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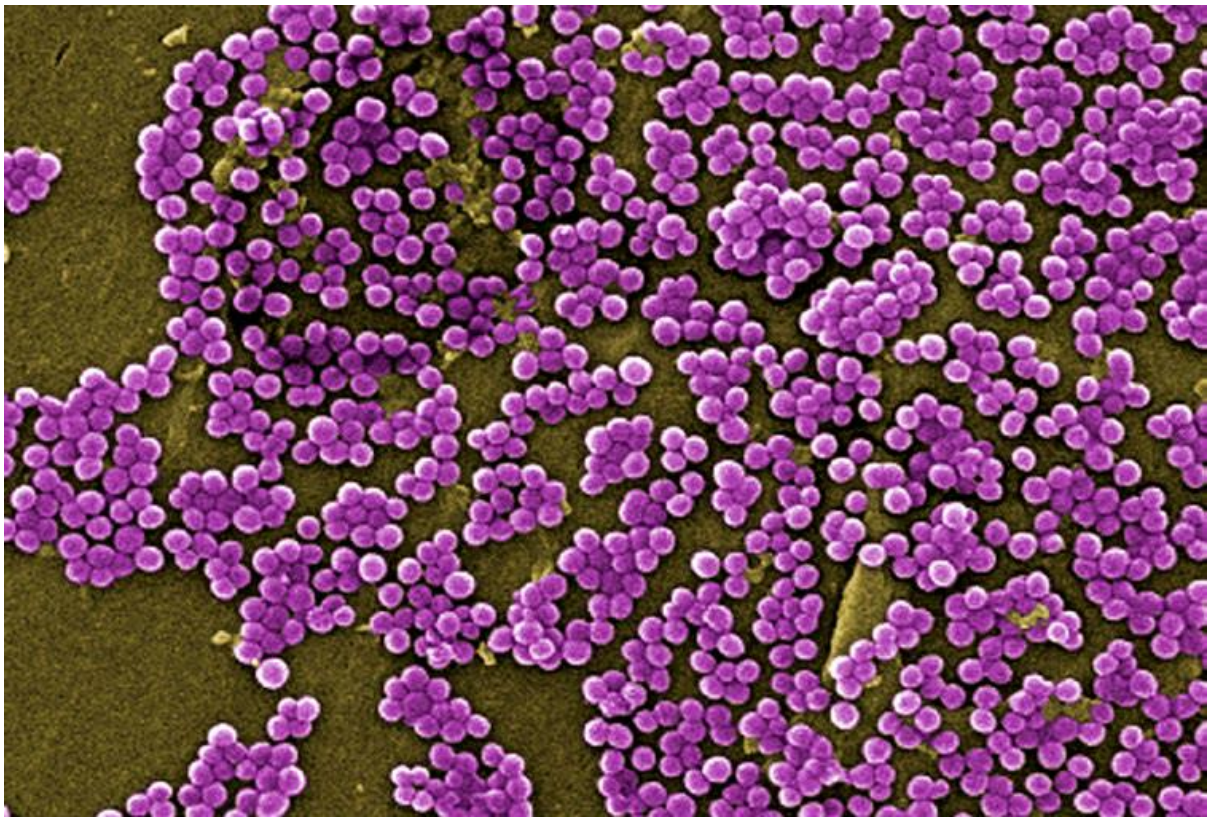

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December 2019

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Executive Summary

In 2013, the Department of Health released its UK Five Year Antimicrobial Resistance (AMR) Strategy. One of the seven key areas identified by the Strategy for future action was "*better access to and use of surveillance data"*.

The Department of Health and Social Care commissioned the Policy Innovation Research Unit at the London School of Hygiene & Tropical Medicine to lead an evaluation of the process of implementation of the Strategy and the evidence underpinning key mechanisms of change required to deliver it. One of the elements of this evaluation is "*How data have been used to effect changes in behaviour and their impacts*".

The element consists of three complementary strands which will form the basis for the recommendations on how access to, and use of, surveillance data might be improved to help the Strategy better achieve its stated goals. The first strand explores the availability of surveillance data, the second strand identifies the data use and needs of clinicians, commissioners and policy makers through qualitative interviews, and the third strand aims to identify any gaps that exist between what users identify as their needs and the data available.

The work has highlighted that AMR-related data systems in the UK are complex, with significant variation between the four nations of the UK, as well as between human and animal health surveillance systems. Availability and ease of access to data is dependent on specific needs and location, though there is continuing development and improvement across the UK for both animal and human data.

Interview respondents identified a range of uses for data, but also gaps related to the availability of data on private healthcare practice, non-medical prescribing (such as dental prescribing), internet prescribing and prescribing in certain special settings like care homes. Many informants perceived a gap in secondary care prescribing data, linked to the absence of electronic prescribing systems. The findings suggest that there may be a mismatch between availability of data systems and awareness of them, in part due to the relatively rapid development of AMR-related data systems.

The policy implications relate to raising awareness of data system outputs, exploration of the extent of prescribing not captured by current systems, consideration of how the four UK nations might identify opportunities for collaboration and UK-wide working to implement the data requirements of the future national Strategy more effectively and exploration of the possibility of developing standard definitions for surveillance across human and animal health.

1 Background

In 2013, the Department of Health released its UK Five Year Antimicrobial Resistance (AMR) Strategy with an overarching goal of slowing the development and spread of AMR [1]. The Strategy focuses activities on the following three strategic aims to:

- Improve knowledge and understanding of AMR;
- Conserve and steward the effectiveness of existing treatments;
- Stimulate the development of new antibiotics, diagnostics and novel therapies.

One of the seven key areas identified by the Strategy for future action was "*better access to and use of surveillance data"*, and over the Strategy a number of sophisticated means of utilising existing routine data for both human and animal health have been developed.

The Department of Health and Social Care commissioned the Policy Innovation Research Unit at the London School of Hygiene & Tropical Medicine to lead an evaluation of the process of implementation of the Strategy and the evidence underpinning key mechanisms of change required to deliver it, in order to contribute to the review of the Strategy undertaken during 2017-18. The evaluation consists of the following eight elements:

1. Evaluating the national and local implementation of the Strategy
2. Synthesis of evidence underpinning:
    a. Use of surveillance systems in an infectious disease context
    b. Use of diagnostic tests for infectious/communicable conditions in a secondary care setting
    c. Use of diagnostic point of care tests in primary care
    d. Implementation of 'prudent use' principles in veterinary medicine
3. How data have been used to effect change in behaviour and their impact
4. Implementation of the Strategy and evidence of effectiveness in the food chain
5. How the Strategy has addressed challenges to innovation in the biopharma industry
6. Strengthening international collaboration
7. The role of patients and the public in implementation of the Strategy
8. Challenge to, and validation of, findings

Element three (How data have been used to effect changes in behaviour and its impacts) contains the following research questions:

- To what extent have the objectives in the Strategy related to increasing data availability and improving surveillance been achieved?
- How has the Strategy's implementation been affected by limitations in the available data?
- How have data and indicators been used to change the direction or emphasis of the Strategy?
- To what extent do existing data meet the needs of users at national, regional and local levels?
- How could better data and/or better use of existing data assist potential users at national, regional and local levels better achieve the goals of the Strategy?

The element consists of three complementary strands of analysis which formed the basis for recommendations on how access to, and use of, surveillance data might be improved to help the Strategy achieve its stated goals. The next section outlines our approach to answering the research questions in each of the strands.

2 Methods

2.1 Strand One: Availability and Quality of Surveillance Data

This strand explored the availability of surveillance data on the following key measures outlined in the Strategy document:

- Epidemiology of bacterial infections
- Changes in bacterial resistance (the main pathogens that have developed resistance/ non-susceptibility to antibacterial agents)
- Drug utilisation (marketing, distribution, prescription and use of antibacterial agents)
- Clinical outcomes.

We explored the availability of surveillance data across the four countries of the UK for human health and animal health. With regard to drug utilisation data, we investigated the availability of data in the following settings:

- Primary medical care setting (General Practice and other community settings)
- Hospital inpatient
- Hospital outpatient
- Veterinary services (sales and usage)
- Dental services (both General Dental Practice and hospital services)
- Private health care

We also explored whether a platform had been developed to enable better sharing of information on issues that might pose risks to human and animal health at local, regional and national levels; whether an "early warning system" had been set up to initiate containment measures to resist the spread of resistant microorganisms; and how it seemed to be performing.

This strand was undertaken through the exploration of publicly available data, and seeking clarifications from data custodians if there were questions arising from reports.

Our approach 'mapped' the data systems that are in place. We began by reviewing the sources of data used in national reports produced in each of the devolved countries, and commonly used portals to access this data. The map was expanded and detail added until we could account for all the key measures outlined in the strategy document.

We then considered the systems underpinning these data, and identified strengths and limitations of the quality of the data they provided. This was achieved through a combination of reflecting on stated limitations from national reports, wider literature, and reference to the set of interviews used for Strand Two of this work.

We made a top-level, qualitative evaluation of the systems we identified, drawing on the CDC framework for evaluation of surveillance systems [2], focussing on data quality.

The complexity of systems means that not all CDC quality criteria are appropriate for each data set, but we broadly considered:

- Accessibility
    - Can the public or authorised personnel see the data when needed?
- Accuracy
    - Are the data likely to reflect the real-world situation?
- Completeness
    - Are all relevant aspects of the situation present in the data sets?

- Coding and Aggregation
    - How are data collected and processed?
- Frequency
    - Are the outputs of the data system timely?

A limitation of our approach is that an arbitrary decision had to be made on the level of detail at which to review surveillance systems. For example, there are a wide range of proprietary software systems in use across the country in human and animal health, which access existing data sets and offer varying levels of analysis. Some are mentioned in this report to aid understanding, but an exhaustive list was beyond the scope of this study. The outcomes here reflect the key elements of high level data infrastructure used across the UK.

Regardless of the intended audience, data should be consistently and contemporaneously compiled in routine reports so that clinicians, researchers, policy-makers and the public can access the data in a manageable format and make sense of them. This should ideally provide the foundation for clinical decision making at the patient level, including the provision of clinical decision support tools [3].

2.2 Strand Two: Data Use and Needs

This consisted of qualitative research in the form of semi-structured interviews. We drew on interviews undertaken as part of the implementation element of the overall evaluation (Element 1) where appropriate. The interviews reported were undertaken between March 2017 and June 2018.

Questions relating to the use of data to effect change were included in the topic guide for interviews conducted with 41 national level staff who played a role in the design and/ or implementation of the Strategy and included: policy officials from relevant government departments, members of the High Level Steering Group, relevant policy staff in the Devolved Administrations, and key experts and academics (including people who are not currently engaged in the development of official AMR policy). At a local level, questions relating to the role of data were included in six case studies exploring the local implementation of the Strategy and employing a maximum variation design. These included a site from each of the Devolved Administrations as well as taking into account a range of area characteristics that might influence experiences and views of respondents. These characteristics included antibiotic prescribing levels, deprivation levels, urban/rural nature of the site and agricultural activities. Employing such a sampling strategy in qualitative research aims to obtain a diversity of views rather than statistically representative results. A limitation of the case-study approach is that the numbers of interviews per site is not large, even though the overall number is substantial. There are differing views on the extent to which findings from case-studies research can be generalised to other settings, as this research is often described as having higher internal than external validity [4]. The case studies were conducted in: West Norfolk (n=14 interviews); Blackburn with Darwen (n=12); Derry/ Londonderry (n=13); Betsi Cadwaladr (n=12); Glasgow (n=11) and Camden (n=9). The findings from each site were analysed independently. However, they are presented together in this document to provide a more coherent narrative.

As a result of the significant differences in the nature of prescribing and resistance/Infection Prevention and Control (IPC) activities, interview data on each were analysed separately. Similarly, we present views in relation to Primary Care Level, Trust Level and National Level, separately. We describe the findings of nine interviews conducted with animal health professionals in the section that follows the National Level interviews.

The general approach to this thematic analysis explored the views of the users of data at various levels (including what data are available to them; what they use the data for, and their perceptions of the problems, gaps and benefits of the systems) as well as respondents' suggested improvements. The analysis also separately explored four cross-cutting interface Issues. Figure 1 illustrates the analysis approach.

2.3 Strand Three: Gap Analysis

In the last strand, we identified gaps that existed between what users identified as their data needs for the Strategy to succeed and the data (and surveillance tools) available. This was used as the basis for our recommendations on what additional information is needed to help achieve the Strategy's goals. This strand of the research primarily consisted of comparing the findings of the two previous strands.

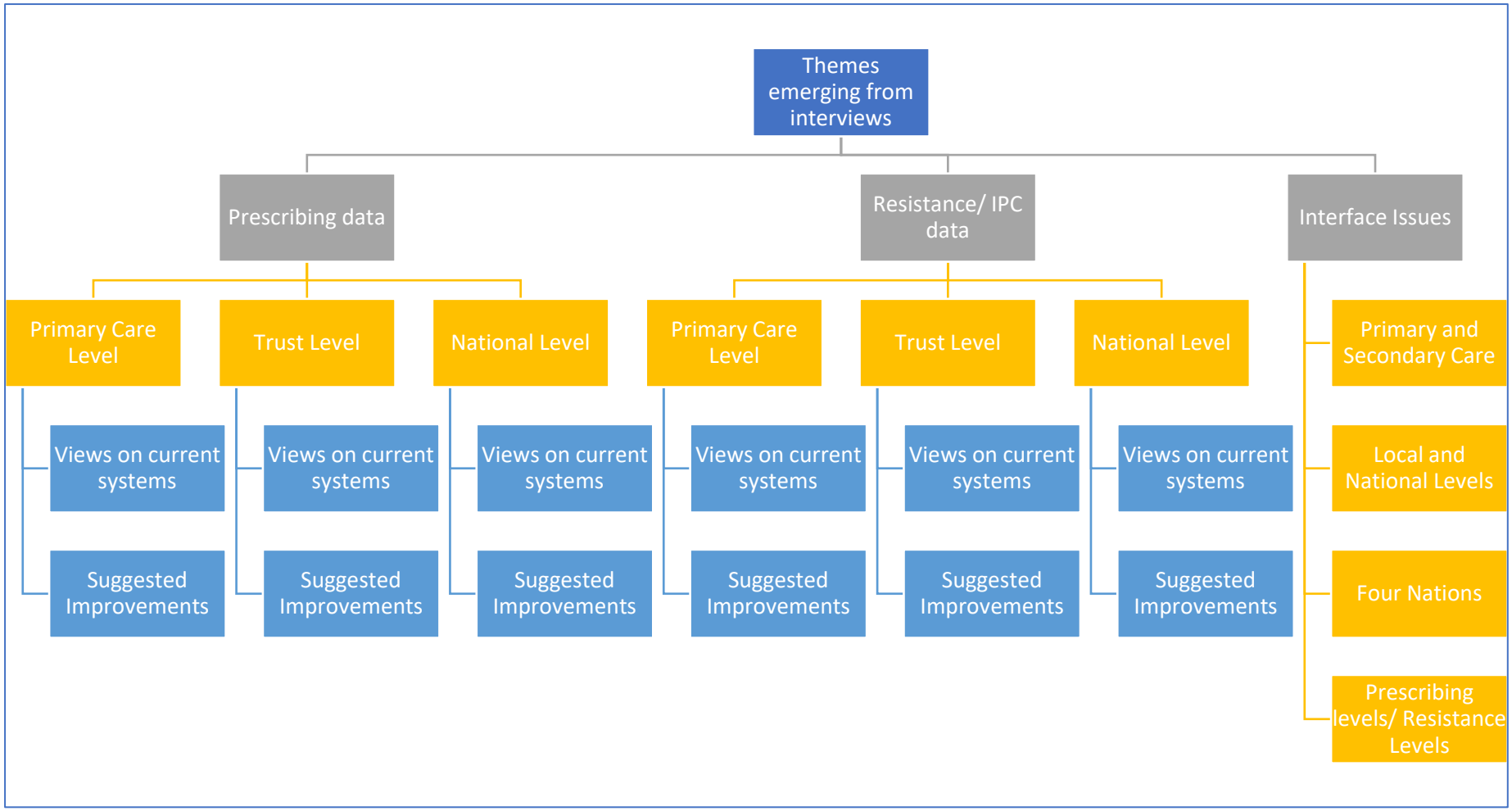

Figure 1 - Approach used for Strand Two analysis

3 Results – Availability and Quality of Surveillance Data

This section of the report assesses data systems across the four countries of the UK that relate to monitoring trends in antimicrobial resistance (AMR), antibiotic prescribing and clinical outcomes in different healthcare settings. It also considers veterinary antibiotic use through antibiotic sales and consumption data.

