engineers, Clinicians and Qualitative Researchers, Project Management and Communications Professionals.

Trustworthy Research Environment: (TRE) is a facility for the secure analysis of health data at The University of Manchester. This cutting-edge facility was built to offer a unique interface for researchers to securely access and analyse health data while protecting confidentiality of staff and patients. The data held in the TRE is anonymised before the data is made available to researchers. The TRE is DSP Toolkit (formerly IG Toolkit) certified and has its own connection to the NHS HSCN (formerly N3) network.

GDPR compliance: To ensure good governance according to GDPR requirements, privacy impact assessments were conducted. In order to meet the principle of data minimisation and ensure anonymity of the EHR data extract, a specification was developed in consultation based on what analysts needed for their models. Data sharing agreements were created to ensure the safe use and sharing of data, to be established with the owners of the data (GP practices) the data provider (external provider) and the University of Manchester.

METHODS

The multidisciplinary team took a multi-step approach to the delivery of the BRIT project, which included

- Analysis of existing datasets to identify issues pertaining to antibiotic prescribing
- Prioritisation and mapping exercises to establish the requirements of the dashboard, through stakeholder engagement and qualitative research.
- Infrastructure development of the DataLab, including data transfer mechanisms, development of a common data model, use of analytical tools and design and implementation of dashboard outputs.

- Communications and user engagement, including a comprehensive communications plan for national dashboard engagement and engaging local GP practices as test sites for the GP dashboard.

Analysis of existing datasets.

BRIT analysts made use of a number of large datasets containing information about antibiotic prescribing including data from Clinical Practice Research Datalink (CPRD) [11] linked to Hospital Episode Statistics (HES) [12] for England, the SAIL databank [13] in Wales and the NHS digital practice prescribing data (NHS-DPPD). Several research questions were addressed: (1) To understand prescribing patterns across different geographical regions of the UK, (2) To assess determinants of antibiotic prescribing, (3) To examine variations across general practices and factors associated with antibiotic prescribing for common infections, and to identify potential targets for improvement and optimisation of prescribing. (4) Understanding the rates and drivers of potentially inappropriate antibiotic choice, predictors of such prescribing and the clustering effects at practice level.

Stakeholder engagement:

The priorities and assumptions underpinning the BRIT dashboard have been informed and defined through consultation exercises including workshops and a survey.

Workshop: The first was the consultation exercise undertaken with Greater Manchester Public Health Intelligence Network (GMPHIN). This workshop, held in early March 2017 included round table discussions and helped inform the design of the BRIT survey. A second workshop in June 2018 had focus groups give feedback on usability of a demonstration version of the dashboard.

Survey: The online BRIT survey ran from May to July 2017. Links to the survey were widely disseminated in order to ensure a diverse range of professionals responded to the survey. Survey responses were mapped against the BRIT team's original documentation of the purpose and design of the dashboard, using methods to ensure that the software incorporates those requirements considered most important by the end users and equip them to optimise antibiotic prescribing.

Qualitative research:

To understand differences between practices that were identified as high or low prescribers, semi-structured interviews were conducted with 41 GPs in Northwest England between January and June 2018. [Outputs; 15] Participants were representative of low, medium and high-prescribers. Data was analysed using a thematic approach [14]. This study received approvals from the University of Manchester Research Ethics Committee and the Health Research Authority on 20th Nov 2017 (IRAS 234292)

Data Sources

Views in the DataLab were designed for different prospective user groups: practice level users interested in their own performance, and regional or national level users interested in understanding patterns of prescribing across practices. For each DataLab view, a different dataset was used to prepare the analysis presented.

The national level dashboard makes use data from 300 practices from CPRD data (2000-2017), and a further 300 practices from the SAIL databank containing data for all registered practices in Wales.

The practice level dashboard makes use of data extracted from GP practice eHR's. This view presents more individualised feedback tailored to each practice, providing context and highlighting mitigating/extenuating circumstances for each practice. This approach incorporates an understanding that most practices are not directly comparable due to the different makeup of their patient populations, patient management procedures and, regional pressures (e.g. local resistance patterns or outbreaks of infection).

Infrastructure development:

General practice data comes from different sources depending on the provider of the EHR system. Examples include EMIS and Vision, which are commonly used by practices in the Northwest. The data provider processed the data to ensure all identifiable data was removed prior to receipt into the BRIT servers. Where data was received from multiple sources a new common data model was created to allow data from different sources and formats to be assimilated and standardised before analysis. The data was then combined with the national database to provide a sense of comparison for each individual practice engaged in GP-BRIT, and presented as a Datalab in a web application.

The software development for the dashboard was primarily done using the free statistical computing language R, which is proficient at data processing and statistical analysis, so it could be used for both the data preparation and the final presentation in the dashboard. R and its Shiny dashboard package were chosen as it was one of a limited number of platforms that allowed statistical plots and graphs to be shown in a web application. [Outputs; 7]

