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The HOTspots Digital Surveillance: Conceptualisation to Clinical Deployment

Teresa M WOZNIAK [a,1], Elizabeth COOPER [a], Majella G MURPHY [a], Anthony NGUYEN [a], David CONLAN [a], Vanessa SMALLBON [a] and Jingjing SHI [a]
[a] *Australian e-Health Research Centre CSIRO, Brisbane, Queensland, Australia.*

ORCiD ID: Teresa M Wozniak https://orcid.org/0000-0003-3182-8348, Elizabeth Cooper https://orcid.org/0000-0002-4219-9447, Majella G Murphy https://orcid.org/0000-0002-0348-4827 , Anthony Nguyen https://orcid.org/0000-0002-6215-6954, David Conlan https://orcid.org/0009-0005-9593-4619, Vanessa Smallbon https://orcid.org/0000-0002-8183-0916 , Jingjing Shi https://orcid.org/0009-0004-8250-3492

Abstract. The HOTspots digital surveillance platform (HOTspots) is a critical technology of the HOTspots Surveillance and Response Program. It provides timely point-of-care access to pathology and demographic data from previously underserved regions. Co-designed with clinicians, epidemiologists, and health policy makers, the platform provides the evidence-base to empower efficient clinical management of patients with antimicrobial resistant (AMR) infections and supports national disease surveillance efforts in Australia. The pathway from conceptualisation to deployment for the HOTspots digital surveillance platform is described.

Keywords. digital surveillance, antimicrobial resistance, pathology, remote health, clinical, health policy.

1. Introduction

The HOTspots Surveillance and Response Program (HOTspots) monitors the epidemiology of antimicrobial resistance (AMR) across northern Australia, where the burden of AMR is exceedingly high and geographically diverse [1-3]. Northern Australia, the region north of the Tropic of Capricorn, is vast and sparsely populated, with a third of its population residing in rural areas. The infectious disease and AMR burden is high [4], often necessitating treatment and medical evacuation to a larger urban centre. An important impediment to timely treatment of patients in community settings is remoteness [4, 5] and limited diagnostic capacity, delaying pathogen confirmation and access to antimicrobial susceptibility data (i.e. antibiograms) commonly used to inform clinical management in hospital settings. Therefore, optimal empiric antibiotic selection at the point-of-care saves lives and reduces the need for patients to leave their communities and be transferred to urban hospitals.

[1] Corresponding Author: Teresa Wozniak, Teresa.wozniak@csiro.au.

Development of an AMR digital surveillance concept arose from the identified need of healthcare professionals to access local AMR patterns at the point-of-care to inform clinical and policy decisions. Clinicians and policy makers sought an interactive visualisation of antimicrobial susceptibility data from regional and remote areas historically falling outside surveillance reach [6]. A technology concept was formulated, and a prototype was validated, evaluated [7], and updated. The HOTspots digital surveillance platform currently captures pathology and demographic data on antibiotic-resistant infections from both hospital and community patients across over 200 clinical sites in northern Australia. Herein the HOTspots concept will be described and the technology supporting regional and remote healthcare settings in mitigating the threat of AMR.

2. Methods

2.1 Concept and Technology Development

The concept and development of the HOTspots digital surveillance platform were driven by an identified data gap in monitoring and responding to AMR in regional and remote Australia [6]. While there was no pre-existing blueprint for developing such technology in this setting, the team drew insights from the European Centre for Disease Prevention and Control Surveillance Atlas of Infectious Diseases [8] as a model. A system needed to be developed that not only permitted ongoing sharing of AMR pathology data between sectors (primary healthcare and hospitals) and across jurisdictions, but was also useful to the needs of clinicians, microbiologists, and policy makers working in a region that has a high turnover of healthcare staff, limited diagnostic capacity and frequent shortages of antibiotics. Concurrently, several burden of disease studies and a call-to-action were published [1-3, 9].

2.2 Stakeholder Engagement

In 2018, engagement with health service stakeholders commenced by mapping an initial cohort of clinical and policy stakeholders. This cohort included pathology providers, antimicrobial stewardship pharmacists, health policy advisers, and infectious diseases clinicians working in northern Australia. Initial discussions commenced with the Northern Territory Department of Health, followed by individual meetings, group workshops, and scientific presentations to scope the design of the HOTspots digital surveillance platform. The team engaged with experts working in primary healthcare, hospitals (regional and urban) and Aboriginal Community Controlled Organisations.