Overview of UK-wide data systems

There is significant variation in AMR data systems and reporting between the constituent UK countries. England has an accessible, comprehensive data access portal with annual reporting since 2014, whereas Northern Ireland produced its first report in 2017. Wales produces a range of annual reports alongside point prevalence surveys. Scotland now produces a single annual report for animal and human health, and has made considerable recent progress in developing an integrated data portal. However, progress appears to have paused and the portal is not yet publicly accessible.

Although a UK One Health report was published in 2015 [5] in line with the UK AMR strategy, Scotland is the only country producing annual reports using a One Health approach, including animal and human data.

AMR data systems in England are furthest advanced in terms of accessibility. The two organisations responsible for national reporting are Public Health England (PHE) and the Veterinary Medicines Directorate (VMD). AMR data for humans are available on a monthly-updated dashboard known as *Fingertips.* This is a publicly accessible and comprehensive database which contains data on a wide range of public health issues, or 'profiles', for example child and maternal health, physical activity and tobacco control. AMR is one of the 34 profiles, containing a number of indicators with more continuing to be added (over 100 currently).

Data for animals are provided through the annual *Veterinary Antimicrobial Resistance and Sales Surveillance* (VARSS) report. The data sources for this report are less directly accessible for both the public and veterinary professionals, for commercial reasons and because there is no online data portal. VARSS presents combined data on veterinary antibiotic sales, usage and resistance in bacteria from animals in the UK [6].

The following sections of this report cover the four UK nations, identifying where data collection is a UK-wide endeavour. The Appendix to the report illustrates the result of our mapping exercise of the sources of data used in national reports produced in each of the devolved countries, and commonly used portals to access these data.

3.1 England

3.1.1 What Data are Available?

Clinicians in different healthcare settings, commissioners, policy makers and researchers are all likely to approach the problem of AMR from different perspectives with varying data requirements. A qualitative exploration of this issue follows later in the report. Table 1 summarises key data sources that are most easily accessible and most pertinent to these groups.

All stakeholders in England have access to publicly accessible sources of data on AMR. The most important of these are the *English Surveillance Programme for Antimicrobial Utilisation and Resistance* (ESPAUR) Report, and the online data portal *Fingertips*. Additionally, national prescribing data are available from the NHS Business Services Authority (NHSBSA) *Information Services Portal.*

Primary Care

In primary care, GPs will liaise with local microbiology laboratories to determine resistance of organisms tested in patient samples and appropriate antibiotic chemotherapy. Local monitoring of resistance patterns may influence prescribing recommendations and formularies overseen by microbiologists and medicines' management committees. Although broader regional or national epidemiological data may be less useful at a patient level, any significant outbreaks or clusters would be monitored and flagged by local and national surveillance teams. *Fingertips* contains indicators for resistance at the clinical commissioning group (CCG) level.

Prescribing data are an important issue for clinicians as prescribing is a potential determinant of AMR over which GPs and other prescribers have some control. Key indicators at the practice level are available through *Fingertips*. The local medicines' management committee as part of the CCG would typically be involved in monitoring prescribing rates among practices in each area and supporting good prescribing practice.

The PresQIPP AMS Hub is another platform that provides subscribed organisations (80% of CCGs in England according to their website) with data on their prescribing levels (including their use of antimicrobials) down to the practice level with bench-marking tools. Additionally, the platform provides a number of antimicrobial stewardship resources to assist practitioners with their prescribing.

Secondary Care

Secondary care clinicians work with local and national reference laboratories to obtain resistance data from individual patient samples, with consultant microbiologist input on antibiotic recommendations. Acute trust infection control teams are responsible for monitoring data on resistance patterns, and these will often be obtained through locally implemented software systems, such as ICNet and Rx Info. These systems can synthesise outputs from a range of sources to monitor trends and patterns and identify at-risk patients. They can also provide comprehensive data on healthcare associated infections (HCAIs).

Prescribing data are routinely available at the Trust and ward level, through hospital pharmacy submissions to the national data set. The ePACT2 system allows access to national prescribing data for authorised users. Authorised users include:

- NHS England Local Teams Controlled Drugs Accountable Officers

- Primary Care Organisations (PCO) which includes CCGs,
- Local Authorities
- Independent Sector Healthcare Providers
- Secondary care Providers
- Commissioning Support Units (CSUs)
- Public sector and other organisations who need to monitor and manage prescribing data in primary care

Other organisations who are permitted to access the system if they can provide valid reasons for doing so include:

- Department of Health and Social Care
- NHS Digital
- Other Organisations who need access at the National level (England)

The system can include hospital data down to practitioner level. However, data are often not available at that level and rectifying this remains a challenge, as many secondary care providers have not yet moved to electronic prescribing systems.

Policy Makers and Commissioners

Policy makers and commissioners have access to *Fingertips*, PresQIPP (where subscribed), ePACT2 and routine national reporting (ESPAUR, VARSS and NHSBA prescribing data) to inform their activities. NHS England also provides annual figures in the form of an interactive "dashboard" that provides details of the performance of CCGs against the *NHS England Reducing Gram Negative Bloodstream Infections and inappropriate antibiotic prescribing in at risk groups* Quality Premium.

Table 1- Summary of AMR Data availability in England

ENGLAND	Resistance Data	Prescribing Data	Infection Control/HCAI	Other
General Public Access (Including all groups below)	ESPAUR Report VARSS (UK Wide, animals) Fingertips *AMR Local Indicators*			
		• NHSBA data on prescribing, dispensing and organisation plus reports • Open Prescribing- EBM DataLab. (prescribing down to practice level) • Fingertips selected indicators (prescribing down to practice level)		
GPs and other primary care	• Patient specific laboratory results with antibiotic sensitivity testing	• PrescQIPP AMS Hub (Practice Level) • Open Prescribing- EBM DataLab. (prescribing down to practice level) • Fingertips selected indicators (prescribing down to practice level) • Individual prescribing patterns from practice management software		
Secondary Care	• Patient specific laboratory results with antibiotic sensitivity testing • Fingertips selected indicators • Proprietary systems (e.g. ICNet)	• ePACT2 • Fingertips selected indicators • Proprietary systems (e.g. ICNet, Rx Info)	• Fingertips selected indicators • Proprietary systems (e.g. ICNet)	
Veterinarians	• APHA testing and reporting			• National sales data reporting (VARSS)
Local Commissioners (CCGs)	• Fingertips selected indicators	• Fingertips selected indicators • ePACT2 • Open Prescribing- EBM DataLab. (prescribing down to practice level) • NHSE Antibiotic Quality Premium Monitoring Dashboard (prescribing down to CCG level) • PrescQIPP AMS Hub (prescribing down to practice level)	• NHSE Antibiotic Quality Premium Monitoring Dashboard	• Fingertips antimicrobial stewardship indicators
Policy organisations		• ePACT2 (National level data on request) • Open Prescribing- EBM DataLab. (prescribing down to practice level) • NHSE Antibiotic Quality Premium Monitoring Dashboard		• Fingertips antimicrobial stewardship indicators

3.1.2 What are the Data Systems?

Accessibility of data depends on a complex network of data systems across England. The following sections assess these systems and their quality, under the following headings:

1. Development and maintenance
2. Data capture and processing systems
3. Data access platforms
4. Data reporting
5. Data quality

3.1.3 Development and Maintenance

The Role of Public Health England

PHE provides surveillance data at the country level as well as providing some services for other UK countries - for example, Health Protection Scotland (HPS) commissions reference laboratory services, notably from the *Antimicrobial Resistance and Healthcare Associated Infections Reference Unit* (AMRHAI). For example, the AMRHAI is responsible for identifying carbapenamase-producing organisms (CPOs) across all four countries of the UK. CPOs are of particular public health concern as carbapenems are considered a last line drug for treatment of organisms such as *Escherichia coli* (*E. coli*) and *Klebsiella* species. Carbapenem resistance would thus render these organisms difficult or impossible to treat.

PHE operates across four regions, with 15 Public Health Centres and 27 NHS Area Teams. There are eight Local Knowledge and Intelligence Teams (LKIs) responsible for using data to inform local commissioning and delivery of services, such as through reporting on resistant organisms in sexually transmitted infections and data mapping. LKIs cover:

- London
- South West
- South East
- West Midlands
- East Midlands
- North West
- Northern and Yorkshire
- East

There are ten microbiology laboratories in England, supported by Field Epidemiology Teams and national centres at Colindale, Porton Down and Chilton.

PHE is also responsible for annual publication of the *English Surveillance Programme for Antimicrobial Utilisation and Resistance* (ESPAUR) report, established in 2013 as part of the UK AMR Strategy. The report is extensive, at almost 200 pages with supplementary online appendices. The 2018 report highlights that much of the data used in the report are now publicly accessible through the Fingertips AMR Local Indicators.

3.1.4 Data Capture and Processing Systems

Resistance Data

Microbiology reporting for AMR-relevant data (e.g. HCAI, CPOs) operates through the second-generation surveillance system (SGSS). This contains patient identifiable information for authorised users at PHE and is not publicly accessible. PHE Field Epidemiology and Health Protection Teams access these data through the software, HPZone, and a range of systems are in place for sentinel surveillance, routine monitoring and reporting. Microbiological data flow from the originator of the sample, through the laboratory network in England where it is captured in SGSS prior to dissemination of results to clinicians, Health Protection and Field Epidemiology Teams, as required (Figure 2).

In 2017, 97% of laboratories were submitting resistance data to SGSS, with 84% using automated reporting. PHE anticipates future improvements to the system by linking SGSS data with other data sets (e.g. Hospital Episode Statistics), and by improving consistency of coding. This should enhance epidemiological analysis and the development of new control measures [7].

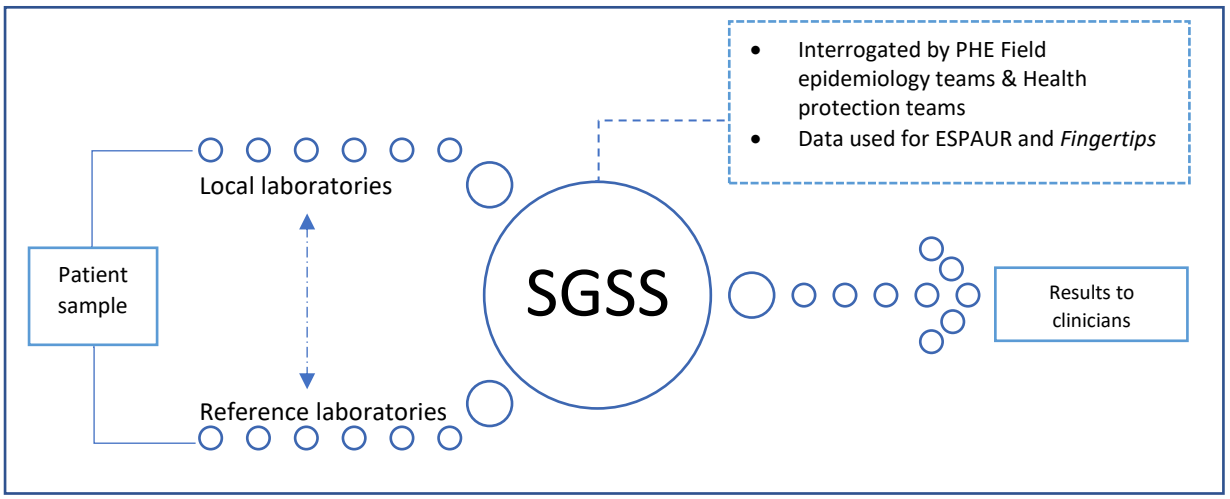

Figure 2 - England/UK Wide microbiology data journey

Prescribing Data in the Community

Prescribing data are extracted each month from the GP Payments System maintained by NHS Digital (NHS Business Services Authority). When dispensed by a pharmacy, prescription data are sent to the Prescription Pricing Authority where the data are captured. The data are available to the practice level, and include drug description, quantity and cost and well as prescriber information.

As well as general practice prescribing, primary care data are also captured from other community settings, which include walk-in-centres and out of hours services (labelled on the data collection system as 'dummy' practices). Unique practice identifier codes avoid confusion between practice names and data duplication, and allow for linkage with other data sets.

Prescribing Data in Secondary Care

Nationally, prescribing data from hospitals are collected by NHSBSA, with reporting for ESPAUR via a proprietary system called Quintiles IMS (recently, IQVIA) covering hospital pharmacy prescriptions. It offers data to ward level.

Locally, ICNet is a proprietary system (claiming to cover around 40% of NHS Trusts), that can be tailored to integrate a range of data sources and prescribing data. Further, it can link data on antibiotic consumption to infection control data to indicate where individual patients may have particular prescribing needs.

3.1.5 Data Access Platform

A Publicly Accessible Database: Fingertips

Fingertips is a data portal managed by Public Health England, covering a wide range of public health issues, categorised as "profiles". These profiles are publicly accessible through an interactive website supplemented with user guides, which allow data interrogation using the online tools provided, or exporting of raw data files to be analysed in other software. There are facilities for importing to *R* and an application programming interface (API) is available.

One of the Fingertips profiles is *AMR Local Indicators.* More than 100 indicators are available and they receive more than 4,000 unique visits per quarter [8]. The range of indicators continues to expand, with more added monthly. Within the profile, data have been uploaded across six domains:

- Supporting NHS England Initiatives (e.g. percentage of frontline healthcare workers vaccinated with the seasonal influenza vaccine, percentage of antibiotic prescriptions with evidence of review within 72 hours)
- Antimicrobial Resistance (AMR)
- Antibiotic Prescribing
- Healthcare-Associated Infections (HCAI)
- Infection Prevention and Control (IPC)
- Antimicrobial stewardship (AMS).

The data can be interrogated by 'area type'; NHS acute trust, GP practices, Clinical Commissioning Groups (CCGs) and Laboratories. Community dentists are not available. Organisations can compare their own performance with their neighbours, regions and England. The indicators available differ for each area type.

Healthcare associated infections (HCAI) and AMR are interrelated, though discussion of HCAI in the UK AMR strategy is limited. An example of this relationship is in rates of *C. difficile* and *MRSA* infections. HCAI data from trusts and CCGs are subsumed in the AMR local indicators on Fingertips (see Figure 3 for examples). Recently added indicators reflect the government target of reducing Gram-negative bacteraemias by 50% by 2021[9], for example "*All counts and rates of Klebsiella spp. bacteraemia by acute trust and financial year".*

Data from Fingertips are available in a range of formats, including various maps, graphs and trends data, with options to display data over different time scales.

Significant effort had been made to make the system accessible and easy to use. Alongside detailed descriptions of the indicators, it also provides information on statistically relevant aspects such as source/definitions of the numerator and denominator, methodology, unit type and benchmarking method. Caveats for the data are also listed to aid data interpretation.