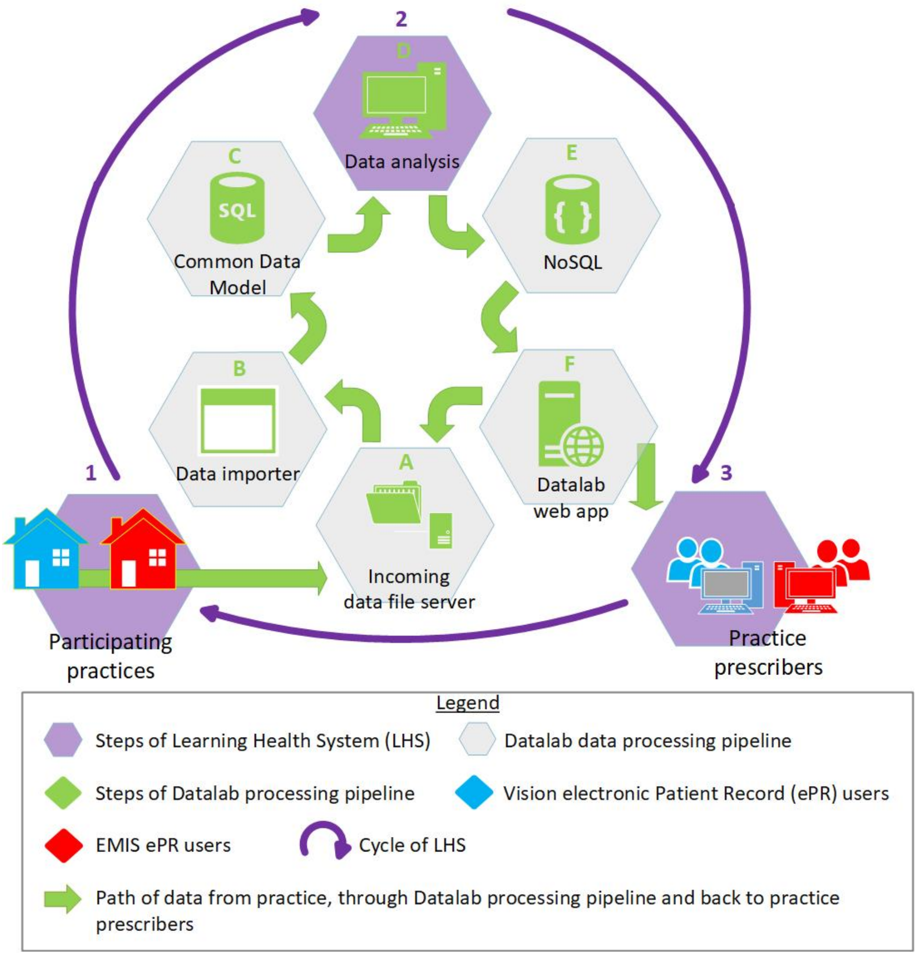


Figure 1 shows how the Datalab processing pipeline complements the Learning Health System methodology

Industry engagement. To add to the analytics proposition, the BRIT team worked with an SME, Imosphere, to provide a complementary analytics platform [Atmolytics] to a number of GP-BRIT users allowing investigation and exploration of independent practice data in a way that suits them. This could provide GPs with the ability to analyse additional data that is not subject to the deep data analytics presented by BRIT, such as financial summaries, generic patient data and trends in terms of patient characteristics. An agreement to pilot Atmolytics for a small number of BRIT practices was initiated to provide the opportunity to develop and validate their product.

Communications and User Engagement

The national dashboard was launched on 14th November 2018 to coincide with the National Antibiotic Awareness Week [15]. (www.britanalytics.uk). Access to the National Dashboard was restricted to people who had recognisable credentials, (NHS, PHE, policymakers), as agreed by the ethical use commitment with the data providers. It was later agreed as the underlying data was not accessible through the dashboard and the risks of de-identifying the data was low, that access could be opened up to all interested parties. A comprehensive plan was developed to include widespread communications to recognised professionals through targeted newsletters and publications, a targeted social media campaign and a national press release, which was picked up by several interested organisations.

The evaluation of the GP dashboard is the subject of an NIHR clinical research Study (IRAS 235520) and approved by South Central Oxford A Research Ethics Committee (REC) and the Health Research Authority (HRA) 20th Feb 2018. Initial recruitment of lead GPs in practices across Greater Manchester was supported by the Greater Manchester Clinical Research Network (primary care) and additionally from local GP Federations and CCG leads. Pilot practices were recruited in June 2018. Additional practices were recruited following a soft launch in January 2019. In order to build relationships with GPs and ensure a 2-way communication around the dashboard developments, GP practices were visited individually by the project manager where the national dashboard was demonstrated with opportunity to discuss benefits of the project. Data guardians at each practice consented to a data transfer agreement with the data provider and a data sharing agreement with the University of Manchester. Approval was requested and granted to open up recruitment of GP practice across the UK and Wales due to demand resulting from awareness of the project through national communications.

RESULTS

Data analyses

BRIT conducted a large number of data analyses, which have resulted in the submission of 16 scientific manuscripts. Important outcomes resulting from this research are described below: [outputs 1-16]

Prescribing hotspots

Existing approaches to quality improvement are often based on the measurement of 'performance indicators', which are applied nationally and hence often non-specific and not tailored to the local challenges. An example is the quality premium scheme launched by NHS England with aims to include the reduction of inappropriate antibiotic prescribing in the UK.

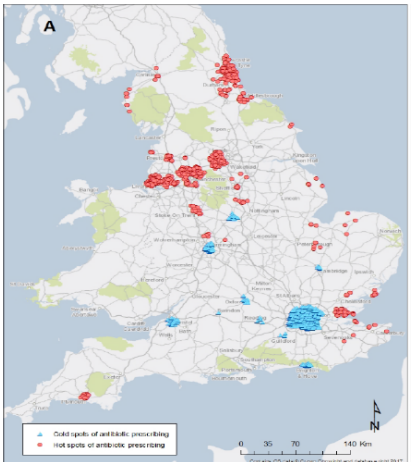


Figure 2: hot and cold spots for prescribing across the UK

The indicators used to support the overall reduction of antibiotic prescribing in practices takes into account the age and sex structure of the practice population, but not important local factors such as practice work load or patient demand. Using the large CRPD dataset from primary care, BRIT researchers identified a number of hot and cold spots of antibiotic prescribing, with hot spots predominantly in the North of England. Spatial regression showed that patient catchments of hot spot practices were significantly more deprived than patient catchments of cold spot practices, especially in the domains of income, employment, education and health (as shown in Figure 2). Area level strategies may be needed for antimicrobial stewardship rather than national level strategies.

