Mr. Silva and Patient Zero: A Medical Social Network and Data Visualization Information System

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Abstract. Detection of Patient Zero is an increasing concern in a world where fast international transports makes pandemia a Public Health issue and a social fear, in cases such as Ebola or H5N1. The development of a medical social network and data visualization information system, which would work as an interface between the patient medical data and geographical and/or social connections, could be an interesting solution, as it would allow to quickly evaluate not only individuals at risk but also the prospective geographical areas for imminent contagion. In this work we propose an ideal model, and contrast it with the *status quo* of present medical social networks, within the context of medical data visualization. From recent publications, it is clear that our model converges with the identified aspects of prospective medical networks, though data protection is a key concern and implementation would have to seriously consider it.

Keywords: Medical social networks · Data visualization · Epidemiology

1 Introduction

Global epidemic outbreaks are increasing in frequency and social concern, with recent proposals focusing on global and transversal possible solutions to act with speed and feasibility in the development of vaccines and therapeutics [1]. However, another issue is essential in approaching global or local epidemiological outbreaks, which is the sure and fast identification of Patient Zero. This identification matters because: (a) knowing the medical history of the first individual to become infected with the pathogen and, thus, becoming the first human infectious vehicle, can help determine the initial conditions of the outbreak; (b) it can also indicate the original non-human source of the

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epidemiological context; and (c) the knowledge of the primordial exposure allows for the epidemiologists to acquire precision on the 'who', 'where', 'how' and 'when' of the outbreak.

Nevertheless, we cannot resist to quote David Heymann, of the London School of Hygiene & Tropical Medicine, when he says that the search for Patient Zero is paramount as long as they still disseminate the disease as a living focus, which, for most of the occasions, does not happen [2]. And it is regarding this latter, the localization of Patient Zero still alive, that the use of medical social networks may be invaluable.

What we call a medical social network is a medical-based application of the principles of social networks. Barabási, one of the pioneers of medical social networks, wrote that networks can be found on every particulars and features of human health [3]. However complex the relationship between the network individuals, the organizing principles are attainable through graph theory and visualization, namely as nodes and edges [4]. In a medical context, the nodes may represent biological factors, which can be as diverse as diseases or phenotypes, and the edges represent any chosen relationship, from physical interaction to shared trait. In the field of Epidemiology, for instance, the nodes can be infected individuals, and the edges the physical interactions between them. Albeit this simplification, other aspects can be added (e.g., distinguish between female and male individuals while maintaining the infected information – *vide* Fig. 1). This fusion between social networks and medicine may allow for the detection of patterns of symptomatology, within a community, of public health interest.

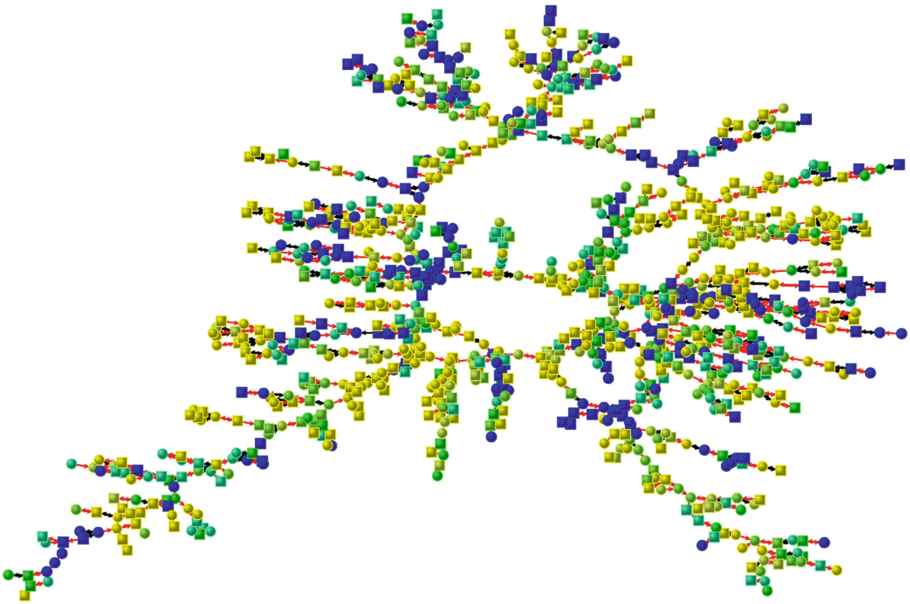

Fig. 1. Example of a medical social network. Each node represents a person - circles denote women, and squares men. Node colour denotes happiness: blue indicating the least happy, and yellow the happiest (green are intermediate). Black edges represent siblings' relationship, and red edges denote friendship or spouses. [Adapted from [5], courtesy of the authors]. (Color figure online)