- All *C. difficile* rates by reporting acute Trust and financial year
- Trust-apportioned *C. difficile* rates by reporting acute Trust and financial year
- All MRSA bacteraemia rates by reporting acute Trust and financial year
- Trust-assigned MRSA rates by reporting acute Trust and financial year

Figure 3 - Example Fingertips *indicators*

3.1.6 Data Reporting

English Surveillance Programme for Antimicrobial Utilisation and Resistance (ESPAUR)

ESPAUR reports annually, and includes data on antibiotic resistance, antibiotic consumption, antifungal resistance and prescribing. It also contains sections on quality improvement and antimicrobial stewardship. A focus of the most recent (2016) report is on Gram-negative bloodstream infections (GNBSIs), reduction of which was a key ambition set out in response to Lord O'Neill's Review of AMR [9, 10].

Other Data Sources

Both ESPAUR and *Fingertips* pull data from a range of sources [11]. In addition to those discussed above (NHS Digital, SGSS, Quintiles IMS), other sources include:

- National surveillance programmes (*Clostridium difficile, E. coli*)
    - Use of broad-spectrum antibiotics is associated with an increased incidence of *C. difficile* infection [12]. Admission with *C. difficile* infection within 28 days of a hospital discharge is a marker used in the annual point prevalence survey of HCAI in England
- Acute Trust (Commissioning for Quality and Innovation, CQUIN) and CCG data (Quality premium, QP)
    - This relates to quality improvement initiatives; the most relevant here being reducing prescribing. At CCG level, prescribing is measured per 'STAR-PU' (Specific therapeutic group age-sex prescribing unit), a weighted population measure accounting for different antibiotic needs
- Healthcare worker influenza surveillance
    - Reducing influenza rates may reduce secondary bacterial infections, with concomitant reduction in antibiotic prescribing

Intended use

The ESPAUR report is intended to provide data for benchmarking against national and regional antibiotic resistance and prescribing, enabling organisations to inform appropriate local action.

In addition to prescribing and resistance data, a significant part of the report discusses stakeholder engagement since the ESPAUR oversight group works with a broad range of organisations. It also provides data on public engagement, such as the number of signatories to the Antibiotic Guardian campaign and use of the online resource *e-bug.*

3.1.7 Data Quality

Table 2 summarises the quality of resistance and prescribing data in England according to a selected range of criteria.

Table 2 – AMR data quality in England

Attribute	Data Topic		Comments
ACCESSIBILITY	Resistance		Raw data from SGSS restricted to authorised personnel at PHE - field epidemiology and health protection. Clinicians receive direct results from local or reference laboratories at patient level Data used to inform publicly accessible ESPAUR and *Fingertips*
	Prescribing	Primary Care	Regular annual reporting, information platforms for public and prescribers (e.g. PrescQIPP AMS Hub, Open Prescribing, *Fingertips*). ePACT2, PrescQIPP AMS Hub for CCGs and other authorised organisations.
		Secondary Care	Some metrics at trust level available through Fingertips, and nationally via ESPAUR. Other hospital prescribing data not publicly available, used with local proprietary systems (e.g. ICNet, Rx Info)
ACCURACY	Resistance		Reference laboratories provide gold-standard testing
	Prescribing	Primary Care	NHS Prescription Services audit shows 97.5% accuracy Unidentified prescribing is not included in data
		Secondary Care	Data submission automated for electronic prescribing systems, but paper prescribing in some trusts means greater scope for errors and inaccurate reporting
COMPLETENESS	Resistance		Comprehensive, with continual addition of new indicators for Fingertips. Detail available down to individual patient level and whole genome sequencing for organisms. Multiple levels for epidemiological analysis – practice/trust, regional, national Ability to assess impacts of prescribing on resistance across the health system if data linkages developed in future
	Prescribing	Primary Care	Payments to dispenser dependent on data submission, which should encourage completeness. No data on prescribing in private practice No data on diagnosis or reason for prescription
		Secondary Care	Data only available to ward level unless local systems record prescriber details
CODING AND AGGREGATION	Resistance		Well-established pathways and protocols for sample collection and testing with results uploaded to centralised SGSS system. 97% of laboratories submitting to SGSS, and 84% are automated. Stated intention in ESPAUR to enhance consistency of coding and linkage with other data sets
	Prescribing	Primary Care	Automated through GP payment systems
		Secondary Care	Data submitted through hospital pharmacy, with variation between local systems, some paper, some e-prescribing
FREQUENCY	Resistance		Annual publication of ESPAUR, monthly update for Fingertips. Individual test results via SGSS available immediately following laboratory upload
	Prescribing	Primary Care	Monthly data uploads to ePACT2, 2-month lag from dispensing date
		Secondary Care	Monthly for Fingertips, annual for ESPAUR

3.1.8 Other Data Sets

Healthcare Associated Infections

PHE has overseen mandatory HCAI surveillance data collection since 2001, when *methicillin-resistant staphylococcus aureus* (MRSA) levels were rising [13]. Subsequently the surveillance programme has been extended to other infections. These now comprise:

- MRSA
- MSSA (*methicillin-sensitive staphylococcus aureus*)
- *E. coli*
- *C. difficile*
- *Klebsiella spp.*
- *Pseudomonas aeruginosa*

HCAI data are submitted from hospitals via a web portal, the *Healthcare Associated Infection Data Capture System* (HCAI DCS) run by the HCAI and AMR Unit at PHE. Data are published on a monthly, quarterly and annual basis, with data tables and epidemiological commentary. This mandatory data collection system is not comparable with other devolved nations due to differences in case definitions, age groups covered by the schemes, and differing population sizes and demographics [13].

In addition to mandatory reporting, ESPAUR includes results from the annual *Point prevalence survey of healthcare associated infections, antimicrobial use and antimicrobial stewardship in England* [14]. This survey has been conducted five times since 1980, the most recent in 2016. The aim of the survey is to estimate the total burden of HCAI and antimicrobial usage in acute care hospitals, as well as describing preventive systems in place, identifying common problems, raising awareness and developing tools and guidance for quality improvement.

3.1.9 Other Settings

Dental Services

Dental prescribing in primary care is now incorporated in the annual *Prescription Costs Analysis Report,* with the raw data available as a separate file through NHS Digital. Data are limited to NHS prescribing, and are not available for private dental prescribing (according to the 2009 Adult Dental Health Survey, 27% of dentate adults in England received private dental care in their last completed course of dental treatment [15]. Dental prescribing in hospitals would be recorded through hospital pharmacy data submissions.

Private Healthcare (Primary and Secondary)

Currently there are no routine data available for prescriptions provided privately. It is unclear how much of an impact this is likely to have on overall antibiotic usage and resistance.

NHS regulations state that GPs cannot prescribe on the NHS if they are treating the same patients privately and NHS GPs cannot give private prescriptions to their NHS patients. Sometimes, a private prescription may be cheaper for a patient than paying the NHS prescription charge, and any breaking of the rules would create a source of inaccuracy in prescribing data.

Other than GPs, “independent prescribers” are permitted to prescribe, including doctors, dentists, nurse independent prescribers, pharmacist independent prescribers, optometrist independent

prescribers, and European Economic Area (EEA) health professionals. “Supplemental prescribers” may prescribe in accordance with a clinical management plan (some pharmacists, registered midwives, registered nurses, chiropodists, podiatrists, physiotherapists, radiographers and registered optometrists) [16].

3.2 Scotland

AMR data in Scotland are most readily available through a national report, *Scottish One Health Antimicrobial Use and Antimicrobial Resistance Report* (SONAAR). This is unique among UK routine annual publications as it takes a One Health approach, covering both humans and animals. The UK One Health report was published in 2015, though annual reports on human AMR remain separate to the animal VARSS report in England, Wales and Northern Ireland.

In terms of direct access to data, significant work has been done to build a centralised data platform and access portal, although this has not yet been made ready for public use.

Scotland has an organisation dedicated to combating AMR, the Scottish Antimicrobial Prescribing Group (SAPG). It has responsibility for many of the data systems and surveillance in Scotland and works directly with professionals to educate and support good practice.

3.2.1 What Data are Available?

In addition to results from local microbiology laboratories, GPs and hospital clinicians have access to four Scottish reference laboratories, offering specialist services for different microorganisms. Some services not available in Scotland are commissioned by NHS Scotland from PHE [17]. The *Electronic Communication of Surveillance in Scotland* (ECOSS) contains individual patient and antimicrobial resistance data.

GPs in Scotland have access to the *Prescribing Information System in Scotland* (PRISMS), which provides data on community prescriptions over the last five years and is updated monthly. The database is held centrally by National Services Scotland (NSS). Prescribing data from hospital pharmacies can be accessed through the *Hospital Medicines Utilisation Database* (HMUD). The intention is to replace PRISMS with an updated system that can access the entire national data set for prescribing, offering further data on financial items and linking to the Community Health Index (CHI), which contains patient level demographic data.

3.2.2 Development and Maintenance

The SAPG leads on multiple streams of AMR-related work. In addition to education, quality improvement initiatives and antibiotic awareness raising, it is also responsible for developing information systems to measure antibiotic use and resistance. It is directly involved with clinicians in providing and interpreting data to improve clinical practice.

The SAPG has produced a framework for local surveillance to be implemented by local Antimicrobial Management Teams. This is intended to collect and feed data back to clinicians and prescribers, alongside national surveillance. The recommended indicators for local Teams are:

- Total antibiotic items per 1,000 patients per day
- Use of agents associated with a higher risk of *C. difficile* infections (cephalosporins, fluoroquinolones and coclindamycin) items per 1000 patients per day.

In previous years, the SAPG has been the lead reporting organisation, producing reports such as *Scottish antimicrobial use and resistance in humans.* These have now been superseded by the Health Protection Scotland SONAAR report. The SAPG is still involved in working with prescribers and supporting the surveillance framework.

3.2.3 Data Access Platform

Infection Intelligence Platform

The construction and testing phases of a Scottish national Infection Intelligence Platform (IIP) have now been completed. In response to the UK AMR Strategy, the *Scottish Management of Antimicrobial Resistance Action Plan* (ScotMARAP2) called for the development of an IIP, described as an *"ambitious programme that aims to move to a position of enhanced connectivity of datasets to achieve a comprehensive, dynamic and responsive integrated informatics resource to support improvements in outcomes for patients with, or at risk of, infection."* [3]

The initial phase of IIP aimed to link and analyse data sets, to improve the responsiveness of the system and to enhance the accessibility of key infection data. The core data for the platform are derived from several different existing data systems:

- Electronic Communication of Surveillance in Scotland (ECOSS): all positive microbiology laboratory specimen results and a subset of antimicrobial susceptibility/resistance data in Scotland;
- Hospital Medicines Utilisation Database (HMUD): information from hospital pharmacy systems across Scotland on medicines supplied to clinical wards and units;
- Prescribing Information System (PRISMS): NHS prescriptions dispensed in the community in Scotland;
- Scottish Morbidity Record (SMR): inpatients, day cases, discharge and diagnosis (SMR01), maternity inpatients, day cases, discharge & diagnosis (SMR02) and mortality (SMR99);
- Surgical Site Infection Reporting System (SSIRS): Surveillance of surgical site infections [18].

Those working on IIP note that future expansion of the range of datasets available through the IIP should address the current absence of both national patient-level hospital prescribing data and laboratory data beyond microbiology [3].

Although significant progress has been made on the NHS Scotland Infection Intelligence Platform (IIP), it is no longer a funded programme of work [19].

Accessibility Issues and Ongoing Development

Access to IIP is only for authorised NHS National Services Scotland (NSS) staff and approved academic researchers who must have undertaken the necessary information governance training. These datasets include patient identifiable information (only used in line with Caldicott guidance for data linkage or data quality assurance). ECOSS is accessible for health protection and research use, and HMUD data are available to staff in NHS boards.

Work has commenced to establish a national laboratory 'data mart', a publicly accessible portal built on top of the IIP which is intended to be included in the platform in the future. Additional data sources and local information will be able to be linked to this core national data. However, as stated, whether further progress will be made on this remains unclear [19].

3.2.4 Data Reporting

Scottish One Health Antimicrobial Use and Antimicrobial Resistance Report

In addition to the reporting from the SAPG already described, Health Protection Scotland is responsible for the production of the *Scottish One Health Antimicrobial Use and Antimicrobial Resistance Report* (SONAAR) [20]. This report replaces the previous *Scottish Antimicrobial Use and Antimicrobial Resistance Report*. It contains resistance and usage data for humans, and resistance data for animals. Raw data are provided annually alongside the report for download. Data are provided at regional and health board level.

The data areas are arranged as follows:

Antimicrobial usage data:

- Antibiotics and antifungals, in primary and secondary care;
- Antimicrobial usage by doctors, nurses, dentists and pharmacists.

Antimicrobial resistance data:

- Gram-negative HCAIs (*Acinetobacter spp, E. coli, Klebsiella pneumoniae, Klebsiella oxytoca, Pseudomonas aeruginosa*);
- Gram-positive HCAIs (*Enterococcus spp*. and *Staphylococcus aureus*);
- Sexually transmitted infections/bloodborne viruses (*Neisseria gonorrhoeae* and human immunodeficiency virus (HIV);
- Gastro-intestinal infections including Salmonella (from human and animals) and Shigella;
- Veterinary clinical isolates for selected organisms;
- Veterinary surveillance of *E. coli.*

Veterinary Data

SONAAR veterinary data originates from clinical specimens submitted to the farm and companion animal diagnostic services, provided through collaboration between the Scottish Agricultural College and *Capital Diagnostics*. These are both part of Scotland's Rural College (SRUC). Sales and consumption data for animals are reported UK-wide through VARSS and are not included in SONAAR.

There are some limitations with these data. Firstly, sample testing for private veterinary treatment is charged on a fee-per-item basis, ultimately incurring a cost to the animal keepers. This is likely to introduce bias to the data.

Secondly, testing for resistance is done to inform treatment, relying on specific testing methodologies that may be hard to interpret for public health purposes. The Control of Antimicrobial Resistance in Scotland (CARS) team have made efforts to standardise AMR data for animals and humans. For the SONAAR report, organisms are included based on prevalence and similarity to organisms that cause morbidity in people [20].

3.2.5 Other Data Sets

Healthcare Associated Infections

The SAPG produces the *National Point Prevalence Survey of Healthcare Associated Infection and Antimicrobial Prescribing,* conducted every five years. The report measures the types and prevalence of HCAIs, prevalence of antimicrobial prescribing, and compliance with SAPG quality indicators. It also contributes to the ECDC prevalence survey to inform the European strategy to reduce HCAI and AMR.

3.3 Wales

3.3.1 Overview

The NHS Wales Informatics service is responsible for collecting and reporting information on patient demographics and antimicrobial prescribing activity across the NHS in Wales.

Public Health Wales has responsibility for data collection and reporting on AMR and HCAIs. This process involves a laboratory network in nine sites around the country, with microbiology results maintained in the DataStore repository maintained by Public Health Wales.

Reporting in Wales comes through a series of documents produced separately by the Welsh Antimicrobial Resistance Programme Surveillance Unit. Not all these documents are produced annually. They consist of point prevalence surveys of prescribing in primary and secondary care, antibiotic usage reports in primary and secondary care, and surveys on quality measures for antibiotic prescribing. *Antimicrobial Resistance in Wales* is a report produced on a consistently annual basis.

3.3.2 What Data are Available?

Prescribing Data

Prescribing in primary care is routinely collated and published monthly via the Wales Primary Care Services website. This is item-specific and is at the practice level. Prescribing data in hospitals can be accessed through the same portal, though as the data are extracted from the hospital pharmacy, only medications dispensed from that location will be included (i.e., outpatients going to other community pharmacies would not be). Neither data set offers data routinely at the prescriber level.

Usage Data

Hospital usage data are presented in the report, *All Wales Antimicrobial Usage in Secondary Care*. This is derived from hospital ward stock data, and combined with in-patient activity data from the *Health Solutions Wales Information and Statistics* website. Producing these data appears to be a relatively labour intensive process and currently must be done manually.