Risk of infection related complications and hospital admissions

Another challenge with the strategy of focusing on an overall reduction of antibiotic prescribing is that higher levels of incidental[1] antibiotic prescribing in practices are associated with lower risks of infection-related hospital admissions. BRIT also found that antibiotic prescribing is rather suboptimal in UK general practices with a considerable postcode lottery (varying levels of prescribing) and suboptimal targeting to patients at high risk of infection-related complications. The variability with prescribing has not reduced over the 15 years of the study despite the introduction of multiple treatment guidelines and antibiotic stewardship initiatives.

General prescribing behaviours

The propensity of GPs to prescribe medications in general is an important driver for antibiotic prescribing. The figure 3 below shows the rates of antibiotic and other prescribing in NHS-DPPD and CPRD practices (each circle representing a practice). Practices that prescribed higher levels of other medicines also issued considerably more antibiotics. BRIT concluded that interventions that aim to optimise antibiotic prescribing would need to target general prescribing behaviours of GPs in addition to specific work on

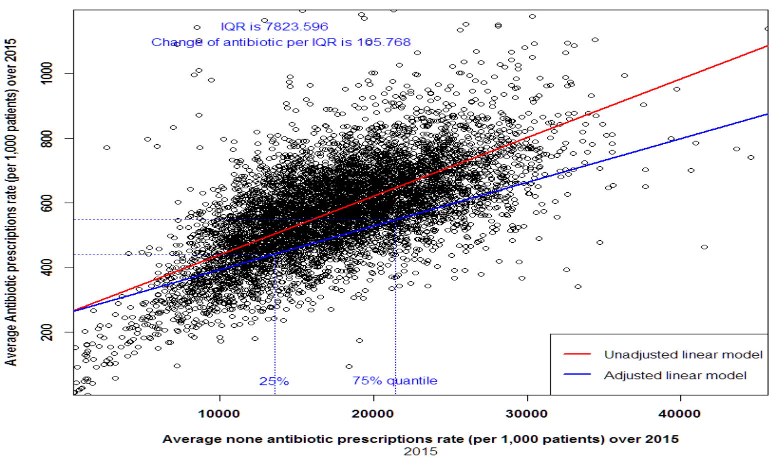


Figure3: rates of antibiotic and other prescribing

[1] where the first time an infection related READ code has been recorded in the patients EHR for 3 months, when just one READ code has been recorded during the consultation and one antibiotic prescribed during the consultation

antibiotics.

Appropriate prescribing

BRIT evaluated the rates of potentially inappropriate antibiotic choices, when prescribing for common infections in UK general practices. For example, it was found that 61.7% of prescriptions were potentially inappropriately prescribed for Upper Respiratory Tract Infections, which includes influenza, sore throats, ear infections and sinusitis. Guidelines state that most cases of URTIs will resolve without antibiotics and only if duration is longer than a certain number of days (depending on the condition) should antibiotics be considered [16.17]. Amoxicillin was the most commonly prescribed antibiotic for all respiratory tract infections, accounting for 76.6% of potentially inappropriate prescriptions for URTI (54.1% for common ear infections). There was a great variation between practices in relation to the proportion of prescriptions considered potentially inappropriate especially for UTI in children and common ear infections (between 0% and 100% of prescriptions).

Complications from repeated use of antibiotics

We found that the number of antibiotics needed to treat common infections varied substantially between the type of common infection and different subgroups of patients. The need to better target and optimise antibiotic prescribing in primary care is highlighted by the BRIT findings that repeated use of antibiotics is associated with worse outcomes. There are high levels of repeat and intermittent prescribing of antibiotics in primary care. The figure shows the patterns of the rates of infection-related hospital admissions in the 6 months after an antibiotic prescription stratified by prior history of antibiotic prescribing. The highest rates of hospital admission were observed shortly after the antibiotic prescription in all groups. For patients with limited prior antibiotic use, the rates then dropped substantially. In contrast, we see that patients who frequently use antibiotics are more likely to experience infection related complications and be admitted to hospital indicating the reduced effectiveness of the antibiotics over time. There is very little clinical evidence for the effectiveness of repeated and intermittent use of antibiotics.

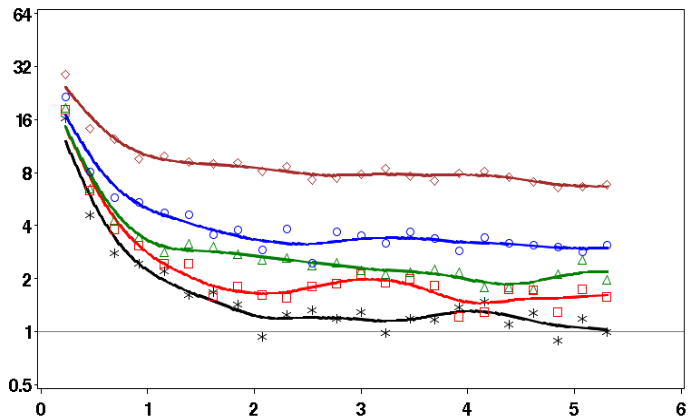


Figure4 : Incidence Rate Ratios of hospital admissions for infection-related complications in the 6 months after in patients with selected infection stratified by quintile of prior antibiotic prescribing; age- and sex-matched cohorts *(*=lowest, □=low; Δ=intermediate; ○=high; ◊=highest; reference is month 6 in lowest quintile)*

Effects on chemotherapy medications

The most profound BRIT results concern the effects of antibiotics on mortality in patients recently diagnosed with cancer (most types of chemotherapy are metabolised by gut microbiota; disturbance of the microbiota due to antibiotics could possibly reduce the effectiveness of chemotherapy. EHRs from England and Wales (the Clinical Practice Research Datalink (CPRD), the Secure Anonymised Information Linkage Databank (SAIL) and Cancer Registry data from Wales) were used. Among the key findings are that patients with leukaemia and lymphoma, namely cancers mainly treated with chemotherapy, who had been exposed to antibiotics up to 3 months before cancer diagnosis, represent a higher risk of death than patients who were exposed in the long past (risk of death more than 50% and 25% correspondingly). The risk is also high for patients with myeloma, melanoma, urinary, kidney and colorectal cancer.

