Infectious Epidemiology as a Dynamic Changing Landscape

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Abstract

Animal life and the environment have a profound impact on human disease. With environmental and climate change, animal and vector habitats are constantly changing which presents a unique challenge in the diagnosis of zoonosis and vector-borne diseases. Our project seeks to shift thinking about epidemiology to a dynamic rather than static entity and then to equip clinicians with a clinical decision support system for this. We propose the tool, DynaEpi, that uses data on animal and vector habitat change to display a dynamic disease risk area on a geographic map. This tool will assist clinicians in recognizing potentially emergent zoonotic disease threats.

Background

One Health is an established concept that human health is intricately connected to animal life and the environment[1,2]. Every year new literature regarding novel emergent zoonotic and vector borne diseases[3,4] is published. During recent history, examples such as the "swine flu", "avian flu", and Ebola have garnered significant international attention[5,6,7]. More concerning, human habitation and climate change may be increasing disease emergence[8,9]. As climate changes, many vectors and animals are expanding their potential habitats, or otherwise have lifecycle changes, such as mosquito reproduction season length adjusting to new or depleted environmental pressures. Specific examples include clinical diagnosis of Toxoplasmosis traced to *Toxoplasma gondii* in arctic beluga whales, where previously the habitat was too cold for the parasite, and the predicted change in the habitat for *Ixodes scapularis*, the vector of Lyme Disease[10, 11]. Indeed, emerging zoonoses and vector-borne diseases are an increasing public health concern.

This project was inspired by a cluster of zoonotic and vector-borne diseases (Histoplasma and others) that were seen in Saskatchewan, Canada and were not thought to be endemic. As Histoplasmosis is generally considered endemic to the Ohio, Mississippi, and St. Lawrence (Canada) rivers, these patients were challenging and mysterious cases, since Histoplasma did not even enter our differential diagnosis[12, 13]. Ultimately, the first diagnosis was almost accidental. After the cluster was identified, we found a potential link to the migration of bats.

As physicians we think of epidemiology in a static fashion, having learned the locations of disease through textbooks or medical lectures. Our commonly used resources, such as UptoDate, describe epidemiology as a static entity through old data[12.] In fact, the reference from the article cited dates back to 1990[14]! Our experience and the research described above illustrate that it is imperative to begin thinking of these diseases as dynamic and changing. To use previously described epidemiology, based on outdated studies, may not be sufficient to deliver optimal patient care. However, there is no easy way for physicians to keep updated on epidemiology.

Our Solution (Prototype: https://dynamicepidemiology.invisionapp.com/public/share/E4WTP2TWY)

We propose to implement a tool, DynaEpi, which will be a clinical decision support system (CDSS) for dynamic epidemiology's.

The advent of big data and informatics has the potential to make a large impact on this field. The capturing of animal migration data and various geographic factors is well established[15,16,17]; however, it has not been integrated into clinical medicine. Ecologists have established and published methods of tracking animal habitat and migration; thus, through that research, constantly updated data exists[18,19].

We propose to use the system ArcGIS[20] and pool existing data from biologists to create real time models of animal ecology that is known to harbor human disease. We would leverage connections we have in animal ecology research and use their databases of animal habitats. A team of clinicians would then correlate what diseases could potentially be found in each of these species of animals. Afterwards we would then approach connections in public health and

microbiology to determine if these vectors or animals have been found to harbor the pathogens or if any human cases have been described in the area. Using all this data we will generate a constantly updated map of disease prevalence in a given area with different regions outlining high or low risk. The high-risk areas would correspond to an area with demonstrated pathogen existence or human cases of the disease, while lower risk areas would correspond to potential disease existence, but with no proven pathogen or a human case. Lower risk areas would represent areas where, with continued current trends, disease emergence could occur.

The ArcGIS map could then be accessible as an on-demand app on mobile devices and on websites for clinician use. The specific situations we envision use in would be 1) when a question of a potential zoonotic or vector-borne infectious disease is queried as a diagnosis 2) in travel clinics to counsel patients on travel risks, and 3) for public health officials in predicting and mapping out disease threats. It could act as a real-time, continuously updated supplement to other accepted sources, such as the CDC's Yellowbook and Shoreland Travax.