Resistance Data

Surveillance data on resistance rates are currently routinely collected by the Welsh Antimicrobial Resistance Programme (WARP), [21] and yearly reports are published on the Public Health Wales website. The *Antimicrobial resistance in Wales* report charts data for the preceding ten years. This provides data on trends, and provides data at the levels of major acute hospitals, district general hospitals, and the local community health boards.

The report provides individual hospital/laboratory resistance rates, though only if >80% of isolates of a given type were tested and the number exceeds nine. The omission of small numbers may have some impact on accuracy and representativeness of the data.

3.3.3 Future Plans

Data systems are set against the AMR Delivery Plan for Wales [22]. This document sets out seven delivery themes, with delivery theme 6 being *"Better access to and use of surveillance data"*. The delivery plan highlights the joint work between Health Boards/Trusts and Public Health Wales, the All Wales Medicines Strategy Group (AWMSG), professional bodies and higher education providers on antimicrobial stewardship, including monitoring of prescribing patterns and usage data across the NHS.

In the delivery plan, the Welsh government has charged Public Health Wales with developing systems for effective surveillance of AMR. The following list of priorities is quoted directly from the Delivery Plan:

- Develop a web access tool for availability of local resistance data.
- Develop regular resistance reports for specific clinical areas (e.g. Intensive care).
- Develop automated trend analysis to enable early detection of threats at local level.
- Develop with NWIS a resistance alerts system to highlight resistant organisms in real time.
- Review with the Welsh Analytical Prescribing Unit (WAPSU) publication of antimicrobial usage with stakeholders (in both primary and secondary care) and implement findings of review.
- Develop Health Board reports that integrate local antibiotic usage and resistance data to inform areas for action.
- Develop IT infrastructure to enable local access to monthly ward-based reports of usage.
- Develop web tools to facilitate annual and local point prevalence surveys.
- Develop outcome measures to establish the baseline and subsequent trends for key drug/bug combinations.
- Develop targeted surveillance of carbapenemase-producing bacteria.
- Develop, with the support of the Welsh government, a genomic platform to support molecular epidemiological studies [22].

Currently, web access tools are not available and stakeholders are limited to monthly prescribing reports online and annual reports produced by Public Health Wales' Antimicrobial Resistance Programme Surveillance Unit.

3.3.4 Other Settings

Long term Care Facilities – National Survey

In 2017 Public Health Wales produced a survey focussing on long term care facilities - *National Point Prevalence Survey of Healthcare Associated Infection, Device Usage and Antimicrobial Prescribing 2017* [23]. This was part of a broader, ECDC supported project providing methods for continued assessment of the prevalence of HAIs, antimicrobial use, infection prevention and control resources, and antimicrobial activity in European long-term care facilities (LTCFs), known as HALT-3.

The report notes that *"Many LTCFs do not have their own surveillance programmes or feedback mechanisms in place to their general practitioner practices in respect of HAIs, antimicrobial prescribing or AMR."* For the LTCFs in this study, the majority did not have surveillance mechanisms in place.

The results of this survey were intended to inform the Welsh Government and Health Boards on key priority areas of work on infection reduction and antimicrobial stewardship in relation to LTCFs.

3.4 Northern Ireland

3.4.1 Overview

The NI Public Health Agency (PHA) oversees health system surveillance functions across the country, which includes the five Health and Social Care Trusts, with each providing a range of routine diagnostic, specialist and regional laboratory services.

3.4.2 What Data are Available?

Prescribing Data

Alongside the annual report *Surveillance of Antimicrobial Use and Resistance in Northern Ireland*, clinicians and the public have direct access to prescribing data in primary care published monthly via the Government OpenDataNI portal. This records all community prescriptions dispensed and paid through the Business Services Organisation (part of the Northern Ireland Department of Health).

Resistance Data

Laboratories submit severe infection data to the CoSurv Information System. Infections that meet specific criteria, for example, blood stream infections, are submitted to the Public Health Agency's CoSurv Information System from each Trust's microbiology and/or virology laboratories.

Suspected carbapenemase-producing organisms (CPOs) are submitted to the PHE reference laboratory in England, which then notifies NI PHA of results. Confirmed isolates encompass both colonisation and infection. There is some development in local capacity for testing of CPO.

Submissions from laboratories are voluntary, potentially limiting the accuracy and reliability of the data.

3.4.3 Data Reporting

The PHA publishes an annual report summarising AMR data, with the first produced in 2017 [24]. It is based on voluntary data submission from a range of stakeholders, including clinicians, hospital laboratories, consultants in communicable disease control and environmental health officers.

The report includes trends in AMR in NI, using drug-bug combinations identified as key indicators in the UK AMR Strategy. Additionally, further combinations are included in alignment with the equivalent document for England, ESPAUR.

The data are extracted from the Electronic Prescribing Database, which covers all primary care including dentistry. Hospital prescribing is extracted from each Trust's Medicines Management System (using proprietary software from JAC). Data are not available below Trust level.

More detail on specific healthcare settings and clinical specialities is envisioned for future reports.

3.5 Veterinarians and Animal Health (UK Wide)

3.5.1 Overview

The key areas of AMR-related data related to animals include antibiotic sales, antibiotic use and antimicrobial resistance.

For practicing veterinarians, resistance data are mostly used for diagnostic purposes and, to a lesser extent, to guide the selection of antimicrobial treatment. In England and Wales, the Animal and Plant Health Agency (APHA) offers services to test samples that also function as a passive surveillance system to monitor emergent patterns of resistance. The Scotland Rural College (SRUC) and Agri-Food and Bioscience Institute (AFBI) provide equivalent services in Scotland and Northern Ireland, respectively, with networks of local disease surveillance centres providing diagnostic and resistance data for vets.

3.5.2 Development and Maintenance of Data Systems

The Veterinary Medicines Directorate (VMD) has a mandate to protect animal health, public health and the environment. It is an executive agency, sponsored by the Department for Environment, Food & Rural Affairs (DEFRA). They have a regulatory role in the responsible use of veterinary drugs, including antimicrobials, monitoring adverse reactions to drugs, and testing for the presence of drug residues in foods of animal origin for human consumption. The VMD is responsible for the annual publication of the *Veterinary Antimicrobial Resistance and Sales Surveillance report* (VARSS).

VARSS covers all four UK countries and includes data on resistance and sales of antibiotics. Data for the antibiotic resistance section of the report are produced and collated by the APHA, AFBI and SRUC. Sales data are submitted by pharmaceutical companies and usage data are collected on a sector-by sector basis (pigs, cattle, poultry, gamebirds, and egg laying birds).

The VMD is also responsible for sales data submission to the European Surveillance of Veterinary Antimicrobial Consumption (ESVAC) project [25], and resistance data to the European Food standards Agency (EFSA) surveillance programs [26].

Early Warning/Sentinel Surveillance

APHA is home to the scanning surveillance system and the Surveillance Intelligence Unit (SIU). Its surveillance activities are intended to detect, characterise and manage risks in livestock and wildlife in England and Wales. Among the threats the organisation lists is '*Novel or rare antimicrobial resistance',* such as transferable colistin resistance (i.e., resistance to the last resort antibiotic colistin that has the potential to transfer to bacteria affecting humans).

The organisation produces regular quarterly threat reports. Findings that represent a potential threat to human health are escalated to the DEFRA Antibiotic Resistance Coordination (DARC) group for consideration and management.

For Northern Ireland, the AFBI produces monthly surveillance reports and contributes to an all-Ireland annual report. In Scotland, the SRUC also produces monthly disease surveillance reports.

3.5.3 Data Capture and Reporting

Veterinary Antimicrobial Resistance and Sales Surveillance Report

VARSS presents combined data on veterinary antibiotic sales, usage and bacterial resistance from animals in the UK. In the foreword, the authors recognise the difficulty in selecting appropriate metrics, and references the debate over different approaches to monitoring. The authors advocate developing sector-specific, relevant metrics for feedback to vets and farmers. The report measures sales and usage in reference to a population correction unit (PCU) to take into account differences in the animal population in size and number, presented as mg/kg [27]. It also presents crude sales data in tonnes.

The veterinary antibiotic resistance and sales data monitoring programme is commissioned and funded by the VMD. Data on antibiotic usage in poultry species are collected by the British Poultry Council (BPC) and shared with the VMD, published in VARSS since 2014. Data from pig, egg, gamebird and dairy industries were published for the first time in the 2017 report. Data are collected and provided on a voluntary basis by different livestock stakeholders [27]. The VMD has also funded research on usage in companion animals.

Resistance Data

Resistance data are collated by the APHA, AFBI and SRUC. APHA includes the national reference laboratory for a range of infections and non-infectious diseases in farm animals, providing confirmatory testing, specialist training and diagnostics research. It provides up to date resistance profiles for antimicrobials in general use in veterinary practice (e.g. amoxicillin-clavulanic acid, tetracyclines) and those undergoing research. Additionally, it maintains a collection of bacterial isolates for further research and antimicrobial susceptibility testing.

Its clinical surveillance programme evaluates resistance in isolates submitted by private veterinarians. The primary purpose is as a diagnostic service, though it can help to identify existing and emergent patterns of resistance. Additionally, it tests for *Salmonella* sensitivities from animals and the environment, relating to the UK Zoonoses Order 1989. APHA raw resistance data do not appear to be publicly accessible and are visible only through the annual VARSS report in aggregate form.

There is also the EU Harmonised monitoring programme which mandates all EU Member States to monitor and report antibiotic resistance in zoonotic and commensal bacteria from healthy food-producing animals at slaughter and food products at retail. Member States carry out, every two years, the sampling, collection and antibiotic susceptibility testing (AST) of each combination of bacterial species and type of sample from the different animal populations in accordance with a rotation system. The isolation of bacteria and AST are carried out by APHA which is the national reference laboratory for AB resistance in the UK. Some samples for Campylobacter testing collected in Northern Ireland are tested by AFBI. Data from this programme is reported in the VARSS report and also submitted by the VMD to EFSA for inclusion in the annually published European Union Summary Report on AMR in zoonotic and indicator bacteria obtained from humans, Food Producing Animals (FPA) and food [26].

Any resistant isolates (detected through clinical surveillance or EU statutory surveillance) considered to pose a risk to human or animal health are reported to the DARC group for consideration and management in accordance with the guidelines of the VMD AMR Contingency Plan.

Sales Data

Veterinary pharmaceutical companies are obliged to provide sales data for all authorised veterinary antibiotics to VMD in accordance with Veterinary Medicines Regulations 2013.

At the request of the European Commission, the European Medicines Agency has developed a harmonised approach for collection and reporting of data based on national sales figures [28], ESVAC. This is designed to be comparable with usage data of human antibiotics. The VMD is responsible for ESVAC data submissions.

Antibiotic Usage Data

The VARSS report has now expanded to provide usage data for pigs, poultry, eggs, game birds and cattle industries. Data were collected on a voluntary basis, and the report notes the increasing commitment across organisations to share data openly among all the different sectors.

The VARSS report notes that as coverage is not 100% across animal industries, and not consistent between them, data may not be representative. For example, it is estimated whilst up to 90% of poultry (for meat) is covered only 31% of dairy is accounted for in the report [6].

Different sectors collect data through a range of mechanisms, resulting in a complex data system:

- The Cattle Health and Welfare Group is working towards increasing the amount of available data in the dairy industry, using the proprietary *FarmVet* software to extract data from practice management systems
- The Red Tractor scheme now requires antibiotic use to be recorded for pigs in the e-Medicines Book.
- The poultry sector (BPC) has a stewardship scheme which records usage nationally in an aggregated spreadsheet. Egg producers report usage data quarterly, along with an annual average for numbers of birds.
- Game bird data were obtained by combining in-feed incorporation records with prescribing records of gamebird vets.

The current voluntary nature of these submissions creates significant potential for bias in these datasets. Those farmers with poorest animal husbandry and farm management practices may have least incentive to voluntarily submit data, making the figures unrepresentative. Sales data are likely to be more accurate but the extent to which these data match consumption is unclear. There may be issues with illicit or unrecorded animal medicines, though this is indirectly monitored to some extent; testing at the abattoir level for drug residues at slaughter are conducted by the Food Standards Agency (FSA).

3.5.4 Data Quality

Table 3 and Table 4 summarise key issues for the quality of data for resistance and sales respectively. Data quality for antibiotic usage is not included here as there is great variation in coverage between sectors and how data are obtained.

Table 3 - Data quality for resistance in animal bacteria

Attribute	Comments
Accessibility	Not publicly accessible, only through VARSS and EFSA reporting
Accuracy	APHA houses the national reference laboratory, drawing on diagnostic definition from the British Society of Antimicrobial Chemotherapy (BASC). Thus, individual results can be considered reliably accurate, but accuracy of resistance patterns may be limited. E. coli, for example, is tested for AMR according to different criteria depending on the organisation. See *completeness* VARSS states that resistance data is from a biased population that should not be considered representative of animal bacterial populations in the UK.
Completeness	Numbers of isolates and percentage resistance provided in VARRS for a range of infection types based on prevalence and relevance to human health. Testing for resistance occurs for diagnostic purposes. Although the data do provide information on resistance patterns, samples tend to be from vets sampling animals not responding to conventional treatments. EU harmonised monitoring occurs on alternating years, thus not providing annual data
Coding and Aggregation	APHA, AFBI and SRUC submitted to VMD, data aggregated in to annual reports. Different methodologies are used in England and Wales, Northern Ireland and Scotland, limiting the validity of UK wide generalisations.
Frequency	Incorporated in to annual VARSS and EFSA reports

Table 4 - Data quality for sales of veterinary antibiotics

Attribute	Comments
Accessibility	Commercial data, not directly accessible – but submitted to VMD for VARSS report under veterinary medicines regulations, and ESVAC for Europe-wide surveillance
Accuracy	Sales data considered to be an overestimate of use –total amount of antibiotic formulations that are not used in animals due to wastage (expired "use by date products), or disposal not known. To check the correctness and completeness, product data entries are compared to those submitted in previous years. If large discrepancies are observed between data provided in successive years, data validity is further investigated. Change to European methodology makes some comparisons with older data difficult – e.g. active ingredient calculations now include weight of salt. However, this does allow harmonisation and benchmarking with other countries.
Completeness	Different animals will use different doses, and without this information data sales can be hard to interpret
Coding and Aggregation	Tonnage calculated by multiplying *summary product characteristic* (SPC) quantities of active ingredient by number of units sold. From 2016, reporting methods align with European methodology (ESVAC)
Frequency	Incorporated in to VARSS annual report.

3.6 Data Sets for Academic Use and Bespoke Analysis

In addition to the national routine data sets, there are a range of organisations that collect data suitable for bespoke research in academic settings and quality improvement.

The Health Improvement Network (THIN)

THIN is a medical data collection scheme, making primary care data available for healthcare organisations to conduct research and analysis. Prescribing data is collected. THIN data covers around 6% of the population, though this is stated to be nationally representative.

Clinical Practice Research Datalink (CPRD)

CPRD is a centre of the Medicines and Healthcare Regulatory Agency (MHRA). They collect de-identified data from GP practices in all four UK countries, which also includes prescribing data. CRPD state that around 1 in 6 practices in the UK contribute data. It is held for observational and clinical research, and a benefit is that it can be linked with other data sets such as hospital episode statistics. Patients are able to opt out of submitting data to the service.

3.7 Surveillance System Evaluation Criteria

A formal framework for evaluating surveillance systems is provided by the CDC [2] and has been used in this part of the report. The framework identifies the following attributes as relevant for surveillance system evaluation: data quality, sensitivity, positive predictive value, simplicity, flexibility, acceptability, representativeness, timeliness and stability. Data quality has been considered in the first part of this report, and we will omit sensitivity and positive predictive value, as they are less relevant for AMR surveillance.