User consultation

Key functional and non-functional requirements of the dashboard reported by user consultation (table 1) were used to direct the functionality and development to the IT infrastructure.

	Functional requirements
Must have (critical to the current delivery)	Level of inappropriate antibiotic prescribing (i.e., wrong type, dose and duration) Guidelines (local and NICE) on how to treat infections Counts of antibiotic prescribing in each general practice Provide access to analyse local data yourself using an user-friendly interface Provide access to prescribing rates, trends, patterns, e.g. by age group
Should have (Important but not necessary for the current delivery)	Access to local guidelines that are based on local resistance data Subgroups of patients in your area at high risk of infection-related complications but were untreated with antibiotics Subgroups of patients in your area at low risk of infection-related complications who were treated with antibiotics Display of main drivers of antibiotic prescriptions (such as ethnicity or comorbidities)
Could have (desirable but not necessary)	Ability to request more analyses Ranking of local practices with respect to overall level of antibiotic prescribing or PSTAR Electronic decision support within the electronic health record (such as symptom scores) Information on the risk for each patient of developing infection-related complications (such as sepsis)
Won't have	Ability to comment on and rate dashboards Point of care testing
	Non-functional requirements
Must have	Provide access to education for both patient and professionals, e.g. to use in consultations
Should have	Increase access to information, primarily seen as important for professionals Provide access to awareness raising material, primarily for patients Provide access to feedback to clinicians Provide access to peer comparison

Could have	Provide access to training for a range of clinicians Peer to peer learning Provide access to risk assessment tools Provide access to audit data Provide access to benchmarking Provide access to local resistance patterns
Won't have	Complex data and or data which requires advanced analytic skills

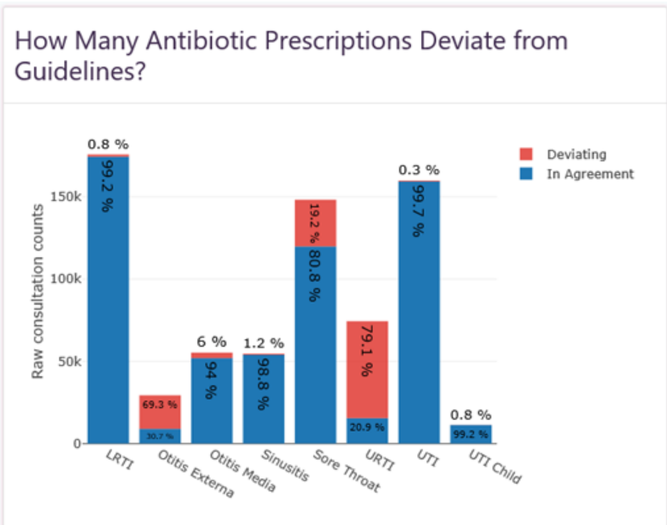
Table 1: dashboard requirements defined through stakeholder engagement

Dashboard Development

Based on findings and outputs of the BRIT research, the analysts within the BRIT implementation team were able to group graphs and tables together on themes, such as 'Antibiotic Prescribing by Infection and Antibiotic Prescribing Deviating from Guidelines', 'Benchmarking of practice antibiotic prescribing', 'Prescribing based on risk of hospitalisation' and overall 'Prescribing volume'. Each of the screens in the DataLab shows a number of interactive graphics with key messages to guide practitioners through.

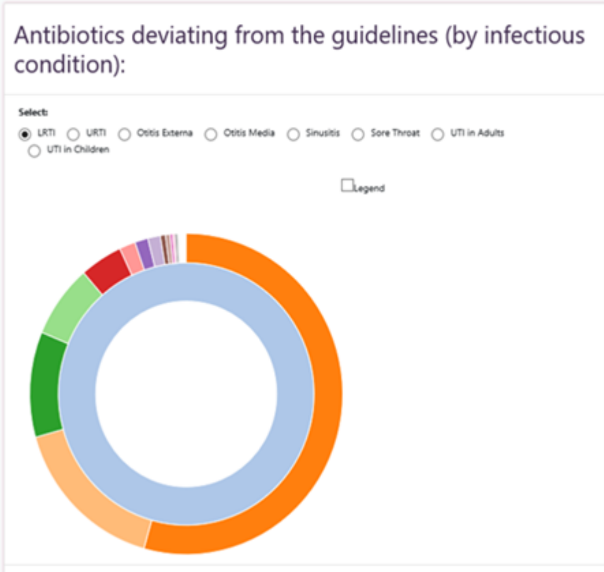
The dashboard has been designed in an extensible way to make it possible to easily develop and incorporate changes. Each graphical plot is a stand-alone entity within the application, which can be easily removed or replaced, as desired so that GPs could see data that represents target areas for improvement. Data is pulled into the DataLab every 2 weeks so that practices are able to see the impact of interventions over time.

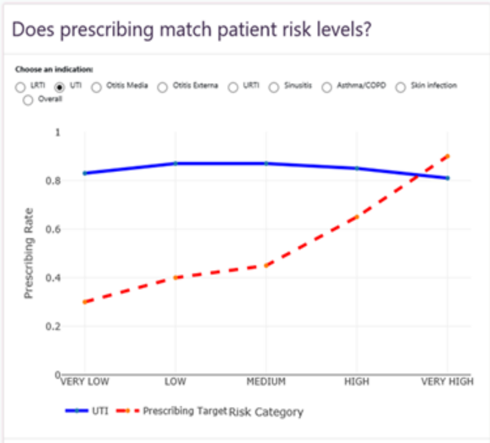
The images below show some of the interactive plots available in the national dashboard, using data from CPRD and SAIL. GP dashboards would show similar plots representing their practice data.



