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Building a national Infection Intelligence Platform to improve antimicrobial stewardship and drive better patient outcomes – the Scottish Experience.

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Synopsis

Background: The better use of new and emerging data streams to understand the epidemiology of infectious disease and to inform and evaluate antimicrobial stewardship improvement programmes is paramount in the global fight against antimicrobial resistance.

Objectives: To create a national informatics platform that synergises the wealth of disjointed, infection-related health data, building intelligence capability that allows rapid enquiry, generation of new knowledge and feedback to clinicians and policy makers.

Methods: A multi-stakeholder community, led by the Scottish Antimicrobial Prescribing Group, secured government funding to deliver a national program of work centred on three key aspects: technical platform development with record linkage capability across multiple datasets; a proportionate governance approach to enhance responsiveness; generation of new evidence to guide clinical practice.

Results: The National Health Service Scotland Infection Intelligence Platform (IIP) is now hosted within the national health data repository to assure resilience and sustainability. New technical solutions include simplified “data views” of complex, linked datasets and embedded statistical programmes to enhance capability. These developments have enabled responsiveness, flexibility and robustness in conducting population-based studies including a focus on intended and unintended effects of antimicrobial stewardship interventions and quantification of infection risk factors and clinical outcomes.

Conclusion: We have completed the build and test phase of IIP, overcoming the technical and governance challenges and produced new capability in infection informatics, generating new evidence for improved clinical practice. This provides a foundation for expansion and opportunity for global collaborations.

Introduction

Health systems are generating increasing volumes of routine clinical data as individuals interact with healthcare services. Strategies for surveillance of Antimicrobial resistance (AMR) and to address emergent problems, requires intelligent use of these new and emerging data streams to augment understanding of

the epidemiology of infectious disease nationally, and contribute to the global public health effort against the threat of AMR.[1-3]

In the UK, the AMR Strategy (2013-2018) defined as a key action, *better access to and use of surveillance data,* and recognised that current information on the impact of antimicrobial use on patient outcome and development of resistance was limited.[4] In response the Scottish Antimicrobial Management of Resistance Action Plan called for development of a National Health Service (NHS) Scotland Infection Intelligence Platform (IIP) recognising the importance of informatics to empower clinicians and healthcare systems to measure the intended and unintended consequences of interventions to prevent and treat infections.[5] The IIP is 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.[6] Underpinning this was our aim to create a more collegiate community of infection control and stewardship clinicians, supported by IIP, to deliver better informed clinical decisions, guide national policy and contribute to the global AMR effort. In this paper we describe our early experiences and results in developing the IIP.

Methods

The AMR policy frameworks provided the stimulus and environment to build a broad coalition of clinicians and national stakeholders to co-create the vision for IIP – *to improve patient outcomes and reduce harm from infection through innovative data integration to support clinicians within the NHS in Scotland*. Led by the Scottish Antimicrobial Prescribing Group (SAPG) and supported by NHS National Services Scotland (NSS), stakeholders from policy, clinical practice and academia produced a proposal describing the benefits of, and target deliverables from, the creation of a

national infection informatics resource. Initial funding was secured from Scottish Government for the initial IIP program from 2013 to 2017. The programme focused on three areas:

- Technical platform development to enable linking of varied NHS datasets to enhance surveillance capability, analysis and responsiveness
- Implementation of proportionate information governance best practices to enable efficient, agile response to important clinical questions
- Generation of new evidence for improved clinical practice through clinical exemplar studies using the IIP

Record linkage capability was core to the IIP development. In NHS Scotland all individuals have a unique patient identifier - the Community Health Index (CHI) number – which enables records for the same patient to be linked across multiple health records data, capturing a patient's pathway through the healthcare system.[7] NHS NSS hosts a range of national health datasets which was the initial focus for IIP. On review, these datasets contained a wealth of information applicable to infection but these were poorly connected and underused by the diverse clinical communities who could benefit from better integration. Supported by a clinical user community prioritisation exercise eight datasets were initially selected for inclusion within the IIP (table1).

Data access is controlled through NSS Information Governance Procedures ensuring NSS analysts can only access IIP data views for which they have underlying dataset approval. In addition, generic ethics and privacy approval for the conduct of linkage studies under the programme was secured with documentation of analyses for audit purposes.

Results

The IIP is hosted within the NSS Corporate Data Warehouse (CDW), the central repository for national datasets, connected by a standardised set of common dimensions. IIP technical developments enabled the creation of virtual "simplified views" of each IIP dataset e.g. the SMR01 view joins over 36 tables in a flat-like structure to expose 50 variables which meet the majority of infection analysis requirements. Analysts run queries across these views within the IIP statistical platform. Further functionality includes a cohort solution enabling definition and extraction of patient cohorts from across datasets, storable for repeated use.[8]

The main benefits arising from the IIP technical build have been: improved data security and reduced errors with fewer data extracts (reducing human errors in multiple file extraction and subsequent linkage) as statistical packages process data directly in the CDW; better flexibility in running repeated linkages and refreshing reporting for common queries; and capability to retain and share analysis programing scripts, backed up within the IIP.