Simplicity

Ideally, surveillance systems should be as simple as possible whilst still meeting their objectives. The mapping of the UK systems revealed a highly complex system, comprised of many separate data collections systems, producing data of varying accessibility, with a range of organisations responsible for final processing and outputs.

Notable issues which limit the transparency of the current system include:

- Different reporting methods between the UK countries make some direct comparisons difficult. For example, antibiotic usage data for hospitals in Wales requires a significant manual effort, whereas in England this is mostly automated (though a lack of e-prescribing in many English hospitals is also limiting).
- Appropriate methods for identifying and reporting on the animal AMR data most relevant for human health are still being established. For example, some key drug-bug combinations in humans are not tested in animals as these drugs are not used in the animal population [5].
- Tasks are duplicated among organisations due to human health being a devolved issue, with different administrations having variable resources to invest in the issue.

Despite these challenges, the trend overall is towards increasingly straight-forward access to processed data for clinicians, commissioners and the public. Our qualitative interviews suggest that awareness of data may be lagging behind what is actually available, so improved engagement may be necessary to ensure people know where and how they can access data.

Flexibility

Flexibility in surveillance systems refers to the ability to adapt to changing informational needs with few extra resources. All four countries continue to develop their systems in response to the Strategy and devolved actions/delivery plans. For England, this is around enhancing existing systems, with better data linkage with SGSS and expanding the Fingertips indicators. In Scotland, following successful development of the IIP, wider roll out to the public and organisations would meet their action plan goal.

An example of flexible responsiveness for the English system can be seen with carbapenamase-producing organism surveillance. As noted in ESPAUR 2018 [7], following difficulties with poor data reporting with the current enhanced surveillance system, efforts are now being made to integrate data from local laboratories into SGSS. This would provide a more comprehensive, single data set for carbapenem resistance, with the aim of developing linkages with Hospital Episode Statistics (HES) with additional clinical data.

Wales and Northern Ireland are at an earlier phase in the development of their data systems. A draft version of the Northern Ireland AMR action plan for 2019-2023 [29] is at the stage of identifying requirements for a regional AMR surveillance system, emphasising automated monitoring of antibiotic use and integrated surveillance for antimicrobial use, resistance and patient outcomes. The draft plan identifies the need for additional resources in order to achieve these goals.

Similarly, the Welsh AMR delivery plan [22] set out an ambitious set of goals to improve surveillance. The plan states the intention of delivering the plan using existing levels of resources, which may limit flexibility in developing surveillance to meet current objectives and potential changing needs in future.

Acceptability

As of 2017, Fingertips recorded over 4,000 hits per quarter, which is an indication that the data are regularly being viewed [8].

The findings of the interviews conducted with local and national users of the data conducted in Strand Two of this research, indicate an overall acceptability of existing surveillance systems in the UK, with the absence of e-prescribing being identified as the main suggested improvement in terms of speed and ease of assessing the data on human health surveillance (which would arguably translate into higher acceptability). Two factors potentially affecting acceptability of the animal health data were the perceived lack of integration with human health surveillance, and the provision of antimicrobial sales rather than usage data in most reports (section 4.3).

Representativeness

A public health surveillance system that is representative will accurately describe the occurrence of health-related events over time and their distribution in the population by place and person. Prescribing data should be representative given the structure of the health care system. For example, in England NHS Digital produces reports that are representative of NHS prescriptions in primary care. The fact that payments for dispensers are dependent on data submissions should ensure data that is representative, as confirmed by an audit showing 97.5% of prescriptions were recorded [30]. One challenge that remains is uncertainty about the extent of private prescribing as there are few or no data.

Usage data can be problematic. For example, in some Wales reports on antimicrobial usage in secondary care, point prevalence surveys are used to make estimates rather than relying on comprehensive routine data. In animal health, data coverage for some sectors on antimicrobial usage remains very limited.

Challenges in representativeness remain around resistance. Voluntary reporting in Northern Ireland for organisms listed in the Strategy's key drug-bug combinations may lead to underreporting and poor representativeness.

Carbapenemase-producing organisms also present a challenge. SONAAR [20] notes that the apparent increase in the number of CPO isolates may not only be attributable to a real increase in infections but also to an increase in awareness and testing. The Welsh delivery plan also identifies the need to improve epidemiology of CPOs.

Timeliness

The timeliness of reporting is continually improving. England, Scotland and Northern Ireland (as of 2017) have annual publications for antimicrobial resistance and usage, with Wales producing frequent separate reports for resistance and usage in primary and secondary care. VARSS is UK-wide and also produced annually.

Fingertips is updated monthly and offers contemporaneous data for England.

In 2015 Public Health England and the Veterinary Medicines Directorate jointly published the UK One Health Report [31], using data up to 2013. This combined human and animal health data, identifying key One Health relevant organisms and presenting data for humans and animals alongside each other throughout the report. Further One Health reports are planned, though it is not being produced regularly at present.

Stability

The review of data systems did not identify any specific issues with data collection system stability, such as frequent failures or inability to access data. Neither were issues of this type identified through the qualitative interviews. However, resource shortages in Wales and Northern Ireland were cited as problematic, suggesting the system might be unstable in some parts of the UK.

Data collection for different animal sectors is progressing unevenly, taking different approaches and different levels of coverage. Although significant improvements have been made, the voluntary nature of these industry changes makes animal data inconsistent.

Overall usefulness

The most recent ESPAUR report states the intention to develop methods of estimating the clinical burden of resistant infections. Similarly, the Welsh and Northern Irish Action plans both cite the importance of providing data that that can support clinicians in improving outcomes.

Our research suggests that this is an important issue, as making a close link between clinical need and prevalence of AMR are relevant for clinicians, some of whom may at present have reservations about the usefulness of AMR surveillance.

The majority of data users interviewed identified important uses for antimicrobial utilisation and resistance surveillance systems, though some described the opportunity cost associated with collecting the data and the workload for clinicians, which leaves them with limited time to read reports and incorporate them into their prescribing practice.

4 Results – Data Use and Needs

This section describes the key themes in relation to the use of data to effect change that emerged from interviews with stakeholders at the various levels. The findings of interviews with animal health professionals will follow the analysis of the national-level interviews. The professional title of the interviewee is presented in parenthesis next to any direct quote or paraphrased statement.

4.1 Prescribing Data

4.1.1 Primary Care

Views on Current Data Systems (Uses, Problems, Gaps, Benefits)

Prescribing data are used in different ways in primary care. In some areas, the information is given to practitioners to reflect on and improve practice, whilst in some GP practices the information is used to "name and shame" individual practitioners (Antimicrobial Pharmacist), and to support discussions among peers about their prescribing choices:

> *'So I give a lot of, I don't know, Penicillin for tonsillitis but you give Amoxicillin, that's the wrong drug, why are you giving that? So it may be high but it's the right medicine, so there are ways of justifying, you don't have to be just embarrassed at it' (GP)*

In addition to helping individual prescribers within practices, commissioners of health services suggested that data could identify issues at practice level that need to be addressed, sometimes through shared learning with other neighbouring practices (Educator/Trainer for CCG). CCGs use prescribing data to advise GPs on what they should be prescribing (Community Liaison Nurse). They also use prescribing data to track the performance of GP practices over time; against each other; and to compare the CCG's performance against other CCGs (Senior Medicines Researcher).

The process of identifying high-prescribing practices based on the proportion of their prescribed antibiotics that are members of the "4 Cs" group of drugs (often targeted in stewardship campaigns), was seen by a GP as potentially unfair on practices with fewer registered patients, as a small number of patients with complex medical conditions would be sufficient to identify the practice as a high prescriber. It was also seen to disadvantage practices that were generally low prescribers of antibiotics.

The results of "root cause analysis" are fed back to the general practice where the patient is registered in instances where it is suspected that a case of *C. difficile* was caused by a course of antibiotics prescribed in primary care (IPC Nurse).

The benefits of having access to prescribing data in primary care were expressed in all of the case study sites as well as in the interviews conducted with national policy officials and professionals. One respondent felt that giving data to practitioners could be a powerful way of illustrating to individuals who overprescribe how they compared with their peers, for example:

> *"I actually went to [an in-house] practice meeting and they'd just run it off [prescribing data] and they'd handed it out. There was a GP there and they just said, 'You know what? I have absolutely no idea why I prescribe more antibiotics than anyone else.'*

She was just, kind of, horrified because she said, 'Why would I ever know that, because I assume that I'm only giving them when they're needed? You know, people come in and they give talks on antimicrobial stewardship and I've always just thought well, you know, they're not talking about this. I'm absolutely bad,' and she was really open and honest about it. She just said, 'I'm just horrified at this data.' You know, that was the most powerful thing that I've ever seen with it was" (Antimicrobial Pharmacist)

A similar opinion was expressed in relation to dental prescribing.

Interviewees noted that the importance of formatting and presenting the prescribing data, and making them easy to interpret, for example:

"I think one of the most powerful tools we have is the data but I guess it's about not just sending them a spreadsheet and expecting them to interpret it themselves… and making it just very visual so, you know, they only have to look at one graph to see where they are. It's not giving them the data to interrogate particularly, it's us using the data to give it to them in a form that's really easily-accessible".

In addition to changing prescribing behaviour, interviewees suggested more detailed data (including the indications for the prescription) would help in evaluating the success of various health policies and initiatives at the local level, for example, in the management of urinary tract infections (including in residents of care homes):

"…in terms of care homes, we've, I'm hugely concerned at the moment, we're doing a big project around UTIs at the moment because we hear some absolute horror stories where, for example, care homes will dipstick, routinely dipstick all their residents' urine on a Friday and if they'll get any positives, they'll ring the practice, the practice won't even come and review the patient, you know, it's all over the telephone, all on hearsay of the care home who, you know, no disrespect, are not qualified nurses most of the time and they will prescribe antibiotics over the phone without even reviewing that patient…" (IPC Nurse)

"…for example I'd like to know what percentage of the antibiotic prescribing that is going on in the community for UTIs, that sort of breakdown, because it would help target, because we are doing lots of targeted interventions. Like we've recently come up with the hydration policy for nursing home residents where they're encouraged to drink more so that they prevent … they stop them getting UTIs and needing antibiotics and hospital admissions, so those sort of initiatives. But in terms of data I think it's really lacking." (Consultant Microbiologist)

The second perceived gap was in relation to data on dental prescribing and prescribing by dermatologists (Senior Medicines Researcher). Section 3.1.9 outlines what data on dental prescribing are currently available in England.

While collection of prescriber level data may lead to prescribers prescribing more appropriately, one respondent was concerned that the collection of prescriber-level data in primary care may lead some practitioners to under-prescribe antibiotics when they are needed:

> *"…I do recall a GP appraiser friend that was describing how she appraised a doctor; he said, 'oh, I am the lowest prescriber of antibiotics in entire [geographic location]', and was extremely proud, and didn't realise that probably being the lowest prescriber might mean that he didn't prescribe enough, that some patients were maybe being denied it whenever it was clinically appropriate to give it to them…" (GP Medical Advisor)*

The third and final gap identified was in relation to CCGs being able to access the indications for individual prescriptions of antibiotics because they have only limited information on the patient's characteristics (for example, age which is relevant for trimethoprim prescriptions). The ePACT2 system does not have the indications for the prescription (CCG Official).

Suggested Improvements

In primary care, respondents suggested several potential improvements to prescribing data:

- Having rolling data collected at regular intervals (for example 12 months) to take into account seasonal variations. It is currently labour-intensive to obtain these data (Antimicrobial Pharmacist).

- Providing data that would permit different types of prescribers to compare themselves against peers, as well as other practitioners within a geographic area:

  > *"…it would be nice to compare myself against other nurse practitioners rather than other GPs and things like that." (Nurse Practitioner)*

- Providing data in a format that can be easily understood by users of data could make them more useful. One respondent suggested adopting a traffic light system to display the results of performance indicators in one place (General Practitioner).

- Tools that have been developed locally to enable the interrogation of prescribing data (such as prescriber-level details) should be made available nationally.

- Another respondent suggested adopting a more "personalised approach" to the data sent to prescribers in primary care, highlighting what is happening locally, and positive changes (General Practitioner).

- Linking prescribing volume and outcomes (such as secondary complications) in the data that are shared with prescribers in primary care (Senior Medicines Researcher), as well as capturing the number of patients who experienced side-effect of antibiotics (such as nausea) or presenting the numbers needed to harm to clinicians (Senior Medicines Researcher).

4.1.2 Secondary Care

Views on Current Data Systems (Uses, Problems, Gaps, Benefits)

In hospitals, prescribing data are used as part of performance management systems within divisions and departments (Chief Nurse). It was felt that the production of "league tables" for prescribers was very important for motivating change in behaviour, as doctors were described as naturally competitive, and would not want to be at the bottom of the table. However, respondents cautioned that the prescribing data need to be accurate. For example:

> *"The big danger with producing surveillance data is that it'd better be accurate, otherwise you're feeding rubbish centrally, which will produce a rubbish output that people will then be judged* on." *(Lead Consultant Microbiologist)*

Senior clinicians in hospitals also reported using audit data to motivate their teams to improve their practice:

> *"…one of our surgeons can go in, find himself and look at how many of his patients have been audited in the last month, two months, six months, and see where his compliance rate is. Then if he thinks he's doing better than that, he can then go around to his team and go, I think we should be better than that, why aren't we better than that..." (Medical Director)*

In Glasgow, monthly point prevalence surveys are conducted in one of the hospitals to determine the appropriateness of prescribing through linking in-patient prescribing with indications, which is then fed-back through the clinical governance network.

Prescribing data were also considered to be useful for understanding variation and trends, for example, helping commissioners of service understand seasonal variations in prescribing in secondary care (Dental Advisor).

Respondents also identified a number of limitations of current prescribing data systems. For example, , in some areas respondents felt that annual prescribing surveys were not frequent enough:

> *"…So they do, across [geographic location], an annual point prevalence survey of antimicrobial prescribing, which is fabulous but it's only one a year, the report normally takes months and months to come …" (Assistant Director of Nursing and IPC)*

Additionally, the time consumed in data collection, combined with the difficulty of collecting relevant data, reduced their value:

> *"We've been presented with a form that has 20-something questions on it, and the questions relate to antimicrobial use in the last 28 days. Did somebody have a catheter at any stage in the last 28 days, and various other questions which relate to the patients, but not to how the patient is today, and how on earth am I going to, with any reliability, determine whether someone did or didn't have a catheter three weeks ago, on a different ward, on a different admission?" (Lead Consultant Microbiologist)*

They also noted that the process of producing these reports creates friction among colleagues:

> *"We're being used as the police, frankly, in practice observation of other clinicians, which I don't know exists anywhere else in the Health Service. Are cardiologists being policed by other cardiologists to see if whatever they're up to is?"*

Users considered the current data systems' outputs as requiring considerable manipulation before they could be used meaningfully:

> *"I guess we don't have a hospital pharmacy prescribing system. We only have a what issues have been supplied from pharmacy within the hospitals…And I guess the challenge there is it needs significant data manipulation in order to get something meaning because you've got to make adjustments for daily divided doses and so forth… You'd make that adjustment, manipulate it and it would then give you something meaningful. Whether the usage is high, medium, low." (Pharmacist)*

In the absence of software that can process data and present them in a format that is accessible to users in secondary care, there is a reliance on local data analysts who have particular skills in processing data and presenting it in an accessible format (Site Medical Director).

In some hospitals, it is not possible to obtain prescribing levels by ward or by prescriber as a result of the paper-based format of prescribing requests. The only available data are the amount of antibiotics issued in every ward on a weekly basis (Medical Director). Although some hospitals do have electronic prescribing, the absence of these e-prescribing systems precludes the ability to target individual over-prescribers with stewardship interventions:

> *"at least you can target particular prescribers, and say you are outlier from your colleagues. Can you tell us why you're an outlier? Maybe you're right; maybe they're right, but at least you'd be able to have the conversation." (Lead Antimicrobial Pharmacist)*

This absence of e-prescribing from hospitals also made it harder to anticipate issues that may arise as a result of changes in prescribing volumes, since these figures are currently about one month out of date (Consultant in Infectious Diseases).