This plot analyses incidental prescribing only The plot displays the proportion of consultations where the prescriptions were in accordance with prescribing guideline (blue) and the where the prescriptions deviate from the prescribing guidelines (red) for each infectious condition. Analysis is based on the most recent first and second line antibiotic treatment in national guidelines.

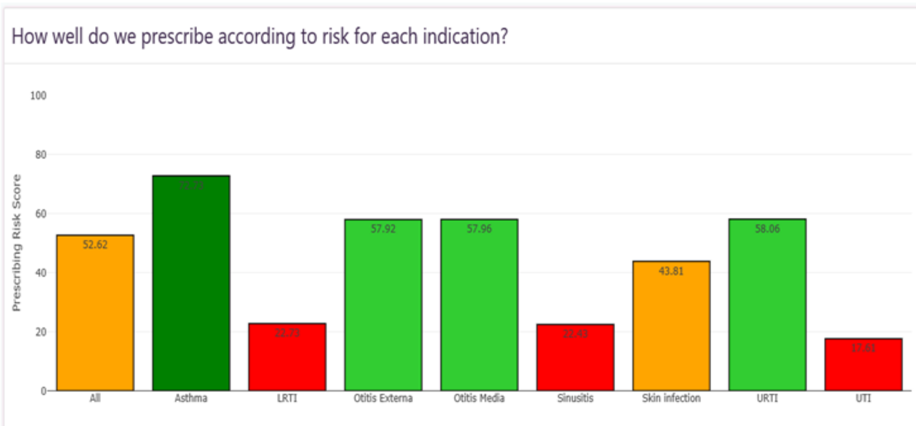
The dashboard shows a number of interactive sunburst plots. In this example, users can filter the prescriptions issued by each infectious conditions. The outer ring indicates which antibiotics were prescribed for each conditions that deviate from the recommended guidelines. Data is a summation of incidental prescribing only





This graph spits patients into five groups from the lowest to the highest risk (as assessed by a clinical risk prediction model), and shows the corresponding prescribing rate for each of the groups. Ideally the majority of the highest risk patients should receive antibiotic prescriptions whereas the majority of the lowest risk patients should not. The red line shows a theoretical prescribing situation where the blue line show the current state of actual prescribing in primary care.

BRIT found that General Practitioners (GPs) did not prescribe according to the risk of being admitted to hospital with infection related complications, with high-risk patients being prescribed antibiotics in a similar way to low risk patients.



This graph shows how well prescribing matches patient risk level for each indication. The risk score is a number between 0 and 100, which measures the accuracy of the prescribing to patient's risk. The higher the number the more closely prescribing matches the risk level of patients

Access to data for GP dashboard development

Datawell was a Greater Manchester initiative to develop a software platform that enables the electronic exchange of NHS patient record information from multiple sources, and was chosen as the data provider during the development of the GP-BRIT application. However, the technological maturity of Datawell was insufficient at the time BRIT was ready to progress and an alternative data provider was sought. Agreements were established with Apollo Wellbeing services to provide the required data from GP practices, however, alternative arrangements would be required to get hospital admission data and microbiology data. As Greater Manchester does not operate a shared microbiology service, each NHS Trust providing microbiology services to GP's was approached separately to establish local patterns of AMR in their locality. These discussions are on going at the time of writing. There were some delays for installation of Apollo software into GP practices due in part to local accountability and responsibility for the installation at individual practices and approval requirements for practices linked to the recently established Greater Manchester Shared Services (GMSS) who provide IT support to healthcare providers. Additional delays were caused by connection issues and incorporating changes from the N3 network to the HSCN network within the TRE.

BRIT_WIRRAL

The success of being able to replicate and transfer the BRIT infrastructure and expertise is demonstrated in the collaborative arrangement with Wirral University Teaching Hospital (WUTH). WUTH operates a combined integrated electronic healthcare record (The Wirral Care record) administered from a single site, obviating the need to pull in data from individual GP practices using a data provider. This means that data remains in situ and within the control of the organisation who own/administer the data, and provides an example of the different applications for BRIT. Discussions with the Director of IT services at the Wirral University Teaching Hospital (WUTH) concluded in an agreement to trial the installation of BRIT at WUTH and as such forms part of the research protocol (IRAS 23550). The BRIT-WIRRAL installation occurred in March 2019 following approval from a local ethics committee and a local privacy impact assessment, addressing the prior consent of GPs for data to be shared in this way. The BRIT WIRRAL implementation complements the importance of our findings and consolidates the demand for a data driven approach to medicine prescribing.

Impact of Engagement

The launch of the National dashboard on 14th Nov 2018 and up to 14th Feb 2019, (www.britanalytics.uk) led to 488 unique accesses with 139 account registrations. Interest was widespread across the UK, but also internationally with clicks to the homepage from countries including the USA, India, Norway, Japan, Nigeria and Australia. Users contacted the BRIT team via email with questions about the data sources and reliability of data. As a result, a FAQ page was added to the dashboard view.

Recruiting to the GP-BRIT dashboard was subject to processes approved by the REC and HRA and was facilitated by the NIHR Clinical Research Network in Greater Manchester. Further engagement with the GP Federations of Greater Manchester and interested CCG leads led to additional support in generating interest. There were 25 pilot practices in Greater Manchester who completed the end to end testing of the pilot dashboard. Further interest in assessing commercial interventions led to additional support from the Greater Manchester Health and Social Care Partnership to roll out recruitment across Greater Manchester, focussing initially on a single local authority so that a CCG level view could be created and demonstrated to improve wider take-up. This is in progress at the time of writing.