In 2022, a two-stage online survey and workshop using the Delphi method were conducted in order to establish consensus on the feasibility and importance of a range of features to be incorporated into the HOTspots antibiogram, which is a common clinical decision tool used by hospital stewardship teams. To date, there were no community antibiograms available. The first-round survey was developed, and participants were asked to assess their level of agreement on a range of statements regarding the importance and feasibility of utilising data presented in the HOTspots antibiogram. In the second round, participants summarised each feature's responses and revisited their

ratings for statements where consensus had not yet been reached. Following these surveys and a workshop, the HOTspots digital surveillance platform was updated.

2.3 Governance and Ethics

All surveillance data was handled as per CSIRO's Information and Data Policy and was governed and protected in accordance with legislative, ethical, cultural, and contractual obligations, as well as government and organisational requirements.

Ethics Committee (CHMHREC 2020_090_RR). Further, the program was authorised under the powers of the Queensland Health Public Health Act 2005 (Section 280) in Queensland. Jurisdictional participation was voluntary, and all data provided to the program was authorised by the respective data custodians and owners.

2.4 Data Collection

HOTspots digital surveillance platform integrates data from four main pathology providers (Northern Territory Pathology, PathWest, Western Diagnostic Pathology, and Pathology Queensland) representing over 200 public, private, and defence hospitals, community clinics, Aboriginal community-controlled health organisations, aged care facilities, and prisons across northern Australia. Data are updated every six months and validated when data is received. Participating pathology providers supply data on all clinical specimens where antimicrobial susceptibility testing was performed during the surveillance period. Invasive and non-invasive isolates of eight clinically important bacterial species are collected: *Escherichia coli, Klebsiella pneumoniae, Staphylococcus aureus, Pseudomonas aeruginosa, Streptococcus pyogenes, Haemophilus influenzae,* and *Acinetobacter baumannii*, along with a combination of antimicrobial agents. The laboratories utilise two widely accepted international susceptibility method systems: the Clinical and Laboratory Standards Institute (CLSI) and the European Committee on Antimicrobial Susceptibility Testing (EUCAST). Susceptibility results are determined by VITEK2 (bioMerieux Inc., Durham, NC, USA, AST-P612 susceptibility panel and software version 7.01), and disc diffusion susceptibilities where appropriate.

3. Results

The HOTspots web application originated as a proof-of-concept, initially developed as a PHP web application before being re-developed for clinical testing as an R Shiny application. The R Shiny application was evaluated using the United States Centres for Disease Prevention and Control guidelines for evaluating public health surveillance systems, with three key recommendations [7]. These included the need for standardised data collection, greater support for end-user decision-making, and ensuring regular data updates. These recommendations formed the basis for redesigning the R Shiny application, leading to its current version released in 2023 [10].

The current version of the HOTspots digital surveillance platform is a secure, modern, full-stack web application, employing a multi-tiered software architecture [10]. The front-end user interface was developed in Nuxt.js [11], a free and open-source JavaScript framework based on Vue.js [12] and Vite [13]. The backend comprises a

middleware and database. The middleware was developed in Java Spring Boot [14], an open-source Java framework, serving as an application that provides data access through a REST API (Representational State Transfer Application Programming Interface). The database is managed by PostgreSQL [15], a free and open-source relational database management system. The user interface offers interactive widgets, enabling a filter of the data for display in various formats. Filter combinations can be saved locally and reloaded on subsequent visits.

The web application incorporates a geographical view of the data utilising Mapbox GL JS [16], a client-side JavaScript library for building maps on the web, integrated as a Vue.js plugin (Figure 1). Data visualisation in the form of plots (or charts) was implemented by plotly.js [17], an open-source JavaScript charting library. The presentation of data as an antibiogram used a custom JavaScript code (Vue.js) with interactive modal popups.