Going forward, it may be possible to integrate artificial intelligence and machine learning to predict future areas of endemicity based on patterns of migration and other factors such as climate change. This would help public health officials better prepare for disease outbreaks, surveillance, and management.

Design Steps

We used an iterative design process involving in-depth feedback from a variety of different clinicians with various perspectives. We surveyed generalists and specialists, trainees and attendings, as well as Canadian and American physicians. We began with a prototype as shown (Figure 1) and then used a semi-structured interview process with various physicians to refine our design as well as to gather user requirements. This iterative design process incorporated user requirement gathering, design necessities, and evaluation through cycles of redesigning.

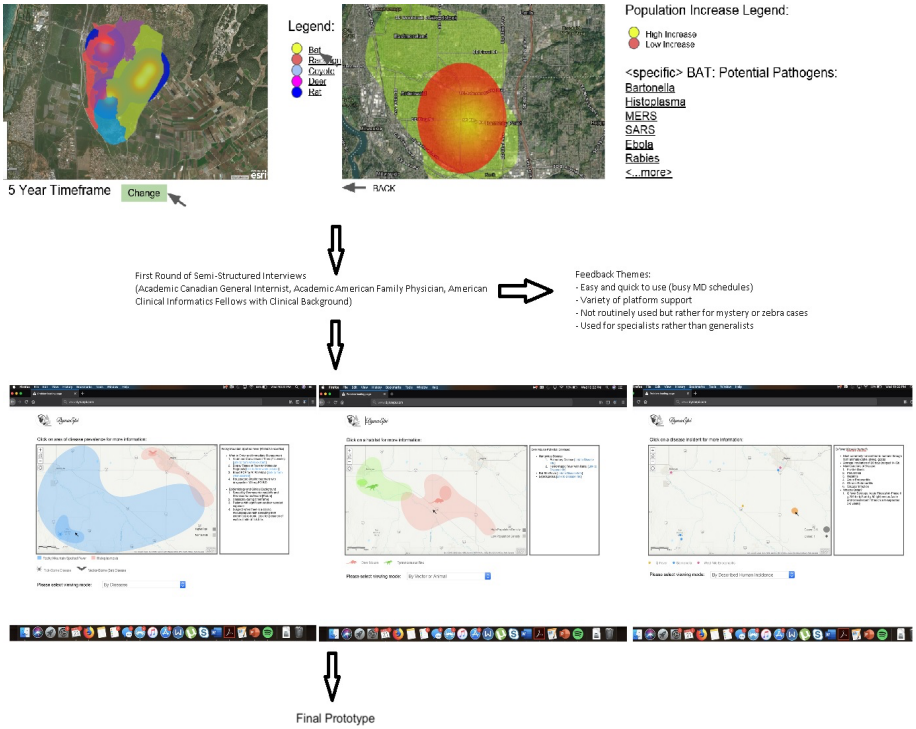

Figure 1. Flowchart of User Design Methodology

Our initial design was focused around the animal vectors. However, feedback identified a series of different general user requirements. The themes of which are (1) the need for a design that makes information gathering and app usage efficient and easy (due to how busy physicians are), (2) the need for a smartphone app, and (3) that the app would primarily be targeted to challenging cases with elusive diagnosis. Our feedback indicated that physicians would be unlikely to think of the animals or vectors that patients were exposed to, rather they would want to see the diseases

that patients could be exposed to. Based on those reviews, we redesigned our application (Figure 1) to be focused around the disease rather than the animal, shortening the cognitive and information gathering process to fulfill these clinician requirements. Going forward we also refined our targeted user population to focus on specialists who would realistically be referred an elusive case and be expected to come up with a diagnosis. These included critical care physicians, internists (the role of a Canadian internist is not primary care, rather a specialist who deals with complicated patients), travel specialists, and infectious disease specialists.

In order to meet deadlines, we were unable to also create a mobile application prototype. The majority of successful clinical resources have both web-based and mobile-phone platforms[21, 22]. Thus, although feedback was that we would require both platforms, we decided to first focus on refining and creating a browser-based application before moving onto smartphone development.

Strengths and Weaknesses of Alternatives

No true alternatives exist to our idea; however, a related alternative is an application called "BlueDot"[23]. The system is proprietary and in-depth information or a trial is not available to general users. From the information supplied by their website, it seems that it is a warning system focused primarily on public health and notifications for infectious disease risks. To the best of our knowledge, its scope is not the same as our application. It targets a system or governmental entity and is not a bedside tool. It is not geared as a CDSS like our planned solution, but rather aimed at high level knowledge dissemination and public health planning. Additionally, it is a prediction system that encompasses more than just zoonotic or vector-borne diseases.