Initial feedback from GPs indicated a desire to show individual prescribing accountability within the practice, support to calculate risk and information on dispensed prescriptions to understanding the effectiveness around delayed prescriptions or prescriptions contained within rescue packs (for example COPD). Individual prescribing accountability could be achieved by providing a summary of prescribing by prescribing identifier rather than individual name. The structure of the dashboard meant that practices could choose to view this information or not. A risk calculator was developed and subsequently added, demonstrating the responsive capabilities of the team and the DataLab. Prescribing data could potentially be sourced from national databases or individual pharmacies. Inclusion of this dataset is out of scope for the current project but under consideration for further funding applications.

GPs were also particularly keen to hear who would have access to their data and whether that would be shared for example with the CCG. Reassurances were given that access could only be granted by the Lead GP or Data Guardian from the practice and the CCGs would only be granted an overview for practices in their area, similar to the national view, should all practices in a CCG area be signed up.

Industry collaborations

BRIT has established successful collaborations with First Databank to implement a decision support system, Imosphere to offer their advanced user-friendly data analytics software to NHS users, and Apollo who deliver practice data securely into the TRE. BRIT has been approached by Health Innovation Manchester to use the BRIT infrastructure to support the analysis of point of care testing for new technology, which can determine between viral and bacterial infection within 10 minutes. In addition, BRIT is working with NICE to show how the application of advanced healthcare analytics can help demonstrate effectiveness of interventions to improve health outcomes with guidelines.

IMPACT

BRIT can assist in *keeping people healthy and support economic productivity and sustainable public services* through the provision of evidence and monitoring for optimising the use of antibiotics in primary care by focusing on patients' risks of hospital admissions, thus tailoring performance indicators to the challenges faced by a GP practice.

BRIT is also able to support the *transformation of primary, community and social care to keep people living more independent, healthier lives for longer in their community* by providing clinicians with patient-level data on individual risks of hospital admission, which will support the patient-doctor communication during the consultation. Both patients and clinicians will benefit from the detailed analytics of their data providing evidence, which can support the patient-doctor communication.

In addition, BRIT provides the data infrastructure to evaluate the cost-effectiveness of innovations around antibiotic use, ensuring *accountability of the health and care system to Parliament and the* *taxpayer,* creating an efficient and effective DHSC through the targeted use of point-of-care testing for patients at high risk of hospital admission.

BRIT also supports the *NHS five financial tests*, through the provision of real-time evidence and actionable feedback to policy makers and clinical staff on the effectiveness of current antibiotic prescribing in primary care, as well as the knowledge base for how to improve and provide the evidence on individual risks for the point-of-care decision support system.

DISCUSSION

The progress of BRIT so far provides evidence for behaviour change processes in one of the biggest areas of health challenge that the world currently faces. The investment provided by DHSC to develop the project to date has been used to address the significant challenge of integrating data from different sources into a common data model and the infrastructure development of a DataLab.

The BRIT project has generated novel insights into the use of antibiotics within the primary care landscape in the UK. Data analyses have shown that antibiotic prescribing in primary care is highly suboptimal. Policy initiatives and introduction of guidelines appear to have had very limited effects, in the absence of tools to help GP's understand the underlying data. The current policy of reducing overall levels of antibiotic prescribing could also inadvertently lead to an increase of hospital admissions, as more indiscriminate use of antibiotics is associated with better clinical outcomes. Our work has also shown that general practices face very different drivers for antibiotic prescribing; the currently policy to financially reward areas with reduce antibiotic prescribing is questionable as it could involve a financial transfer from poorer areas to areas well served. Frequent antibiotic use may be less effective although this practice is widespread in UK primary care. There is a great need for more risk-based antibiotic prescribing in primary care and more data-driven and localised policy initiatives.

However, implementing local policy initiatives and establishing sustained optimised antibiotic prescribing has its own challenges. GP practices in the UK operate as independent business with NHS contracts, and as such have autonomy over their decision-making and tools used for business practices and patient management. Therefore, providing GPs with tools to review their own practice data and identify targets for improvement is essential, but widespread uptake and sustained use requires proactive engagement, communication, demonstration of effectiveness and an understanding of the issues and a commitment to change. Some of this is driven by Clinical Commissioning Groups with reporting requirements and financial incentives, but BRIT encountered a resistance to a top down approach to engagement with the DataLab by GPs, preferring independent assessments of utility and options to take part.

A key challenge is that we are developing this infrastructure in an era where there is unprecedented demand for healthcare, and competing resources of time and staff availability. Even with good quality data, engagement with the DataLab was often limited by the trade-off associated with directly managing patients. It may be therefore that the target audience is not GPs directly but those who support primary care services, such as practice mangers and prescribing advisors. Changes in the primary care landscape during the project development phase were encouraging with the initiation of GP Federations to support primary care service delivery. The introduction of prescribing advisors and GP practices combining management and admin support, may provide a cost effective way for GPs to get the advice they need on prescribing behaviours without having to monitor the DataLab themselves. A change in the access requirements to support single user access to multiple practices was therefore required but was restricted at project initiation, as it was not deemed necessary. By comparison, CCGs demonstrated enthusiasm for such tools that would allow them to have an overview of their local GP's antibiotic prescribing patterns and wished to support wider engagement of GPs. This presents an opportunity for wider discussion of how to best to locally manage support for antibiotic prescribing.

Another challenge is the statistical literacy of the end users. It was clear that initial buy in from stakeholders was limited by their understanding of how to transfer the data on the dashboard into actionable outcomes. Even though our analytics team provided both visual and textual representations of prescribing habits and outcomes, we found users struggling to understand and interpret the results and grasp the true nature of the data shown, without having to walk through each graph with them. The real test was how to perform deep level analytics, but presenting it the simplest form to really help users grasp the true impact of some of the findings (e.g. uniformity in prescribing despite difference in risk of antibiotic related complications).

