Applying the Epidemiologic Problem Oriented Approach (EPOA) Methodology in Developing a Knowledge Base for the Modeling of HIV/AIDS

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Introduction: In the epidemiologic modeling of diseases, the epidemiologic problem oriented approach (EPOA) methodology facilitates the development of systematic and structured knowledge bases, which are crucial for development of models. A detailed understanding of the epidemiology of a given disease provides the essential framework for model development and enables the laying out of the comprehensive and fundamental structures for the models.

Objective: To develop such a knowledge base for developing HIV/AIDS models.

Methods: The EPOA methodology was utilized to develop the knowledge base for HIV/AIDS; it is composed of six pillars within two triads: the Problem Identification/Characterization and the Problem Management/Solution/Mitigation Triads, interlinked by the diagnostic procedure.

Results: Using information from various sources, the triads are decomposed into their respective pillar variables and parameters. The agent pillar identifies the causative agent (HIV) and its characteristics. The host pillar identifies and characterizes the host (human). The environment pillar characterizes the physical, biological and socioeconomic environments for both the host and agent. The therapeutics/treatment pillar considers the treatment options for HIV/AIDS. The prevention/control pillar considers prevention and control measures. The health maintenance/health promotion pillar considers measures for the health maintenance of the population.

Conclusion: Models for HIV/AIDS can be conceptual, *in vivo* or *in vitro*, systems analysis, mathematical, or computational just to name a few. The knowledge base developed using the EPOA methodology provides a well-organized structured source of information, which is used in the variable and parameter estimations as well as analysis (biological, mathematical, statistical and computer simulations), which are crucial in epidemiologic modeling of HIV/AIDS. EPOA methodology has become an important tool in the development of models that can enlighten decision making in public health. (*Ethn Dis*. 2010;20[Suppl 1]:S1-173–S1-177)

Key Words: Epidemiologic Problem Oriented Approach, HIV/AIDS, Modeling

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Introduction

Models for HIV/AIDS can be conceptual, *in vivo* or *in vitro*, systems analysis, mathematical, or computational just to name a few.[1–4] In general, a model can be considered as a pattern, plan, representation (especially in miniature), or description designed to show the main object or workings of an object, system, or concept. In scientific modeling, modeling is the process of generating abstract, conceptual, graphical and or mathematical models. Science offers a growing collection of methods, techniques and theory about many kinds of specialized scientific modeling. Modeling is an essential and inseparable part of all scientific activity; many scientific disciplines have their own ideas about specific types of modeling.

The devastating effects of the HIV/AIDS pandemic are compounded by its complex patterns of transmission. The rate of transmission and the demographic spread of the disease are influenced not only by direct factors such as age, marriage rates, number of sexual partners, sexual preferences, frequency of extramarital liaisons, etc., but indirectly by factors such as psychosocial, socioeconomic, and HIV/AIDS risky behaviors and conditions and ultimately by the complex interactions between all these factors.[5] These interactions and their evolution over time provide a major difficulty in trying to predict the spread and social impact of the disease.[6–8] Defining and structuring these various factors, using the epidemiologic problem oriented approach methodology, will greatly facilitate the development of knowledge bases, which are integral in incorporating these factors in the different models developed.

The objective in this study was to develop such a knowledge base for developing HIV/AIDS models.

Methods

The epidemiologic problem oriented approach (EPOA) methodology is utilized to develop a knowledge base for HIV/AIDS. The EPOA methodology is composed of two triads: 1) the problem identification/characterization triad, which is mainly descriptive in nature, and 2) the problem management/solution/mitigation triad, which is mainly geared toward problem solving. The two triads are interlinked by the diagnostic procedure linkage (Figure 1). The first triad is composed of three pillars: the agent, host and environment pillars. The second triad is composed of three pillars: 1) therapeutics/treatment, 2) prevention/control, and 3) health maintenance/promotion. The individual pillars of each triad are interlinked and decompose into its respective variables and parameters. In the first triad, the agent pillar identifies the agent and its characteristics like infective dose and route(s) of infection, survival under different conditions, pathogenicity, life cycle, transmission pathways etc. The host pillar identifies and characterizes all possible hosts whether they are definitive, intermediate, reservoir or parate-