With the purpose of reviewing the *status quo* of medical networks and data visualization within this context, the present work is divided into the following sections. In Sect. 2, we discuss an ideal medical network model and how feasible it would be dealing with the above mentioned issues. In Sect. 3, selected medical/health network models are discussed in transversal analysis and contrasted with the ideal model. Finally, our conclusions are summarized while also pointing out several prospective paths regarding the development of future medical social networks.

2 Ideal Information System

Let us consider the following hypothetical scenario. I am a doctor and am about to meet Mr. Silva, my patient. Prior to his entering, I access all the data he has given me permission to. In this ideal medical Information System (IS), along with Mr. Silva's standard clinical data (blood tests results, X-ray images, doctor's appointments records, etc.), I also have access to the following social network data: (a) Mr. Silva's kinship network of, at least, two degree relatives (i.e., first degree relatives such as parents, siblings, or offspring, and second degree relatives, such as uncles, aunts, grandparents or full cousins), and their medical data relevant for Mr. Silva's current health condition; (b) through a user friendly interface, I can change the data shown on the network, choosing the information that I see fit; (c) red alerts on medical networks, national and/or local, regarding Mr. Silva's personal connections, that is, connections within a workplace or neighbourhood context. The importance of these outputs lies on cross-referencing Mr. Silva's family medical history with his social interactions.

This ideal IS's purpose is not only to aid physicians during their consultations and serve as a decision support for their diagnoses, but also to act as a disease prevention and public health tool. For that, a work team of skilled IT analysts and managers, data scientists, and health professionals from different areas, will be constantly working with this IS, analyzing all the continuous outputs it provides, namely: (a) different medical social networks illustrating various types of links, such as the family connections between people with a certain medical condition on a certain geographical location, or the working connections between people of a certain age interval that present certain symptoms; (b) alerts for potential health threats already ongoing or as a measure of prevention of those threats. Using this medical IS, this work team should provide frequent reports on the state of the population health regarding all kinds of diseases, and, of course, immediately inform the reporting hierarchies of any and all alerts.

To achieve these outputs, the input of this medical Information System consists of: (a) all administrative data, such as patients full name and address, workplace address, and direct contact number; (b) identification of all the patient's direct relatives, up to the second degree (at least); (c) the physicians' consultations records.

Still in the scope of prevention and treatment of diseases, access to some of these data, and even the use of some of the IS functionalities, may be requested by researchers under official research projects.

Patients' anonymity is of major importance, and even during Mr. Silva's consultation his doctor will only know the type of relationship Mr. Silva has with the people in his social network(s), and their clinical data. Further, the protected data could allow for network pattern and community detection without exposing the identity of the patients, which would be invaluable not only for long-term Public Health measures but also Emergency Management. Regarding public interest, the identity of the connections would only be known in cases of severe gravity and, cumulatively, with external authorization. This would take into account the legal and ethical right of the patient to privacy.

3 Medical Social Networks: The General State of Affairs

Having described the ideal medical IS, we now proceed to discuss the present and general state of affairs of medical social networks.

To begin with, there is not, to our knowledge, a formal medical IS that incorporates social network analysis, but there are several published models which can point out the present capacity, possible implementation and likely reception of a formal medical IS based on them. As such, a selection of those models, chosen due to the specific details that can enhance a cross-reference and discussion with our proposed ideal model, are presented by chronological order and their transversal comparison made by table data displaying and discussion.

Table 1 presents the specifics for identifying the selected models, indicating per row the year of publication, the authors, the subject and the type of sample. The time-span covered by the selected models belongs to the period 2012–2017, and the cultural context presents a wide variety from the USA, to Honduras and India. The subjects approach both physical and emotional aspects of medical social networks, *i.e.*, the models can address, as portrayed in Fig. 1, psychological/sociological aspects of the individuals as components of their overall health situation. Table 2 summarizes the main conclusions and type of data visualization per study.

Table 1. Medical networks' models from recent years.