The BRIT project revealed important aspects of feasibility of collecting and using data from multiple diverse sources. In the early stages, an ambitious project to develop a framework to simplify and share data easily from multiple providers in Greater Manchester called Datawell presented an ideal solution, but failed to deliver due to the considerable complexities of this development. The time constraints of the project meant alternative solutions were required, and this was sourced through an established data provider with a presence across the UK. Apollo Wellbeing Services agreed to a service contract for data provision and this provided the opportunity to engage GPs nationally. Support from stakeholders the Local Clinical Research Network to engage GPs was effective, but delays in development meant building and maintaining relationships was difficult, with the potential to provide local area comparisons if enough GPs are engaged.

There are limitations to the approach that was taken in developing BRIT. The R and Shiny modules are products used in academia and are not commercial grade. The impact of multiple users at any one time has not been tested. Load testing was not possible at the time of writing due to the limited number of practices using the system. The issue will need to be addressed for BRIT to be expanded nationally. In addition, universal-programming languages would assist future development of BRIT. The processing of data was initially completed using SAS, a language that subsequent analysts were not familiar with. However time limitations meant that SAS would continue to be used. The project would benefit from all of the analysis and processing to be completed a common language that the majority of the team are familiar with to enable more people to contribute to the development. Additionally the licence to use SAS is expensive and not a preferred choice of academia but may well be preferred in industry and this should be taken into consideration for UK roll out and the need to establish a more robust BRIT infrastructure.

Future plans/sustainability

The BRIT team have successfully delivered a system through which GP practices can understand and optimise antibiotic prescribing. A significant opportunity persists with continued investment that would deliver replication of the BRIT infrastructure, knowhow and insights into other geographies that have already indicated a strong appetite to optimise antibiotic prescribing using a data driven approach. The overarching goal would be to roll out BRIT web based analytics across the entirety of UK primary care, enabling practitioners to prescribe medicine using a risk based approach - to patients who need them most. Additional investment is also required to upgrade the infrastructure to ensure that automated processes for extracting, converting and analysing the data. This may need industry standard data processing applications and the review of a systems architect to ensure the stability and scalability of the system. This is the subject of a second programme grant application from the University of Manchester, which has been submitted to the NIHR and is currently under consideration.

We have been working with the Greater Manchester Health and Social Care Partnership, in developing how BRIT can be used to investigate the effectiveness of novel technologies in Primary care. One instance already in discussion is a point of care testing device for evidence of bacterial or viral infection, which can determine if an antibiotic should be prescribed. Using the BRIT DataLab means that results can be provided in a "real-time" rather than waiting until the end of the trial period.

Following the proof of concept and analysis of the impact of BRIT over the next 6 months, we aim to discuss with commissioners and the GMHSCP the application of cost models to ensure BRIT can be installed in any GP practice on request at minimal cost to the practice or CCG. Ensuring a CCG overview dashboard would provide benefits over and above existing tools to understand prescribing behaviours in specific localities, and may be a route to ward CCG funding in practices who request the tool. Pilot work to provide an analytics tool to a small number of BRIT users will determine if there is support for GPs to access tools to analyse their own data in addition to the deep data analytics provided by BRIT.

BRIT is an exemplar model of a Learning healthcare system primary care which can deliver benefits to independent practices. This model can be replicated for other disease areas of interest to GP federations or CCGs. As an example a federated GP practices in Greater Manchester asked how this model could be used to look at the impact of respiratory disease in the local area within the federation's area. Having established the challenging routes to extract, processes and analyse data all within the secure HSCN network we are now in a position to expand on this knowledge and support new developments of LHS's within the NHS and develop international collaborations, establishing the UK's expertise and proficiency in delivering healthcare analytics at scale.

Author/Main Contact

Acknowledgements:

This project was part of Connected Health Cities, a Northern Health Science Alliance led programme funded by the Department of Health and delivered by a consortium of academic and NHS organisations across the north of England. The work uses data provided by patients and collected by the NHS as part of their care and support. The views expressed are those of the author(s) and not necessarily those of the NHSA, NHS or the Department of Health and Social Care.

OUTPUTS

1. Mölter A, Belmonte M, Palin V, Mistry C, Sperrin M, White A, Welfare W, Van Staa T. Antibiotic prescribing patterns in general medical practices in England: Does area matter? Health Place. 2018 Sep;53:10-16. https://doi.org/10.1016/j.healthplace.2018.07.004

2. Li Y, Mölter A, White A, Welfare W, Palin V, Belmonte M, Ashcroft DM, Sperrin M, van Staa TP. Relationship between prescribing of antibiotics and other medicines in primary care: a cross-sectional study. Br J Gen Pract. 2019 Jan;69(678):e42-e51. https://doi.org/10.3399/bjgp18X700457

3. Palin V, Mölter A, Belmonte M, Ashcroft DM, White D, Welfare W, van Staa TP. Antibiotic prescribing for common infections in UK general practice: variability and drivers. In Press J Antimicrob Chemother.

4. Nowakowska M, van Staa TP, Mölter A, Ashcroft DM, Yin Tsang J, White A, Welfare W, Palin V. Antibiotic Choice in UK General Practice:- rates and drivers of potentially inappropriate antibiotic type. Submitted.

5. The effectiveness of frequent antibiotic prescribing in reducing the risk of infection-related hospitalisations: results from two large population-based cohorts in primary care. van Staa TP, Palin V, Welfare W, Felton TW, Dark P, Ashcroft DM. Submitted.

6. Do systemic antibiotics prior to cancer diagnosis affect the effectiveness of chemotherapy for malignant cancers? Results from two large population-based cohorts. Domzaridou E, van Staa TP, Renehan A, Cook N, Welfare W, Ashcroft DM, Palin V. Submitted.