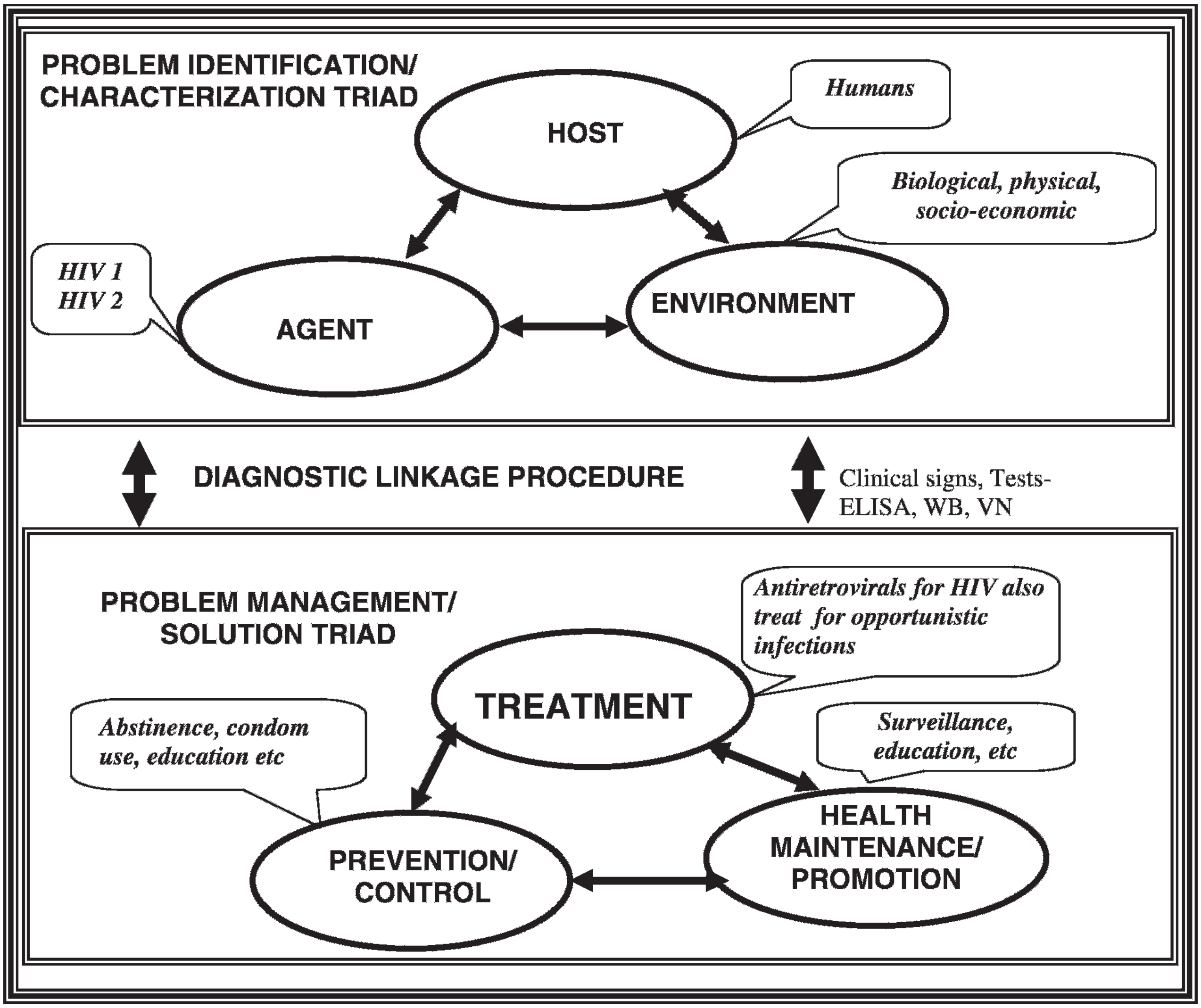

Fig 1. The epidemiologic problem oriented approach model

nic. Host characteristics are identified in detail including intrinsic and extrinsic factors. The environment pillar characterizes the physical (abiotic), biological (biotic) and socioeconomic environments for both the host and agent and defines how they interplay. Psychosocial factors and determinants are considered. In the second triad, the therapeutics/treatment pillar considers if the condition is treatable curatively, palliatively or as secondary problems. Options, ease of availability and accessibility to treatment are taken into consideration. The prevention/control pillar considers if prevention is primary, secondary or tertiary and the health maintenance/health promotion pillar considers, in general, the health maintenance of the population mainly after a disease or condition has already occurred. This pillar is geared toward lowering the prevalence and incidence rates to their lowest level through prevention and control strategies, with eventual eradication of the disease being the ultimate goal.

Data collection is critical for the development of the knowledge base and the gathered data should be in well-structured formats. Table 1 provides an illustration of the variable and parameter estimations that should be collected to assist in problem identification and characterization of the EPOA triads for some aspects of HIV/AIDS modeling.[9] The variables indicate the agent, host and environment with their respective measures, values and units. In the parameter column, the list of parameters related to each variable is indicated and could be used in the modeling of viral and cellular population dynamics of HIV at the micro-environment level.