Study	Year	Subject	Sample
[6]	2012	Aspirin use and cardiovascular events in social networks	2,724 members of the Framingham Heart Study, Massachusets, USA
[7]	2014	Association between social network communities and health behaviour	16,403 individuals in 75 villages in rural Karnataka, India
[8]	2015	Social network targeting to maximise population behaviour change	Individuals aged 15 or above recruited from villages of the Department of Lempira, Honduras
[9]	2017	Association of Facebook use with compromised well-being	5,208 subjects in the Gallup Panel Social Network Study survey, USA

Strully *et al*. depart from a simple interrogation: if the adoption of aspirin of a social element after a cardiovascular event would affect the adoption of aspirin intake as a preventive measure by his/hers social circle [6]. Using a longitudinal logistic regression

Table 2. Medical networks data visualization

Study	Data visualization	Conclusions
[6]	Table with results with columns per statistical functions	- Predisposition for daily intake of aspirin if a social connection presented such routine - Absence of individual discrimination per social network can bias the conclusions
[7]	Table with results of multilevel logistic regression analysis AND network depiction of a village	- Suggestion of organic social network communities more strongly associated with normatively driven behaviour than with direct or geographical social contacts - Norm-based interventions could be more effective if they target network communities within villages
[8]	Network depiction of a block of villages	- Friend targeting increased adoption of the nutritional intervention - Suggestion that network targeting can efficiently be used to ensure the success of certain types of public health interventions
[9]	Table with results from multivariate regression analysis AND box/whisker plots	- The associative process between Facebook use and compromised well-being is dynamic - Suggestion that, overall, Facebook use may not promote well-being

model, and three waves from data extracted from the Framingham Heart Study, they defined as dependent variable the daily intake of aspirin by the individual at the time of the wave. The interest lay if the daily basis intake of aspirin was common in the three waves and, if not, if there was a cardiovascular incident of a social connection that could explain that change. The model considered several aspects of the individuals (e.g., gender or type of social connection) and the results were displayed on tables, with statistical functions, such as average percentage, confidence intervals or adjusted odds ratio. The display of data did not allow a visualization of each individual specific 'decision environment', *i.e*., conclusions are drawn for the population but the individual aspects become elusive. The authors commented that, although they detected the sharing of the doctor as a common feature to change in aspirin intake habits, the data did not allow knowing whether the doctors actively influenced it. In fact, the authors stated that one of the limitations of their research was the lack of randomness, which may have introduced some homophily-driven selection bias, based on unobserved characteristics that may influence the use of aspirin over time, such as drug addiction.

The study conducted by Shakya *et al*. applied an algorithmic social network method to several Indian village communities to explore not only possible connection between latrine ownership and community-level and village-level latrine ownership, but also the degree to which network cohesion affected individual latrine ownership [7]. The authors used a social network depiction to contrast with the statistical results and concluded more strongly regarding the effect of connections in influencing the change in health habits (in this case, ownership of latrine), even stating that one could consider such network understanding a new field of research, which would debunk large data sets analysis into health policies intelligibility and its subsequent efficiency on daily practices.

In 2015, Kim *et al.* evaluated with network-based approaches which methods maximise population-level behaviour change, considering interventions on several health areas (e.g. nutrition), and considered the results evidenced the network-based approach had the advantage of being independent from previous network mapping [8]. Further, they considered that network-based models could sustain the development of health policies intended to change the individual routines, albeit more research should be conducted to discriminate which of the targeting methods presented better adequacy to different classes of interventions.

Our final selected publication deals with the eventual effects of social media network use and well-being. Shakya and Christakis assessed the potential effects of both online and real-world social networks, cross referencing the respondent's direct Facebook data and real-world social networks self-reported data for a longitudinal association in four domains of well-being [9]. They point out that the longitudinal data was size limited due to a small number of permissions to access Facebook data and that the models, though consistent in the direction and magnitude of some associations, did not identify the mechanisms between Facebook use and reduced well-being.

Cross-referencing these models with our ideal medical Information System, it is clear that: (1) data visualization may be the difference between general and non-elusive conclusions; (2) medical social network models are becoming transversal and accepted to understand, identify and be part of the solution of several medical issues; and (3) data protection needs to be carefully implemented for the success of the ideal medical IS.

4 Conclusions and Future Perspectives

Regarding prevention, it is paramount to have a medical tool allowing us to screen the social network of the patient, as it can identify certain health issues per geographical region and per social interaction. Though location of Patient Zero is important in a national crisis, non-epidemiological diseases, such as depression, can present contagion as well and are the silent epidemics. A medical social network as we suggest can locate these silent Patient Zeros and promote overall successful Public Health policies and individual well-being and support.

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