7. Building the Learning Healthcare System to feedback data analytics and support decision making by clinicians and policy makers: an exemplar of optimising antibiotic prescribing in UK primary care. Tempest E, Mistry C, Palin V, Belmonte M, Kapacee Z, Griffiths E, Crotty M, Green B, Couch P, Jury F, Yin Tsang J, van Staa TP. Submitted

8. Predicting the risk of infection-related complications including hospital admission in patients with common infections in primary care. Mistry C, Martin G, Welfare W, Palin V, Belmonte M, Ashcroft DM, van Staa TP. In preparation.

9. Belmonte M, Mölter A, Palin V, Mistry C, White A, Welfare W, van Staa TP. What drives higher levels of antibiotic prescribing in primary care: general practitioners or practice characteristics? In preparation.

10. Are shorter courses of antibiotics an effective strategy to reduce infection-related complications in primary cares? Palin V, Belmonte M, Mistry C, Welfare W, Li Y, Ashcroft DM, van Staa TP. In preparation.

11. Is delayed prescribing of antibiotics a safe strategy in primary care? van Staa TP, Palin V, Belmonte M, Mistry C, Welfare W, Li Y, Ashcroft D. In preparation.

12. Do we need a paradigm shift in the way we handle antibiotic prescribing in primary care? Yin Tsang J, van Staa TP. In preparation.

13. Infection-related complications and hospitalisations after common infections are influenced by the level of incidental antibiotic prescribing in primary care. van Bodegraven B, Belmonte M, Palin V, Mistry C, White A, Welfare W, Ashcroft DM, van Staa TP. Submitted.

14. Number needed to treat in order to prevent infection-related hospital admissions after common infections. van Bodegraven B, Palin V, Welfare W, Ashcroft DM, van Staa TP. In preparation.

15. General practitioners' accounts of negotiating antibiotic prescribing decisions with patients: A qualitative study on drivers of antibiotic prescribing in low, medium and high prescribing practices van der Zande MM, Dembinsky M, Aresia G, van Staa TP. Submitted

16. The role of real-word data in the development of treatment guidelines: A case study on guideline developers' opinions about using observational data on antibiotic prescribing in primary care. Steels S, van Staa TP. Submitted

References

1. 'Review on Antimicrobial Resistance. Antimicrobial Resistance: Tackling a Crisis for the Health and Wealth of Nations. 2014.Jim O'Niell file:///P:/Documents/BRIT%20docs/Final%20report/AMR%20Review%20Paper%20-%20Tackling%20a%20crisis%20for%20the%20health%20and%20wealth%20of%20nations_1.pdf

2. Oxford J., Kozlov R. (2013) Antibiotic resistance—a call to arms for primary healthcare providers. Int J Clin Pract Suppl 180: 1–3. https://doi.org/10.1111/ijcp.12334

3. Annual report of the Chief Medical officer: infection and the rise of antimicrobial resistance. SC Davies, T Fowler, john Watson, DM Livermore, D Walker, The Lancet, Published:March 11, 2013 DOI:https://doi.org/10.1016/S0140-6736(13)60604-2

4. 'Tackling drug-resistant infections globally: Final report and recommendations' 2016 Jim O'Niell. https://amr-review.org/sites/default/files/160525_Final%20paper_with%20cover.pdf

5. Public health England (2015) Behaviour change an antibiotic prescribing in healthcare settings. Literature review and behavioural analysis. R Pinder, Anna Sallis, Dan Berry, Tim Chadborn http://scholar.google.com/scholar?cluster=11953567774088628461&hl=en&oi=scholarrPinder DOH 2015

6. Department of Health (2012). Power of Information. Available from: https://www.gov.uk/government/publications/aging-people-control-of-the-health-and-care-information-they-need

7. Department of Health (2012). Digital Strategy: Leading the Culture Change in Health and Care. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/213222/final-report1.pdf

8. Department of Health (2014). Personalised health and care 2020. Available from: https://www.gov.uk/government/publications/personalised-health-and-care-2020

9. Public Health England. (2018). English Surveillance Programme for Antimicrobial Utilisation and Resistance (ESPAUR). London. Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/749747/ESPAUR_2018_report.pdf. [Accessed: 21 December 2018]

10. Institute of Medicine. (2015). *The Learning Health System Series*. Available at: http://www.nap.edu/ catalog/13301/the-learning-health-system-series. (Accessed: 18 December 2018).

11 CPRD. (2018). Primary care data for public health research. Available at: https://www.cprd.com/primary-care, (Accessed: 18 December 2018)

12 HES. (2018). *Hospital Episode Statics (HES).* NHS Digital. Available at: https://digital.nhs.uk/data-and-info. (Accessed: 18 December 2018)

13 SAIL. (2018). SAIL Datasets. SAIL data bank. Available at: https://saildatabank.com/saildata/sail-datasets/, (Accessed: 18 December 2018)

14. Spencer, L., Ritchie, J., O'Connor, W., Morrell, G. and Ormoston, R. (2014) Carrying out qualitative analysis. In J. Ritchie and J. Lewis, J. eds. *Qualitative research practice: A guide for Social Science Students and Researchers.* London: Sage Publications, pp.296-345.

15. Action. 2019. ACTION, Helping healthcare professionals assess the quality of antibiotic prescribing. University of Manchester. Available at https://sites.manchester.ac.uk/action/. (Accessed 18 January 2019).

16. National Institute for Clinical excellence NICE guidelines for antibiotic management https://www.nice.org.uk/guidance/CG69/chapter/1-guidance#the-clinical-effectiveness-and-cost-effectiveness-of-antibiotic-management-strategies-for

17. NICE Guidelines – antibiotic prescribing for self-limiting respiratory tract infections. https://www.gpnotebook.co.uk/simplepage.cfm?ID=x20080729120250749131