To obtain the data, sources and types of organizations that can provide key information include: academic and research institutions, ministries of

Table 1. Sample of variable and parameter estimations for problem identification/ characterization triad of EPOA for modeling of viral and cellular population dynamics of HIV at micro-environment level

	Variables				Parameters
	Variable Name	Measure	Value	Unit	Parameters related to the variable
Agent	HIV	viral load	133500	virions/mL	Production rate of virions(534.4 per day), death rate of virions (3.07 per day), infectivity rate of virus (3.43×10^{-8} ml per virions per day), etc.
Host	CD4+	CD4+ cell count	infected=1.19 uninfected=178.81	number of CD4+ cells/mL	Production rate of uninfected CD4+ (2 cells mm^{-3} day^{-1}), Death rate of uninfected and infected CD4+ (0.0014 and 0.69 per day respectively), etc.
Environment	blood	volume	100 trillion cells (all types),	in an average 70 kg man, 5–6 L	Role of various other cells eg cytotoxic T cells, supressor T-Lymphocytes, etc in relation to CD4+

health, other government agencies, hospitals and clinics, nongovernmental and community-based organizations, international organizations and partners involved in HIV/AIDS work, such as USAID, CDC, UNAIDS, national and/or regional associations of People Living With HIV/AIDS, private companies, and media. Other sources include: comprehensive program reviews produced by governments, donor agencies, and others, national HIV/AIDS program updates, such as reports from behavioral and biological surveys, and from sentinel surveillance, web-accessible libraries, meeting and conference reports, books, journals, and medical databases generated by research endeavors. The EPOA methodology organizes this data into a well-structured format that is easily retrievable to assist in disease control and prevention.