Our strengths in comparison to BlueDot include:

- Designed specifically for clinicians to easily and efficiently make bedside clinical decisions. BlueDot information does not appear to be easily accessible for clinicians and may be confusing to navigate. Our interface design will allow clinicians to quickly and efficiently access needed information.
- We plan on integrating our application with other widely used resources which will make our application more accessible, advertised, and efficient than BlueDot.
- BlueDot focuses on "warnings" (for global infectious outbreaks) which may be difficult to translate into day to day work. People will not retain daily non-contextually relevant information and it would be difficult to correlate hearing about an outbreak in a remote part of the world weeks ago to a patient being seen locally today. Because our app is designed for CDSS, it delivers timely and contextual information.
- Although they have a head start in the field, it is possible we will gain a bigger overall "buy-in" if we start by targeting providers in our implementation and dissemination rather than starting at the systems and policy level. A top-level approach requires navigating significant bureaucracy and regulation as compared to providers.
- BlueDot has a significantly larger mandate and attempts to tackle many more issues thus is less focused on the specific task of zoonotic and vector-borne disease.

Our weaknesses in comparison to BlueDot include:

- There are significantly more resources dedicated to BlueDot in comparison to ours. However, we have designed a very limited and manageable focus for our project.
- BlueDot has a significantly larger network of supporters than our project (including various governmental organizations in Canada and various institutions within the University of Toronto). However, having started as a partnership from a Canadian physician and an American veterinary professional, we hope to take advantage of our networks and connections in two different countries in two different fields.

Implementation and Dissemination

We modeled our implementation and dissemination plan (Table 1) around the previously used model by the VA System in the United States[24].

Table 1. Implementation and Dissemination Strategies

Level	Focus	Strategies	Strategy Type
Policy	Changing Public Health and Policy Level Clinicians to view Epidemiology as Dynamic	Advertising to public health officials Demonstrated success with providers and local systems to encourage policy makers to adopt	Push/Pull
Provider	Changing Individual Behaviour to view Epidemiology as Dynamic	Advertising to individual clinicians Super-users to encourage colleagues to use application Focus on specialists likely to be early adopters first Fogg Behaviour Model	Push
Local Systems	Buy-in and Further Promotion to their Clinicians	Bypass with independent application User success will give feedback to systems that will then encourage clinician uptake. Encourage local super-users to disseminate to others	Pull
Patients	Willing and accepting of dynamic epidemiology's	Equip providers and public health officials with proper information to counsel patients	Push/Pull
Accountability	Evaluation of the Efficacy and Reliability of Information	Continuously obtain feedback with surveys Ask users to quantify a measurement of success (see section on Evaluation)	Push

Encouraging Adoption and Sustained Use by Providers

This level of implementation is the most crucial to our success. Our approach is to encourage a behavioural change: to have physicians view epidemiology as dynamic rather than static. Once they accept these new changes, this CDSS will provide a platform with which they can carry out this behaviour.

The Fogg Behavioural Model theorizes that three factors must intersect in order to cause someone to change their behaviour: motivation, ability, and prompt (or trigger)[25].

The first factor is ability. One of the easiest ways to change behaviour is to make the task easier to perform, allowing for the "ability" to change. Based on our user feedback of time constraints and how busy a doctor is, time will be a barrier to interventions. We also identified user-friendliness ("…not finicky…") as a key factor. Thus, we need to ensure that our tool consumes minimal time, increases efficiency, and can be easily accessed at any time. We also need to ensure that the interface is easy to use and there are minimal bugs. We have designed our current prototype around these values, making a disease-first model which our reviewers identified as easier and more efficient to use. It will be available via web browser and mobile app, which makes it consistently and conveniently available at any time. Finally, we will continuously refine our tool based on feedback to address performance issues and improvements.