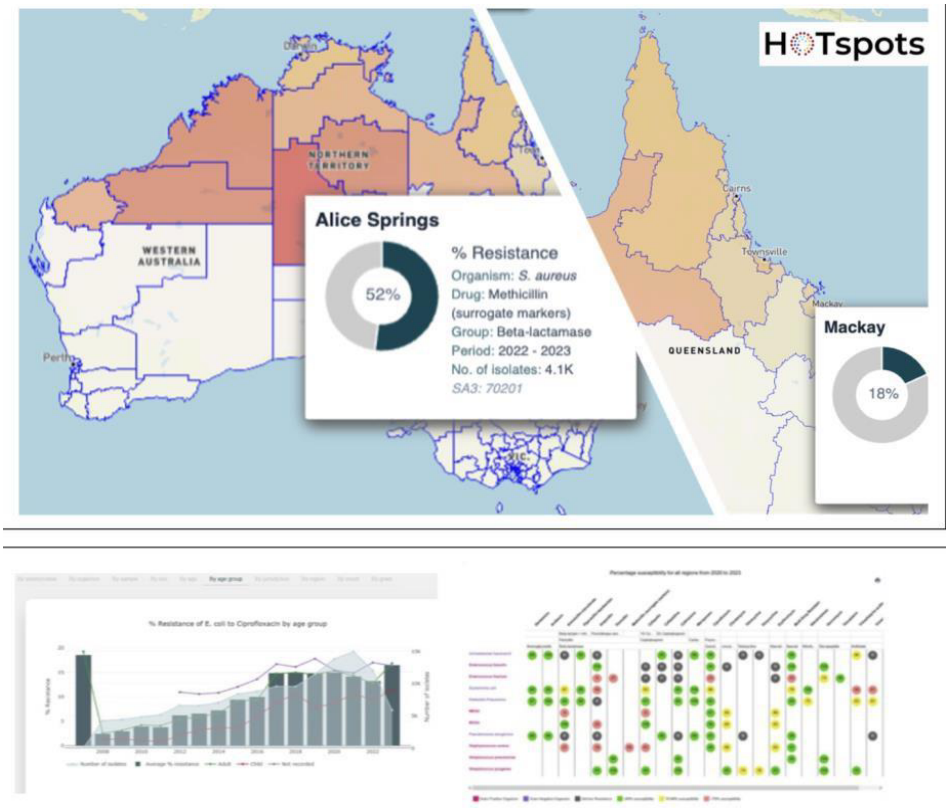

Figure 1. The HOTspots digital surveillance platform (https://amr-hotspots.net/).

A Member's region was included, requiring self-registration and access using third-party authentication services. This feature enables users to customise their default filtering options and request access to filter by a specific provider. The web application was hosted on an external server located in Sydney, Australia, provisioned by the Google Cloud Platform and restricted to Australian IP addresses.

4. Discussion

The digital surveillance platform provides clinicians with timely access to region-specific AMR data at the point-of-care to support optimal antibiotic treatment without diagnostic capacity. Timely treatment saves patients' lives, reduces complications (arising from treatment failure), and hospital admissions. HOTspots' data are incorporated into local treatment guidelines and national AMR surveillance programs. The growing interest from other surveillance programs in digitising their data attests to the trustworthiness and scalability of the HOTspots' technology.

The program's impact is realised through targeted implementation in resource-poor and high-burden settings. HOTspots technology was co-designed with end-users to enable access to timely local data and to facilitate data-sharing between sectors (community-based and hospital physicians), linking often isolated remote healthcare services with local stewardship teams. It addresses the disparities in healthcare delivery in regional Australia and the right for all Australians with access to the benefits of effective antibiotics. This approach aims to achieve early containment of resistant infections, empowering community-based healthcare staff to make decisions based on their patient population, thereby fostering a healthier and safer environment and enhancing the quality of life for some of Australia's most vulnerable communities.

The HOTspots team continually innovates and expands, bringing new collaborators on board with a plan to broaden the program's geographical reach. The ultimate objective is to establish an Australia-wide AMR atlas.

5. Conclusions

HOTspots digitises disease surveillance, offering timely, region-specific data at the point-of-care, informing treatment guidelines. It empowers local clinicians and influences national AMR policy with insights from previously underserved regions.

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