Once the knowledge base is developed based on EPOA, a systems diagram would be developed. The dynamic epidemiologic model developed for a case study, such as HIV/AIDS among different racial groups, shows the transmission of HIV and its progression to AIDS rely on a set of multiple determinants that affect the epidemiology of HIV/AIDS in populations. In the systems dynamic model shown in Figure 2, the population is divided into five sub-populations based on their demography and into three sub-populations based on their health status: 1) those who are susceptible for HIV/AIDS; 2) those infected with HIV; and 3) those with advanced state of HIV infection or full blown AIDS. The transitions between the states of health are regulated by rates of conditions such as birth, infection, progression to AIDS, and death. As illustrated in Figure 2, an individual can stay within their sub-population for a period of time, transfer to another adjoining sub-population, exit the model from causes other than AIDS (eg, dying from causes other than AIDS at any stage in the model), or exit the model due to AIDS (ie, death from AIDS). The movements between sub-populations are governed by transfer rates. The model considers five ethnic populations: White (not Hispanic), African Americans, Hispanic, Asian/Pacific Islander, and American Indian/Alaska Native. Within each ethnic group, an individual's sex is either female or male. Each individual is also considered to be engaged in one, two, three, four or all of five HIV/AIDS risky behaviors: male-to-male sexual contact (MSM), injection drug use (IDU), male-to-male sexual contact and injection drug use (MSM/IDU), high risk heterosexual contact, and others (eg, blood transfusion, perinatal exposure, and risk factors not reported or not identified). The HIV/AIDS infection rate in a given susceptible population directly depends on the proportion of MSM, IDU, MSM/IDU, high-risk heterosexual contact, and other risky factors. Manipulation of one or several of these variables changes the behavior of the system and result in an increase or decrease of the incidence of HIV/AIDS, thus allowing critical evaluation of alternative disease control strategies.

Based on the conceptual model developed, a mathematical model, which should have several sub-models would be developed. The mathematical model is more detailed and based on in-depth data and analysis.

RESULTS

Information from various sources on the epidemiology and determinants of HIV/AIDS is reviewed and organized into a knowledge base that serves as the foundation for building the dynamic epidemiologic models, which include triads, which are decomposed into respective pillar variables and parameters, as described earlier. This analytical approach to model development consists of seven major steps which are all interlinked: a) developing a knowledge base b) developing a conceptual model c) developing systems analysis model d) developing a mathematical model e) developing a simulation model f) testing, validating, performing sensitivity analysis and updating the model and g) implementing the model. As an exam-