The key deliverable beyond creating the platform and assuring robust governance was the completion of data linkage studies, pertinent to the clinical community, to test the agility and robustness of the IIP to inform national policy and antimicrobial prescribing practice. This has been delivered through a series of studies under two broad themes: *intended and unintended effects of antimicrobial stewardship and infection management intervention; and infection risk factors and clinical outcomes,* Table 2 summarises key studies which provide: reassurance to the clinical community as we seek to safely reduce antimicrobial use; national quantification of clinical outcomes following a healthcare associated infection (HAI), and; application of data at scale to identify and quantify risks associated with infection to inform development of patient centred clinical decision tools. This evidence is shared with

the clinical community through SAPG, the IIP website, regular newsletters and publication/presentation at international meetings (Table 2).[6]

Platform development and evidence generation has been underpinned by two components: a skills development programme for analytical and statistical staff supported through a joint academic-NHS network to build capability and capacity in infection informatics, and a clinical engagement and communication strategy to build awareness and knowledge of the IIP potential in supporting infection management and control.

Discussion

In Scotland taking a national perspective to infection informatics was logical given: the population size (approximately 5.3 million); a national, clinically led approach to antimicrobial stewardship and infection control, and our capability to capture comprehensive healthcare activity for all citizens. IIP sought to build on earlier Scottish experiences gained in diabetes through the Scottish Care Information – Diabetes Collaboration [SCI-DC],[9] a national collaboration which has successfully supported this community in providing and improving patient care, screening services and data for improvement.[10]

Previously, Scottish infection publications mainly involved small scale studies[11,12] working with local NHS Health Board datasets but the infection community wished to maximise use of existing data to replicate such studies nationally. This desire, coupled with the evolving national and international health policy frameworks, recognising the role of health informatics, provided the environment to articulate the benefits of investing in a national IIP which has enabled:

- Better identification of the intrinsic and extrinsic risk factors for, and outcomes from, infection
- Better clinical decision making through enhanced intelligence on best practice
- More rapid, effective identification of unintended consequences of antimicrobial misuse
- Improved measurement of health intervention impact on patient outcomes
- Enhanced evidence base to inform policy

Central to our success has been clinical engagement and designated, resourced, clinical leadership as a component of the program. This leadership has ensured that IIP aligned with clinical priorities and had a clear translational pathway to impact. Evidence generation from the exemplar studies is already shaping clinical practice (table 2). Moving forward clinicians' expectations of IIP intelligence are twofold: incorporation into clinical decision tools available at the point of care to inform management of individual patient episodes, and timely tailored information resources, well visualised and clinically meaningful, to drive quality improvement.

Future expansion of the range of datasets available through the IIP must address the current absence of both national patient level hospital prescribing data and laboratory data, beyond microbiology. Both these gaps are recognised in our eHealth and informatics strategies for Scotland.[13,14] A plan for rollout of Hospital Electronic Prescribing has been secured and the challenge of laboratory datasets is acknowledged as a priority for action. More collegiate working across NHS, academia and industry should be part of future solutions to enable more rapid innovation in data collation and analytics to improve health outcomes. Such an approach will also enable efficient utilisation of expanding data streams being

generated through technology advancements, including next generation sequencing, diagnostics and behavioural risk factors.

Encouragingly, we are not alone in the effort to build better intelligence and utilise routine data and record linkage to improve infectious disease surveillance.[2,15,20] Like others we have found generation and use of indicators (AMR, antimicrobial use) at a population/geographical level, accessible to all stakeholders, is a strong foundation to identify an agenda for patient level analysis and a move towards point-of-care clinical decision support tools. Our "build and test phase" has identified a number of key enablers, potentially transferable to other health care systems: government/policy support; unique patient identifier; strong clinical engagement and leadership; collaborative academic research; and technological "know how" with proportionate information governance. We are part way along our IIP journey and have begun to increase our responsiveness to address important clinical questions that could be answered through a data linkage approach. We hope our shared experience will inform and encourage others to embark upon this journey and catalyse opportunities for global collaboration.

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Transparency declaration

None of the authors have any conflict of interest in relation to this work.