Another respondent noted the absence of data on whether the antibiotics being prescribed in hospitals were on a reserve list (Non-executive on hospital Board). The respondent was unaware of the large amount of data available on the Fingertips Portal, and options for benchmarking the hospital's performance:

> *"…can we benchmark ourselves against other hospitals? Again, I don't know what benchmarking data may be available. Do any of the chief pharmacists in different hospitals do any of that benchmarking already? I think it would certainly be of interest to me as one of a wide range of measures, as long as there was some context to it. If we simply told what percentage of our prescribing is Gentamicin it wouldn't really tell me very much." (Non-executive on hospital Board)*

Respondents were concerned that the current IT infrastructure within trusts makes collation of information difficult:

> *"IT systems that we have, that don't really make collation of information easy. It tends to be a lot of paper counting exercises, so there is definitely ... and within [geographic region], everybody seems to be doing something different. There's nothing uniform around being able to collate that information..." (IPC Nurse)*

Suggested Improvements

Introducing e-prescribing throughout secondary care was often identified as a priority for the future, whilst acknowledging that persuading the NHS and the Government to invest in such systems would be the main challenge:

> *" I mean everyone is talking about [e-prescribing], everyone is saying we need it for so many reasons, for so we know what we're doing, for patient safety stuff, to reduce medication errors, to reduce administration errors, I mean there are so many reasons why e-prescribing would be a good thing… But it is getting Welsh government to say, this is now our priority for Wales…." (Site Medical Director)*

Respondents described their expectations of what an e-prescribing system would deliver, suggesting, for example, that an e-prescribing system would permit the examination of prescribing levels by ward and prescriber level (Medical Director); and that being able to link prescribing with diagnoses, and compare trends on the same ward over a period of time would be a great driver for change:

> *"…if I could say, okay, in respiratory over the winter months, on average we have 80% of patients on IV antibiotics; in the summer we've got 60% - oh, but this month we've only got 20% - that would be like, well, what's different? So, a prompt to go and look at that." (Chief Pharmacist)*

One respondent, however, also pointed out that e-prescribing would not eliminate all the difficulties associated with data collection, as in some hospitals where these systems were introduced there continued to be problems with some prescribers still not stating the indications for their prescriptions (IPC Nurse).

National audits were the second demand reported by respondents, as it would enable hospital staff to compare themselves with similar hospitals across the country (Pharmacist) and with national benchmarks (Medical Director).

4.1.3 National Level

Views on Current Data Systems (Uses, Problems, Gaps, Benefits)

Similar to its use in primary and secondary care, prescribing data are used at national level for performance management in a number of different forms.

The first of these is to target over-prescribers. NHS England uses the information on prescribing to "red flag" CCGs that over-prescribe (Registered Nurse), but it is not clear what benchmarks are used to identify over-prescribers. Similarly, The Scottish Antimicrobial Prescribing Group uses its data as part of its stewardship initiatives:

> *"…we look at it in our hospitals so we can tell which hospital uses more, what the patterns are of prescribing. We feed that back to prescribers and we feed it back in hospitals through our governance structures" (Infectious Disease Consultant)*

The data can also be used to encourage good practice, for example in Scotland they encourage practitioners to continue with their good prescribing behaviour:

> *"At board level… when you see somebody is good and gives you a gold star that says your performance is really good, your data is really good, it encourages you to do more." (Infectious Diseases Physician)*

The rationale for providing these national data was to influence prescribers and organisations at various levels by giving them a picture of their prescribing levels relative to peers as well as bringing prescribing, HAI and resistance data together in one place, which according to one respondent, might enable the measurement of the relationship between prescribing and local resistance levels:

> *"… And in a primary care sense what we're trying to do is, for the first time bring together resistance data, Healthcare Associated Infection data and prescribing data…what we've done to add value to that is put the resistance data and the infection data there as well so they can start to compare what the impact of their prescribing is having on the resistance across the whole health economy and so I think that adds value… it was really to have somewhere that people can go to and say 'Well actually we've got high levels of an infection, is that related to our prescribing and could that be related?' And to start to give them hypothesis and think about things in a slightly different way." (Policy Official)*

The same respondent added that the transparency afforded by this system allows the identification of good practice (evidenced by low prescribing and low infection rates) and learning from it. The public availability of the data provided another incentive for prescribers to reduce their prescribing rates:

> *"… So the Commissioners right down to a local level are using this data to help prescribers. So I think, you know, is a prescriber going to look at it on a daily basis or see what's changed but I think the fact that they know it's out there and that they know people are looking at it has some element of forceful effect in changing their prescribing habits." (Policy Official)*

Furthermore, the respondent felt that the Fingertips Portal provided clinicians with guidance and tools for appropriate prescribing, rather than simply telling them what to prescribe and had been used as part of stewardship interventions to reduce prescribing:

> *"... And we know that that's had some impact, for example, from the CMO letters which says you're a high prescriber and actually your data is publically available to say that you're a high prescriber is one of those things that can influence behaviour change".*

A number of respondents at national level, however, identified limitations of the current prescribing data systems. For example, the data collection process can be laborious (a similar limitation was identified by respondents in secondary care):

> *"I suppose it is a challenging workload in terms of the targets that SAPG have, so collecting some of the data sometimes can be quite challenging… almost like feeding the beast in some ways. That can be quite time consuming, quite laborious" (Director of Pharmacy at Scottish Health Board)*

Related to the limitation above, and echoing the views expressed by primary and secondary care data users, national users identified the absence of an e-prescribing system as a limitation. Another benefit to e-prescribing identified here was the ability to track patients as they moved through the different specialties in the secondary healthcare system:

> *"…So in secondary care the data that we have at the moment is starting to get down to specialty level but there are lots of problems with that in the sense that patients move specialties day by day within hospitals and therefore what we've got is this sort of, if you like, a snapshot of how much is prescribed to them by a specific specialty, not necessarily over the total patient journey." (Policy Official)*

Data accessibility was another issue. One respondent identified challenges for potential users in locating data, unless they are already very familiar with systems:

> *"For instance, if I wanted to know how often Drug A was prescribed in England, so I could see if it was worth me doing some basic research on that drug, it would not be that easy for me to find that data." (Academic Researcher)*

The next issue related to the range of data. A gap was identified in relation to private sector medical prescribing, and internet prescribing, in particular:

> *"We do have a small amount of independent sector prescribing that's collated by Quintiles IMS and they've shared that with us which is quite small. But we have no assessment of what the high street is delivering essentially. We have no assessment about what's going on in the internet… And internet prescribing as a whole and many of those it's going to be ... will be very difficult to determine because many of the providers are outside England and the UK." (Policy Official)*

A gap was also identified in relation to private prescribing by dentists, veterinarians and other non-medical prescribers:

> *"…we have systems that are designed for collecting information about prescriptions that are well defined. They're increasingly automated, so they don't require huge amounts of human input, and the data we get out of it is relatively good, it's not terribly sensitive, but we get a lot of data, and we get a good understanding of trends. But, we don't have that for dentists, we don't have that for the increasing number of non-medical prescribers, who might be prescribing privately, and we don't have that for veterinary medicine, but it feels like we could." (Pharmacist)*

> *"… One of the things that we've tried to do is look at almost like tonnage of usage of antibiotics and, again, we can see human consumption but we can't see veterinary consumption anywhere. So most veterinary prescribing is private and I don't think there's an NHS… so it will all be through private veterinary, so yeah, it is a challenge getting hold of that data." (Pharmacist)*

A third informant noted that only certain data that are currently deemed important are collected:

> *"So Public Health England, because they're cash strapped, they can only collect data on certain types of infections and certain bacteria. What that means is that you collect data on the infections that are important now caused by the bacteria that are important now. So there's no horizon scanning capacity…So if you're going to collect information, and that's what PHE are really good at doing, it shouldn't have a narrow remit, which is what it has, that "What can be afforded, we will do." It should actually be what is needed and then, "How do we fund it?" (Academic Researcher)*

The absence of an accepted definition of what "appropriate prescribing" makes it difficult to measure change:

> *"How are we actually going to measure improvements in appropriateness of prescribing? We can look at decreased prescribing, we can look at changes in patterns of resistance, but we can't actually measure appropriate prescribing. Unless somebody's come up with some novel way of doing it, but we don't have it." (Policy Official)*

Finally, the absence of a single repository where "prescribing footprint" can be found was seen as a limitation:

> *"You can look what happens in primary care in an area, you can look what happens in a hospital in the area but there's nothing that says within the [geographic region], this is the total consumption or within an STP [Sustainability and Transformation Partnership] footprint, this is the total consumption." (Consultant Pharmacist in Antimicrobials)*

In addition to the limitations above, one respondent cast doubt over whether the provision of prescribing data would make a difference to prescribing behaviour:

"… So we've done loads of things but it's just the impact that they have… It's really hard to say whether any of it makes any difference, I'm not entirely sure, if you were to ask any GP, that they would know what their prescribing is like, I don't think any of them would probably be under any illusion about what they're doing, and providing them with data. I think, currently, a lot of them will just say 'Well, that's just indicative of where we're at at the moment, we haven't got the resource to do an awful lot about it.'… Not to labour the point, but I suppose it is trying to think well we know we do, we threw all these indicators and money sometimes and information and resources to GP's, but it doesn't necessarily make a difference." (Pharmacist at Health Board)

Suggested Improvements

The two wishes consistently expressed by national users of prescribing data were electronic prescribing in secondary care and closer integration with animal health and agriculture counterparts.

Electronic prescribing was the most prominent wish expressed by national-level respondents to improve prescribing practice, for a number of reasons that are explained in the quote below:

"…electronic prescribing would allow us real time to capture prescription data and actually where that wasn't in accordance … if you had electronic prescribing … I know that within our intensive care units, we have it kind of and we were able to put a form in place before you can prescribe an antibiotic, that made you document down your indication, your intended duration, it checked, it reminded you when you had to review the antibiotic and if you were continuing it on past its recommended us, you had to document a reason why. So, all those sorts of things, it would be nice to have an electronic system to do that, that you could then go back and have an audit trail. When we're relying on pieces of paper, it becomes very piecemeal and what one person will write down won't necessarily make sense to the person coming behind them, it's not that it's not written down." (Consultant Microbiologist)

Closer integration with animal health and agriculture counterparts was another suggested improvement:

"We don't really have formal connections with veterinary, other than in certain research bits…in terms of veterinary medicine how much antimicrobial is being used, be that sales data, be that consumption geographically. Again, it's not just in livestock and animal husbandry, it's also in other aspects of agriculture. We don't get too many citrus fruits growing in [geographic location], but I'm sure there are compounds that are being used in horticulture that are similar to human antimicrobials and antifungals, in particular, that may be having an issue for us further down the line. If we could capture all of that data" (Consultant Microbiologist)

This view is in harmony with the comments made by animal health professionals (section 4.3).

4.2 Resistance/ IPC data

4.2.1 Primary Care

Views on Current Data Systems (Uses, Problems, Gaps, Benefits)

In relation to primary care, there was a concern that some of the data available on resistance and IPC (for example, the *C. difficile* database) were not being used appropriately, and therefore not contributing to new understanding or better identification of cases:

> *"…we knew the association with the Cephs, the Quins and Co-amoxiclav, we knew that, but what else was it telling us? And actually it didn't tell us anything and so we did it for another year, to see if anything changed, and again it didn't and so that was abandoned. So, for the last year, I haven't, you know, it just sits on my file but never gets used." (Community Liaison Nurse)*

One respondent noted there was a lack of compliance from certain bodies whose involvement is needed to produce good data. The following quote was in relation to GP practices:

> *"…Most of the problems that we have seen, as a widespread, a total CCG, come from [geographic area]. [Geographic area] are very precious about sharing information, I have a GP practice that absolutely, at all costs, refused to give me any information about a patient. We have a problem, a current problem with the LMC [Local Medical Committee] advising GP practices that we need patient consent before they'll share any information but I ask for anonymised information and I don't need to know anything about the patient and under Section 251, I need to know that information purely for education and patient safety because it's a disease, C. diff. is something that can be spread. But the LMC have decided that no" (Community Liaison Nurse)*

One GP reported using local sensitivity data to inform their prescribing decisions for urinary tract infections, whereas other respondents suggested that GPs would not be interested in receiving surveillance data on AMR, suggesting that this may be related to the excessive volume of information they receive:

> *"…GPs, I don't think would have any interest in [surveillance data] whatsoever, to be honest… I don't think so… Secondary care is, most definitely. They rely on it heavily. I think GPs get so inundated with information that to start giving them surveillance data, it's something that just goes straight in the bin, straight in delete, I'm afraid. It's interesting, but it's not something that's going to really change much, I don't think. They need to be told what to do. I know that's almost a nanny state or whatever, but that's what they want. They want, "This patient has this condition, this is what you give." (Pharmacist at Health Board)*

Finally, a CCG official expressed a desire to have access to resistance data, which would give a better indication of the appropriateness of prescribing (when used in conjunction with prescribing data).

Suggested Improvements

Primary care users of resistance/IPC data suggested that the provision of easily accessible and timely information was an area for improvement:

> *"…it would be nice to, if there was an easily accessible table to say, in [geographic location], or in the [trust name] in [geographic location], the majority of UTIs are … whatever, or whatever, E.coli, and the first line drugs are this, and patterns resistance are increasing in this, this and this – you would like to have something like that, that'd be very easy to use, but like the guidelines, where you can check it up online if you're interested, and maybe if it were updated, say, annually, would be brilliant; quarterly would be even better, if you could do something like that there, it'd be nice…" (General Practitioner)*

4.2.2 Secondary Care

Views on current data systems (uses, problems, gaps, benefits)

IPC data produced in hospitals are used in quality improvement audits. They are sometimes helpful in identifying links and patterns that are acted on to prevent outbreaks of infections, when the necessary resources and capabilities are available. However, one view expressed was that there is too much data available to make sense of (IPC Nurse). Three of the limitations of IPC and resistance data identified by respondents echoed similar limitations noted earlier in relation to prescribing data. These were in relation to the format in which data are presented; the opportunity cost associated with collecting these data; and the gaps that exist in the data. These limitations are detailed below.

One respondent held the view that the complexity with which the data were presented limited their use by clinicians in secondary care:

> *"… [Organisation name] do a lot of epidemiology for health boards in [geographic location], which is great, but again they send these very complex reports with, you know, all sorts of stuff on which is great for epidemiologists but I'm really not sure that your jobbing GP, junior doc, registrar, staff nurse, can make head nor tail of a load of box and whisker plots…" (Senior IPC Nurse)*

Another respondent felt that collecting data was as an inefficient use of limited resources:

> *"This is ridiculous! Why are we spending all our time doing it when, actually, we know the lessons to learn? Let's not bother doing it and focus our efforts on reducing gram negatives, or let's have a look. Why are we spending all our time on stuff that we already know?" (Lead Nurse for IPC)*

Three gaps were identified in relation to resistance/ IPC data; the first was the limited access to community laboratories (Pharmacist); the second related to generating data on compliance with universal MRSA screening; and the third related to community carriage levels. The quotes below illustrate the second and third gap (respectively):

> *"…it should be relatively simple, we have the IC Net information management system, which is fabulous, so it should be relatively simple to go, here's our MRSA screens, here's our list of admitted patients, bang the two lists together for those codes and say compliance with universal screening in that group was 80%, it seems beyond the wit of man at the moment to get that." (Senior IPC Nurse)*

> *"…my worry there is that there's just a lot of the stuff out there, very little strong data on what the community carriage rates are, and the more you look, the more you'll find. And, I mean, these are – you can't call them outbreaks in the sense of, they're carriages – the patients aren't sick. So, really, it's just, the more you look, the more you find…" (Medical Director of Trust)*

There were also doubts expressed over the accuracy of data available on Fingertips and of the comparability across hospitals that treat a different profile of patients (IPC Nurse).