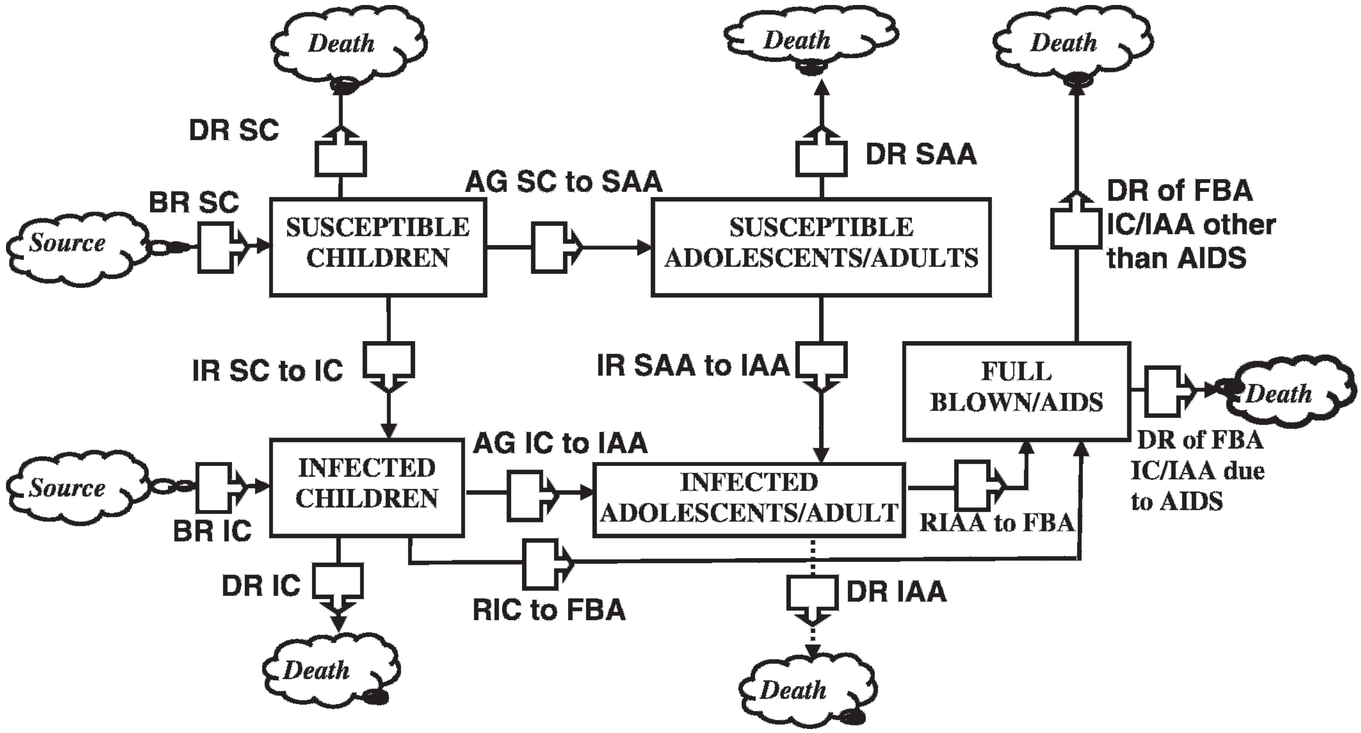

Fig 2. A conceptual systems dynamics model for HIV/AIDS
Abbreviations:
BR SC birth rate of susceptible children
BR IC birth rate of infected children
AG SC to SAA aging rate of susceptible children to susceptible adolescents/adults
AG IC to IAA aging rate of infected children to infected adolescents/adults
IR SC to IC infection rate of susceptible children to infected children
IR SAA to IAA infection rate of susceptible adolescents/adults to infected susceptible adolescents/adults
RIC to FBA rate of infected children to full blown AIDS
RIAA to FBA rate of infected adolescents to full blown AIDS
DR SC death rate of susceptible children
DR IC death rate of infected children
DR SAA death rate of susceptible adolescents/adults
DR IAA death rate of infected adolescents/adults
DR of FBA IC/IAA other than AIDS death rate of full blown AIDS infected children, adolescents/adults not due to AIDS
DR of FBA IC/IAA due to AIDS death rate of full blown AIDS infected children, adolescents/adults due to AIDS

ple, a systems analysis model identifies links between the sub-systems, and defines variables, rate of variables, parameters and constants in a system. The goal is to develop a representative diagram/chart of the system as shown in Figure 2. The developed models can be used to provide important insights in population dynamics at the human population level and to evaluate alternative HIV/AIDS control and prevention strategies. Dynamic epidemiologic modeling for HIV/AIDS is an essential tool for making prediction estimates of current prevalence and future incidence of HIV/AIDS cases.

CONCLUSION

The knowledge base developed using the EPOA methodology provides a well-organized, structured source of information, which is used in estimating variables and parameters and in conducting analyses (biological, mathematical, statistical and computer simulations) that are crucial in epidemiologic modeling of HIV/AIDS. These models are cost-effective; they are easily manipulated for different scenarios and not dangerous, in comparison to human experimentations, for a disease such as HIV/AIDS. This ethical approach has enabled great strides in the area of HIV/AIDS research. A model is evaluated first and foremost by its consistency to empirical data; any model inconsistent with reproducible observations must be modified or rejected. However, a fit to empirical data alone is not sufficient for a model to be accepted as valid. Other factors important in evaluating a model include: ability to explain past observations; ability to predict future observations; cost of use, especially in combination with other models; refutability, enabling estimation of the degree of confidence in the model and; simplicity. The EPOA methodology has become an important tool in the development of HIV/AIDS models that are crucial in decision making in public health as it relates to prevention, control and treatment strategies. As more knowledge becomes available, the knowledge bases can be updated and used to improve the models and thus stimulate better decisions to ameliorate the HIV/AIDS pandemic.

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