The second factor is motivation: to convince physicians to desire behaviour change. We plan on focusing our strategy on early adopters. Physicians have traditionally been a very mentor-mentee culture, where younger and less experienced physicians will look up to and emulate the practice of senior physicians. Indeed, the role of peer-networks is well recognized[26] and in the age of social media, ideas from role models become disseminated even faster. We will focus our efforts at marketing to a group of core users who will adopt our tool and act as role models. We will approach clinicians who are regarded as experts in zoonotic and vector-borne diseases (infectious disease, microbiology, and public health). As our team consists of an infectious disease physician and a veterinary professional, we can start by capitalizing on personal connections. We will also advertise at events geared towards these professionals, such as Infectious Disease Conferences like "AMMI" (Canada) and "IDWeek" (United States). Afterwards these early adopters will encourage other professionals at their institutions to change their behaviour.

The final factor is triggers: something must prompt behaviour change. We plan on doing this via word-of-mouth from our early adopters, but also through connections to commonly used resources. We will strive to work with established technology firms to better incorporate the application into commonly used clinical information resources. Thus, physicians will be prompted to change behaviour when considering a zoonotic or vector-borne disease.

Policy Level Changes Regarding Dynamic Epidemiology

The primary amount of policy change will be handled by public health professionals; thus, we plan on targeting public health clinicians who are the leaders in the field. Our tactic will be very similar to encouraging provider engagement as outlined above. By targeting early adopters in public health, we hope to disseminate behaviour change in this realm.

Barriers in Local Systems to Implementation

Our project is special because it bypasses barriers in healthcare systems. We are completely separate from electronic medical records and health systems, and while it would be optimal to have system level buy-in, this is not a barrier to implementation. Users will have the ability to access it via their own accord, in the same way as UptoDate and Medscape (both of which require no interaction or buy-in from healthcare systems).

However, if we secure health system buy-in, we would be able to increase awareness. Many different health systems have portals which physicians log into and access a series of different applications (ex. call schedule, electronic medical record, and clinical resources). If our application is listed alongside other resources it will likely encourage more usage. Our strategy will be to indirectly demonstrate utility through positive reviews from users (pull strategy).

Increasing Public Awareness and Patient Understanding

Our application will not primarily target patients, however patient buy-in is important as they ultimately drive care. Patients should be willing to accept care resulting from our intended behaviour change. For example, if a patient previously travelled to a country and did not require malaria prophylaxis, our plan may change this understanding. Additionally, if the general public is aware of the dynamic nature of epidemiology, it will further encourage policy, provider, and local systems buy-in.

Our plan is primarily a pull strategy, the initial adoption by clinicians will translate to increasing public awareness and buy-in. Other strategies include a presence in social media links (ex. having articles on the issue of dynamic epidemiology's "shared" on Facebook) as well as publishing in online and print consumer news articles.

Proposed and Completed Evaluation Plan

Our design process was an iterative design, using design critiques during the process to continually modify and refine our design. Our initial prototype was iteratively evaluated through individual and group design critique interviews. The feedback came from a mixture of diverse backgrounds whose professional roles led to useful and meaningful feedback: 1st round – American Academic Rural Family Doctor (OHSU), Canadian Academic Internist (University of Saskatchewan), and 6 American Clinical Informatics Fellows (OHSU) who had various backgrounds (Pediatrics, Internal Medicine, Pathology); 2nd round – Community Infectious Diseases Physician (Joseph Brant Hospital, Canada) and a Board Certified Internist, Gastroenterologist, Hepatologist, and current Critical Care Fellow (University of Toronto, Canada).

Based on our design critiques we created a prototype with Invision (Suppl. Materials). We plan to use a cognitive walkthrough process to evaluate efficacy. We will curate a list of real clinical scenarios and have users diagnose and manage them, with CDSS as a possible resource. In this way, we can evaluate how the CDSS integrates into existing applications and workflow in addition to how users will interact with the CDSS. A randomized control trial with a group of clinicians with access to the app versus no access could also further demonstrate efficacy.

We plan to get travel, public health, critical care, internal medicine, and infectious disease clinicians to participate in this cognitive walkthrough feedback. Participants will be recruited from sites that the authors have connections with (clinical/graduate training and current practice sites) which will be multi-centre in two different countries (McMaster University, Canada; University of Saskatchewan, Canada; various Canadian community hospitals; and OHSU, USA). Recruitment will be significantly easier due to the personal connections the authors have.

See Supplementary Materials for Link to Prototype, Semi-Structured Interview Guide, and List of Interviewed Clinicians

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