Suggested Improvements

Respondents discussed several priority areas for resistance data systems in secondary care in the future.

The first was more detailed laboratory reports than are currently produced that provide information on susceptibility of microorganisms to a wider range of antibiotics, to give clinicians more freedom when deciding on the most appropriate antibiotic to prescribe:

> *"I think the labs report, like, the top three or four antibiotics, or something, and susceptible to, but not always all of them, but I know that that's to try and gauge, or to help prevent resistance, to guide people down a certain route, but sometimes it would be useful to have more of a span of antibiotics that people could potentially be prescribed, because I suppose those antibiotics don't ... Those results don't always bear in mind someone's allergies and things like that, so sometimes it's hard to navigate." (Pharmacist)*

The same respondent also asked for more Information on the prevalence of resistant microorganisms (Pharmacist), but there was no agreement over the benefit for hospital staff in receiving information on resistance and prescribing in the community:

> *"I think the problem is that there's ownership of who should be doing something about this, and we are in charge of looking after the hospital service, and so therefore, the usual things like antibiotic appropriateness, the frequency with which antibiotics are being prescribed in particular teams, and all that kind of stuff, it's not really us here in the hospital that needs to hear about this – it's the people charged with doing the job we're doing in hospital, in the community. Sending it to me is not going to affect any change in the community, is it?" (Lead Consultant Microbiologist)*

Respondents also discussed warning systems to issue alerts regarding Healthcare Associated Infections:

> *"Warning systems would be good, so that if you have ... if you're talking about colonisations of MRSA, for example, what would be the expected number in a given area, so that you know you can actually set warning limits for individual wards, that would be really good to be able to do that, so that you're not reacting to something that is, you know, oh, look, they're creeping up, they're four or five now." (IPC Nurse)*

Automating the methods of entering data into systems, to overcome the time spent currently in making submissions (IPC Nurse), and ensuring that secondary care staff are allocated sufficient time to collect data (IPC Nurse), were also significant issues.

4.2.3 National Level

A range of uses were identified for resistance data at national level. Firstly, data are used in research and this can help to raise awareness if promoted by the media:

> *"In my personal research area, we use a lot of data, particularly on genome sequencing, what we call transcriptomics, which is looking at how bacteria respond to certain environments or drug treatments or whatever...So big, big repositories that I'm able to put my data into and then use those as searchable databases." (Academic Researcher)*

The findings of research are also sometimes picked up by the media to raise awareness (Consultant in Health Protection).

Resistance data can also be used to inform policy:

> *"It's information that tells us what bugs are going around, where are the settings that you're finding most resistant strains. We know, for example, that about 30% of people going into hospital from care homes are carrying MRSA; they're colonised with MRSA. You only really know that from surveillance, and so that can inform your policy on screening in patients for MRSA and for decolonisation … that is really part of your evidence base for new interventions" (Policy Official)*

Related to the above, resistance data helps service providers/ commissioners plan services and react to emerging trends, and enables them to alert the public:

> *"…it's there for the use of healthcare professionals to try and pre-empt what's going to come in the door of casualty. So, you know in the summertime, you're going to get more food poisoning and D&V [diarrhoea and vomiting] type illnesses coming through, but also then it lets the general public know that there might be something circulating…" (Consultant Microbiologist)*

However, one view expressed by an official at Health Protection Scotland was that it was not necessarily helpful to provide the details of the sensitivities of microorganisms associated with local outbreaks to national level officials, as there is no need to act in the majority of these instances, and it would be more prudent to let the disease take its natural course than try to intervene in all local outbreaks.

Generally, it was felt that the UK was in a much stronger position with regard to data generation now in comparison with when the Strategy was launched. However, there were limitations identified with resistance/ IPC data at the national level. For example, there can be difficulty in finding data if an individual does not work in the field already (similar to a limitation identified earlier in relation to prescribing data):

> *"And it's not easy. If you just did a Google search, it wouldn't necessarily bring it up, because people might be looking for bloodstream infections, because they're … I don't know, they might be somebody who works on environment and contamination of water, but now wants to work on AMR. They wouldn't know that it's not bloodstream that it goes down as. It goes down as bacteraemia." (Academic Researcher)*

Four gaps were identified in relation to the data provided by resistance/ IPC surveillance systems. The first was related to negative test results often not being reported:

> *"…we don't know who gets samples sent so, and that's quite important because we don't know the positive predictive value of samples and we don't understand sort of who is getting tested and are the right people getting tested so, because we don't have the negative results." (Policy Official)*

Legislation and clinical guidelines partly explain why negative cases are often unreported:

> *"…there's also an issue about how that fits under our Section 251… Section 251 is legislation in the Acts of Parliament that allows us to collect patient identifiable information related to infection and Public Health purposes... Also we have the biases that are within the data that are sent to the laboratory. So we have, for example, ambiguous urine samples is a really good test of that. So we have all of the positive urines that are in the laboratory, we don't know what urines have been negative but even more we don't know what people have been treated and haven't had a urine sent. Because we know that the guidelines at the moment nationally, and in many cases internationally, recommended that the first episode of infection doesn't have a urine sent, you just treat based on empiric guidance." (Policy Official)*

The second gap was in relation to the reporting of the results of rapid diagnostic tests:

> *"…And increasingly in the era of modern analytics, we don't have any point of care testing results, the results that are done on that. And we also don't have any molecular diagnostic tests, so we don't have if people are doing rapid PCRs for example. And that again is quite important because increasingly people are tested for things like carbapenems producing bacteria by molecular methods rather than by traditional susceptibility testing." (Policy Official)*

This could suggest that the quality of surveillance systems may deteriorate in the future if they do not incorporate the results of rapid diagnostic tests, as their use increases.

The third gap was in relation to animal health surveillance:

> *"…veterinary practice is mainly delivered privately. It's all delivered privately so it's going to have some big hurdles to try and overcome. From the point of view of their resistance surveillance testing, they have resistance surveillance testing in two ways. So one they have the EU sort of mandated at abattoir surveillance testing and it allows you to look at what is in the poo of healthy animals. But it doesn't allow us to determine what's in the general environment of farms because any of the sick animals don't go to the abattoir." (Policy Official)*

This was seen as the reverse of the gap that exists in relation to human health, where surveillance provided more information on patients exhibiting symptoms rather than the public.

The fourth and final gap was in relation to the reporting of vaccinations (other than flu vaccinations) and sepsis data integrated alongside other indicators in England (Consultant Pharmacist in Antimicrobials).

Variations in lab-based systems in Northern Ireland caused differences in test protocols and results:

> *"systems that we're working with were built ... I don't know exactly how many years ago, but a long time ago, so they're based on whatever the technology was at that time. And within Northern Ireland, we have five Trusts, and four of them work through one lab system and the other works through another, the largest one is a different provider. So already, with the different providers, we've had different set-ups for recording of the laboratory tests and so what that means is that, basically, within each lab they'll have different ways of coding the different bugs… And the diversity in terms of that was shocking and that's for something that we would regard as quite standard, so all of the labs, their coding is very different in how they record the organism. And then beyond that, obviously, with the resistance aspect, we are interested in the antibiotic susceptibility information and within that, there has been quite a lot of work done around standardising the test, the first-line testing panels. But there's still quite a bit of diversity there, they have their own local freedom to decide what they're going to test in second-line panels and stuff, which means that the antibiotics that are actually tested aren't completely standardised across the labs." (Public Health Official)*

Confidentiality was raised as a challenge when reporting small number of cases without breaching the relevant data protection acts:

> *"They [PHE]'re struggling with this whole risk assessment because when you get down to the level of resistance, you can be reporting small numbers and then that's a risk of disclosure for the individual." (Public Health Official)*

Current laboratory information management (LIM) systems limit the range of data that can be provided by the surveillance system:

> *"…we are restricted to electronically reporting only 12 antimicrobials and that's per sample, not per bug. So, if we've a swab of an ulcer and there's 4 bacteria in it, you might only be able to report three antibiotics on each and that means when you're coming back with the surveillance programme, because the surveillance programme reads the data from the LIM system, that it's only as good as the data that's going in" (Consultant Microbiologist)*

Suggested Improvements

Respondents identified four main areas for improvement for the national level resistance/ IPC data. Firstly, there is a need for provision of a central "hub" for data:

> *"…So I would like to see the UK website where everything on AMR is gathered. So it doesn't matter whether we're talking about data that is collected by Public Health England or whether it's data that the MRC might have on their cross-funder call or the projects they've got." (Academic Researcher)*

Another informant identified a benefit to collecting data in one place, which is to enable data analysis that would not be possible otherwise, acknowledging that this might not be permitted due to research and data governance issues:

> *"I would love if all of our laboratory data was just sucked into one great big data warehouse and we could mine it as much as we wanted. I realise there are information governance rules around that, but it's not really something that I can … to me, the means justify the end on that." (Consultant Microbiologist)*

Secondly, both positive and negative cases should be reported to surveillance teams, to give a more complete picture:

> *"I suppose, in an ideal world, I think to fully understand everything, like I think we would be wanting to have the total number of tests, possibly positives and negatives, so at the minute we're only getting the positives through." (Public Health Official)*

Another informant also identified the need for e-prescribing and sentinel surveillance programmes:

> *"…So if I'd like to be where I would see us getting to, I'd like electronic prescribing data on everyone, I'd like sentinel programmes for key drug bugs that I think are going to be a problem in the future and I'd like us to be able to collect both point of care tests that were being delivered in primary care, secondary care or molecular testing in secondary care..." (Policy Official)*

Thirdly, there is need to obtain a better understanding of AMR in the environment, as part of a "One Health" Approach:

> *"…In [geographic location], we don't have a lot of carbapenemase producers or at least we haven't detected a lot of carbapenemase producers, but we don't know what's sitting out in the community and it would be nice to get surveillance cultures. That's where One Health can come in. Is it worthwhile going down the lines of sampling sewage and things like that to look for the things that are coming up from human health, because we don't know what's out there? (Consultant Microbiologist)*

Finally, it was suggested that the development of "intelligent systems" could help guide prescribers and introduce variation to prescribing patterns:

> *"…In an intelligent system and there is bits of work going on round the country trying to set something up, you would have a guideline development system built around personalised resistance where you have data to say Mrs Bloggs comes in and she's got a UTI. You want to treat her and the system will say she's had these antibiotics before, this has been the resistance patterns, it would randomly generate an antibiotic. That would be the preferred process so it gets diversity built into the system." (Consultant Pharmacist in Antimicrobials)*

4.3 Animal Health Data

Accurate data on the use of antibiotics in the veterinary sector was seen by respondents as crucial for the successful implementation of the Strategy and understanding of the risk pathways in AMR, whereas linking the usage of critical antibiotics with AMR surveillance data would help in establishing the success of interventions. An example was cited from Canada, where surveillance data have indicated a reduction in AMR incidence in target species two years after reducing use. The usage data currently collected in the UK could enable the measurement of the reduction in use of antimicrobials, but not AMR incidence (Food Standards Agency Official).

Respondents provided examples of sharing surveillance data across agencies during outbreaks:

> *"…when the MCR-1 gene issue arose, we were getting data through from EFSA on the surveillance information they had on Colistin. So yes, basically we're really utilising all of that data that's coming through and making really good use of it". (European Medicines Agency Official)*

The large geographic coverage of AMR surveillance in the UK, and the consistent methodology used, was seen as providing critical understanding of AMR in the veterinary sector (Defra Official). However, it was also felt that it will require considerable time (estimated by the respondent to be about ten years) to start to understand the trends in AMR in relation to animal health, partly because data on species are collected on alternate years.

One respondent felt that surveillance of antimicrobial agents in the food chain in the UK is extensive. However, they also identified variations in the different food sectors, with surveillance of milk products being very high, whereas surveillance of the meat industry is not as sensitive (British Veterinary Association Official). There is also currently little surveillance of AMR in commensals and pathogens in food. This is being addressed for campylobacters in chicken, salmonellas in pork, and AMR in commensals in both, which will be the first step of integrating food surveillance with human and animal health surveillance (Food Standards Agency Official).

The main criticism of the current UK-AMR surveillance systems for animal health was the lack of alignment with human health surveillance systems. This was expressed in several forms, identified below:

- The indicators used in human and animal health surveillance need to be better harmonised, with a perceived reluctance from the human side to achieve such harmonisation (Defra Official). One view was that this needs to extend beyond the UK to harmonising with systems in the EU (Defra Official).
- The One Health Report published in 2015 was not seen as truly "One Health" in scope, since it only focused on human and animal health data. There are plans to release a second One Health Report that will include data on food from the FSA as well as some preliminary environmental data (Defra Official). The nature of these data was not specified by the respondent.
- In line with what is available in nations with more advanced surveillance systems (for example the Netherlands). This integration should extend to surveillance of AMR in food, and needs to use the same drug-bug combinations in human, animal and food surveillance systems where possible (Food Standards Agency Official).

In addition to the need for harmonising across human, animal and environmental sectors, respondents reported great variation in the availability of data on prescribing in different animal species:

> *"…There's very little data on cattle and sheep in particular. So, whilst poultry is very integrated, it's much easier for them, and they've done an amazing job; pigs are now much better organisation, because AHDB, the levy body, they've come up with the Electronic Medicine Book, and they're doing a great deal with pigs, so pigs is now quite well-organised. Cattle and sheep, there's no data; dairy, there's no data to speak of. There's bits of data here and there…" (RUMA Official)*

This absence of accurate data was perceived to make it harder to work towards, or adhere to, national targets:

> *"…when it comes to national strategy and where we've got to so far, I was very uncomfortable with 50 milligrams, because I had no data on which to base 50 milligrams on…whether I was at 100 or whether I was at five. I had no idea…" (Veterinary Health Official in Northern Ireland)*

The fact that most antimicrobial utilisation data are based on sales figures rather than use (or prescribing data) was also seen as a complicating factor:

> *"…if we look at the VARSS report, it breaks down sales, this is very important, this is sales figures not usage, because sales is very accurately recorded, usage is not so accurately recorded. And, of course, with sales, the problem is, we don't always know what species it's in, it depends on the licence of the drug and then, of course, it could be used off-licence in other species." (British Veterinary Association Official)*

Furthermore, sales data are often grouped together for different species, for example pigs and poultry, but this is starting to change with the poultry sector now collecting their own data on prescribing (Defra Official).

Respondents gave several examples of the role that technology can play in assisting in AMR surveillance. One suggestion was to use existing digital structure such as the "electronic medicine book" website, in conjunction with new barcode scanning technology available on farms, to make the process of collecting usage data easier and more accurate (RUMA Official).

Another potential role for technology would be harnessing genome sequencing to gain a better understanding of the linkage between the different sectors. This can be established by bringing together experts into one forum, for example in a conference setting (Food Standards Agency Official).

4.4 Interface Issues

4.4.1 Primary and Secondary Care

Respondents made two suggestions on how the interaction between primary and secondary care data systems could be improved, with the ultimate aim of controlling AMR, mostly through antimicrobial stewardship. The first suggestion was that linking prescriptions in secondary care to general practices where the patient is registered would help in this process (this occurs in Northern Ireland where all out-of-hours secondary care prescribing is assigned to the GP practice where the patient is registered):

> *"We don't have any data at the moment that captures which GP the patient ultimately [is registered with] so when you come to a minor injuries unit, you may have been to see your GP already who's probably said I don't think you need antibiotics this time and if the patient knows they have minor injuries, they might get some there. How do you link that back? And we have no idea easily about what happens to patients who turn up to hospitals and who are seen in an outpatient environment." (Consultant Pharmacist in AMR)*

However, they also stated that in order for primary and secondary care to be able to work together, we need to measure the total "footprint" of our prescribing, and make information on prescribing levels in primary care available to pharmacists in secondary care (Pharmacist).