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Table 1: Datasets in NHS Scotland Infection Intelligence Platform

Note: NSS monitor data submissions in terms of completeness and quality through the Data Monitoring and Support Service and advise data users of any quality/completeness issues impacting on the use of data

Name	Description	Update Frequency	Earliest data	Total number of records
Prescribing Information System (PIS)	Individual patient level data relating to community prescriptions written and dispensed within Scotland.	Monthly	2009	~1.2 billion
Hospital Medicines Utilisation Database (HMUD)	Non-patient level data sourced from hospital pharmacy stock control systems in Scotland containing information on aggregate issues of medicines to clinical areas.	Monthly	2009	~91 million
Acute Scottish Morbidity Record (SMR01) data	Individual patient level acute inpatient and day case activity data.	Monthly	1997	~91 million
Mental health (SMR04) data	Individual patient level mental health hospital activity data.	Monthly	1997	~1 million
Maternity (SMR02) data	Individual patient level maternity units/hospital discharge data.	Monthly	1981	~4.5 million
Deaths (SMR99) data	Individual patient level death registrations data from the National Records of Scotland	Monthly	1980	~2.1 million
Scottish Surgical Site Infection Reporting System (SSIRS)	Individual patient level surgical site infection data. Caesarean section and hip arthroplasty are the two mandatory procedures required for SSI surveillance.	Quarterly	2002	242,000
Electronic Communication of Surveillance in Scotland (ECOSS)	Individual patient level data on key (e.g. bacteraemia) positive microbiology laboratory specimen results and a subset of antimicrobial susceptibility/resistance data sourced from diagnostic microbiology laboratories within NHS Boards and national reference laboratories.	Monthly	2007	~29 million

Table 2- Examples of key IIP studies (more information available at *http://www.isdscotland.org/Health-Topics/Health-and-Social-Community-Care/Infection-Intelligence-Platform/Study-Outputs*)

Study Topic	Rationale	Key Results	Impact on clinical practice
Measuring potential unintended consequences of reducing community antimicrobial prescribing[16]	Safely reducing antimicrobial use is a priority to minimise development of AMR but clinicians are concerned that initiatives to reduce antimicrobial use could result in patients with serious infections not receiving treatment.	The proportion of the Scottish population overall exposed to at least one antimicrobial in primary care, any time within the year, decreased by 1.6% from 32.2% in 2011 to 30.6% in 2014. Whereas antimicrobial use in the 30 days prior to admission for study patients increased by 1.9% over the study period, from 62.8% to 64.7%.	These findings have been disseminated thorough national and local networks (SAPG, NHS Boards, IIP newsletter) to reassure clinicians that reductions in antimicrobial prescribing can be achieved without adversely impacting on patients who do require antimicrobials for respiratory infections. This analysis will be repeated on a regular basis to continue to reassure clinicians or allow early identification of any emerging unintended harm.
Risk factors for antimicrobial resistance in community urine isolates[17]	Urinary tract infections (UTI) are commonly encountered in primary care. Treatment is usually empiric but there are concerns about increasing resistance to these treatments in pathogens causing UTI.	Analysis of 40984 community urine isolates 2012-2015 showed older age, increasing co-morbidity, care home residence and antimicrobial use were associated with resistance and multi-drug resistance. Cumulative antimicrobial exposure in the six months preceding the isolate had a dose-response effect. Those prescribed ≥29 defined daily doses (DDD) of antimicrobial were 5.53 (95%CI 4.98-6.14) times more likely to have a multi-resistant pathogen.	These data have been disseminated through national and local networks. The output is now being used to design and test a clinical decision support tool which will enable clinicians to identify patients, at the point of prescribing, who are at higher risk of resistance in pathogens causing suspected UTI and thereby optimise initial antimicrobial treatment.
Changes in HAI outcome over time[18]	Surveillance of *Clostridium difficile* infection (CDI) in Scotland monitors trends in the number of new cases; however, there is no mortality information. This study examined mortality trends of CDI and established risk factors associated with death	There was a decrease in all-cause mortality within 30 days of diagnosis of CDI between 2009 and 2013 with a year on year decrease in case-fatality. Older patients, those with a greater number of illnesses, and certain specific conditions such as lung, liver and malignancy were also associated with increased mortality.	Further work focused on identifying those factors associated with increased survival will support quality improvement initiatives to enhance the clinical care of patients with CDI and assure better clinical outcomes.
Association between antimicrobial exposure and HAI risk[19]	The contribution of any antimicrobial, but particularly broad spectrum antimicrobials such as cephalosporins, fluoroquinolones, co-amoxiclav and clindamycin is known to be associated with a higher risk of CDI but the temporal and cumulative association between community use of antimicrobials and community acquired CDI was not well described.	Exposure to any antimicrobial but especially high risk broad spectrum antimicrobials in the previous six months increased the odds of CA-CDI. Individuals with ≥29 DDD of high risk antimicrobial had an odds ratio of 17.9 (95% CI 7.6-42.2) compared to no antimicrobials. The elevated risk following high risk antimicrobials was still present 4-6 months after treatment (OR=2.6 (1.7-3.9)	These findings have been disseminated thorough national and local networks, presented internationally and now published. These data are now being used to generate risk models to create a decision support tool, ready for testing in primary care in 2018. The outcome will be better assessment of the benefit and risk of treatment with any specific antimicrobials.