In one of the case studies, the change in the nature of relationship between primary and secondary care surveillance bodies had had a negative impact on the interaction between the two:

> *"… There's been a change in overall emphasis, I think, in the relationship between ourselves and our community colleagues. When I started work here a long time ago, we were basically colleagues, and there was a CCDC [Consultant in Communicable Disease Control], and very close interaction between his team and our team…That has disappeared, and it's been replaced by a centralised public health agency, that seems to have become our supervisors and auditors, rather than colleagues" (Consultant Microbiologist)*

4.4.2 Local and National Levels

One respondent identified a trust gap that exists between health professionals who are tasked with collecting data, and those bodies that will ultimately use the data in their performance management exercises. They felt that prescribers in primary and secondary care needed to receive assurances that the data they helped collect would not be used against them:

> *"…data is great for improvement, but we very rarely use it for improvement, we use it for performance management. And, quite rightly, people will be sceptical about, you know, picking the stick with which you're then going to come back and beat them with… So, I think that's something that would, in my mind, would really benefit from a national perspective, is a UK wide agreement between the representatives of prescribers, so whether that's GPs, whether it's non-medical prescribers, or whether it's consultants and doctors in secondary care, around the collection of data, the use of existing data. And then, a commitment, on the part of commissioners, Government,*

purchasers of healthcare, as to how they were going to use that, would be really beneficial." (Chief Pharmaceutical Officer)

4.4.3 Four Nations

Comments were made in relation to the interactions, relationships and differences that exist between the four nations in the UK. Principally, and as noted in Section 3 of this report, respondents discussed differences in how data are collected:

> *"…there's a lot of variability in terms of what we actually see and they also authorise what comes through to us, so it's a bit different to what goes on in England, in PHE, in terms of how they get their surveillance data." (Public Health Official)*

Related to the above, the same respondent identified the need for better alignment across the four countries:

> *"I think having a goal then that all the devolved administrations can at least deliver a bare minimum so that that accounts for the variability in terms of processes and stuff. And I think having definitions would also be really good, that could be shared"*

In the case of Northern Ireland, there is a further need to align with the Republic of Ireland:

> *"…our surveillance is always very much linked into the overall UK approach to surveillance, and I think the Republic of Ireland do things a little bit differently. They have their own systems, and they've built their own surveillance systems and software and whatever; they use a completely different system to us. They also have … different organisms under surveillance; they have different list of notifiable diseases. So one of the … I think we need to align our programmes with the Republic of Ireland, just as much as we do with the rest of the UK…we should be doing more work collaboratively" (Policy Official)*

Some also commented on differences in quality. A respondent in Wales felt that prescribing indicators were more developed in England and Scotland than in Wales, and identified possible reasons behind this difference:

> *"…the national prescribing indicators, very highly developed in Scotland, very badly developed in Wales. They almost don't exist here… there's nothing…There is very little of that kind of data available in Wales, which means for primary care prescribing there is very little that we can pull out. And, that data that does exist, most of it we don't have access to, we're not allowed to access it, because of Caldicott, because of other issues. So, there's not a lot I can do with prescribing data, I can't feed back to individual practices, to GP clusters, their prescribing compared to other clusters, based upon various …" (Lead Antimicrobial Pharmacist)*

However, another respondent from Scotland felt that the level of detail available in Scotland was not the same as in England:

"so in NHS England you have the Fingertips so you can … everybody can drill down to sort of GP practice level and see how they are compared to the … you know, the average or the next door's GP practice and you can do that with some outcomes as well. I think Scotland has fallen behind a little bit…" (Infectious Diseases Consultant)

There was also a concern in Wales that they were lagging behind England in relation to data systems and e-prescribing:

"My concern going forward is that Wales continues to be left behind compared to England where the majority in our hospitals do have an electronic prescribing and a modern hospital pharmacy system. And I can foresee that we are going to be left further behind." (Pharmacist)

It was noted that smaller geographic areas makes it easier to collect data:

"…I think in Northern Ireland, that's another way we're different to England in that we do capture everything pretty well, because we're smaller and we only have five labs to deal with, so I think it's easier for us to make sure that it's accurate and that we're capturing everything, even if it's not mandatory." (Public Health Official)

However, the correspondingly smaller size administrative bodies in the Devolved Administrations meant that they did not have access to the same level of expertise and resources that is available in England:

"We have a very broad role and it's hard to get the sub-specialist knowledge and experience that someone who's working as a genuine specialist gets because you have to be able to do most of the stuff that a general health protection unit does plus stand in for the expert team that PHE might have." (Public Health Consultant)

4.4.4 Prescribing Levels / Resistance Interface

A number of respondents expressed a desire for providing prescribing and resistance data in the same location. One suggested this would enable local guidelines to be tailored based on local resistance:

"…the data probably everywhere is the same, it doesn't join up terribly well…so one of the things we thought is that you can try and really marry-up prescribing [and] resistance rates and try and amend guidelines to reflect that..." (Pharmacist at Health Board)

Another respondent gave an example of using resistance data to influence prescribing decisions:

"Probably, one example where perhaps we are using data on resistance patterns to alter our approach, would be urinary tract infections. So, we know the resistance data is telling us that older patients, with uncomplicated UTIs, are highly likely to have resistance to trimethoprim, but trimethoprim is the mainstay of our treatment. So, we have an approach that says our second line treatment will be something else…" (Pharmacist)

5 Summary and Discussion

This report set out to map the availability and quality of data systems in the UK that monitor antimicrobial use by health professionals and antimicrobial resistance levels. It also aimed to explore the views of the users of data at the various levels of the human health system, and to explore how well the data systems met the needs of users of the data at local and national levels. This section will summarise the key findings that have emerged to date, and discuss some of their implications.

Data Systems and Availability

An analysis of the data systems in place across the UK related tor AMR highlights three issues. The first of these is that there is significant variation between the four UK nations.

Systems are furthest developed in England, primarily through the work done by PHE in creating the *Fingertips* portal and publication of the ESPAUR report. Other countries are at different stages of development. Scotland's IIP is advanced and has been demonstrably useful [3]. However, its system appears to currently be awaiting development and access remains limited. Wales and Northern Ireland have plans to develop accessible data portals, though they are not yet sufficiently developed to be in use.

Policy officials in each country identified strengths and weaknesses in their data collection systems so there may be benefits in them working more closely to share learning and experiences. This would help avoid duplication of effort and allow the most effective use of limited resources.

Another important issue to recognise is the complexity of data systems. The full extent of data collection systems relating to AMR is highly complex, necessitating extensive work to even map and describe systems in place. This complexity has arisen for two reasons. Firstly, AMR is a complex phenomenon involving many drug-bug combinations, presenting varying threat levels. It requires an understanding that resistance is not binary but must be understood through long-term trends and pattern recognition. In addition, locally managed healthcare organisations differ with respect to their data needs. Combining animal and human data adds a further layer of complexity.

Secondly, the development of data systems has been incremental and evolutionary. Some of the complexity has resulted from building on existing infrastructure, managing IT limitations, and ensuring public and professional engagement, factors which vary according to the history of systems in the different devolved administrations. The emphasis on improving data in the current UK AMR Strategy appears to have led to significant progress over the last five years. Certainly, the Strategy has been invoked to justify major initiatives, such as progress on the Scottish IIP and England's *Fingertips* AMR local indicators. Plans in Northern Ireland and Wales are at different stages, but working towards the same long-term objectives.

Finally, our investigation of animal health antimicrobial utilisation and resistance data revealed inconsistencies in the coverage across the various sectors (echoed during our interviews), with potential biases in reporting resulting from the voluntary nature of submissions, and the lack of incentives for some farmers to submit their data. The use of sales rather than consumption data is another potential source of bias. The different methodologies used in the four nations for coding and aggregating data limits the generalisability of the data.

The animal health experts we interviewed expressed a desire for better harmonisation of human and animal health data, the inclusion of environmental data in One Health reports as well as the use of consistent definitions for drug-bug combinations across the systems, whilst acknowledging that this may not always be possible.

Views of data users

Users of data at all levels (primary, secondary and national) identified several uses for, and benefits of, collecting data on prescribing of antimicrobials and resistance levels. However, some respondents were sceptical about the benefits, for reasons that relate to the data (and the way they are presented) and the overall system in which clinicians operate.

First, serious gaps were identified in the data, in particular, the availability of data on private healthcare practice, some non-medical prescribing, internet prescribing and prescribing in special settings, especially, care homes.

Second, many informants identified a gap in the information available on prescribing in secondary care where electronic prescribing had not yet been implemented in all Trusts. However, whilst investing in e-prescribing in secondary care is expected to improve the quality and ease of accessing data on prescribing, and may aid antimicrobial stewardship initiatives, implementation of e-prescribing systems can be problematic and costly. A survey conducted in 2017 suggested that 58% of Trusts in England did not have an advanced e-prescribing system in place [32]. The scientific evidence for the benefits of e-prescribing is limited but a recent review looking at the wider impact in secondary care in the UK concluded that these systems overall resulted in improved patient safety [33]. An important factor in this relates to whether electronic prescribing operates as a stand-alone system, or a modular system integrated with other aspects of care. Although the latter can be more convenient for users, interfacing with external systems can be more challenging [34] and may reduce the reliability of national data submissions described in this report.

Third, there is need for an agreed definition of “appropriate prescribing” in relation to the use of antibiotics. Whilst this was highlighted by more than one respondent, ensuring that clinicians follow guidelines on appropriate prescribing is not a straightforward process [17] and may lead to clinicians feeling that they are being “micro-managed”. Careful benchmarking between comparable services (if available) might overcome any scepticism or opposition.

Finally, looking across the two strands of this element in the wider evaluation of the AMR Strategy’s implementation, it is evident that there is a mismatch between the data available and the awareness of these data among healthcare providers. For example, the users of data in primary care were not generally aware of platforms such as Fingertips or PrescQIPP and the data available in them. This could partially be explained by the fast pace at which these systems (especially the *Fingertips* Portal) are developing. There is a need to raise awareness of the data systems and outputs available to stakeholders, which could be achieved through better cascading of information and reports to potential users.

6 Policy Implications

Findings from this report lead us to identify the following policy implications:

1) **Identify opportunities for closer working**
   As the data collection systems in the four nations of the UK have different strengths and weaknesses, and are at different stages of development, it is appropriate to explore opportunities for closer working. This may avoid duplication of effort and allow the most effective use of limited resources. Closer working also includes exploring the possibility of developing standard definitions for surveillance across human and animal health, to facilitate the process of harmonisation across the two sectors.

2) **Quantify prescribing that is not captured by existing data collection systems**
   It is necessary to understand the scale of prescribing in settings where we do not have routine data collection systems in place. This includes private health care settings where the number of prescriptions is not known. There are difficulties associated with accessing commercially sensitive data so it will be necessary to collaborate with the private health sector to identify methods of quantifying the extent of prescribing. It is important to establish the extent and nature of antibiotic prescribing in these sectors not currently covered by existing data collection systems. This would inform decisions on whether more robust data collection systems should be implemented or not.

3) **Support and educate practitioners on available data systems**
   As the findings suggest that some practitioners are not aware of what data are available, further efforts need to be made to raise awareness of data availability and their potential value, and to ensure that data systems are easily accessible. Additionally, any skills gap at local level in how to use data that are currently available needs to be identified and addressed, requiring an exploration of methods to improve support, and education relating to AMR data systems.

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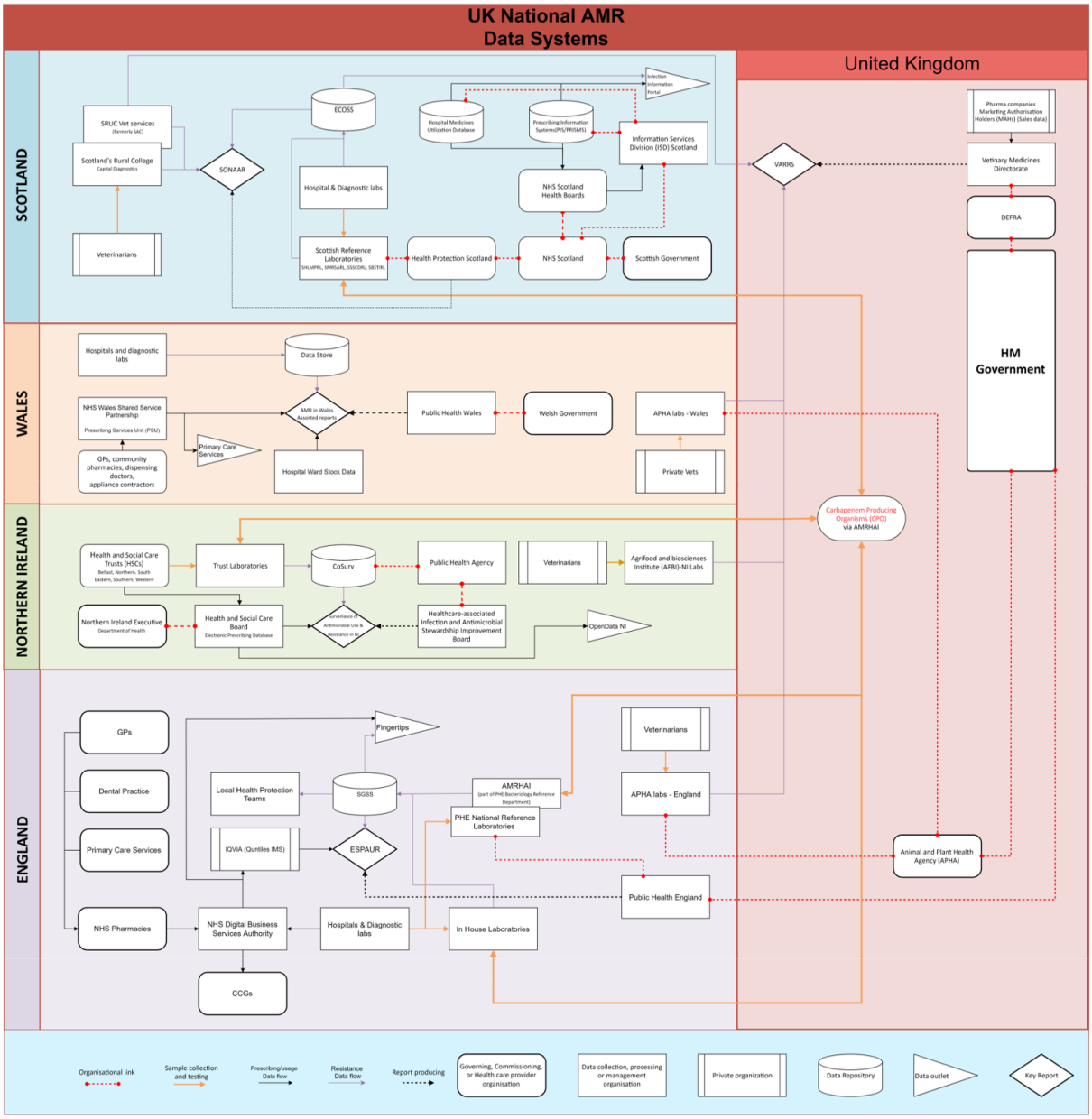
8 Appendix

Result of mapping data systems across the UK



NB. This diagram was developed as an analytic tool to aid the mapping process of AMR data systems across the UK.

It does not offer an exhaustive account of all organisations and bespoke software systems that access and analyse different aspects of the data, and significant sections are simplified for clarity.

The diagram should be considered illustrative and not authoritative.