Computer-Assisted Medical Diagnosis for Rural Sub-Saharan Africa

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There is a pressing need to employ information technology for rural healthcare in Sub-Saharan Africa. Rwanda and Mozambique have one physician for every 25 000 people. It will not be feasible to meet the need for more physicians and professional nurses in a timely fashion through training or recruitment. Computer-assisted diagnostic systems provide an opportunity to help meet the physician shortage in developing countries. A necessary concomitant action to deployment of such technology is the development of appropriate rural healthcare infrastructure. Promising strategies employing computer-assisted diagnostic software have been used successfully for more than seven years in rural India. Similar approaches

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E-health innovation is needed in sub-Saharan Africa.

present opportunities for exploration of new paradigms for rural healthcare delivery in rural Sub-Saharan Africa.

Distribution of Health Care Professionals

Recent World Health Organization (WHO) data [1] reveal huge variations among countries regarding the number of physicians available for a given population. The extremes vary from one doctor for every 169 people in Cuba to one doctor for every 52 375 people in Malawi.

Different healthcare personnel models are found in industrialized countries. The U.S. ratio is 1:384, Canada's is 1:526, while Scandinavian countries average about 1:290. These wide differences in the ratios of people per physician among the developed countries pale in comparison to the ratios in the least developed countries of the world.

Table I lists the 28 lowest ranking countries of Sub-Saharan Africa in terms of the availability of physicians. The median for this group is more than 20 000 people per doctor, 52 times the ratio for the United States.

If a reasonable ten-year goal for increased physician density was to reduce the ratio to 1:2000, it would represent a 10-fold improvement over the existing median ratio for the 28 lowest ranking countries of Sub-Saharan Africa. These 28 countries have a total of more than 435 million people, so achieving a ratio of one doctor for every 2000 people would require approximately 200 000 additional doctors. Over a ten-year period this would require graduating more than 20 000 doctors each year. This is far beyond the capacity of African training institutions.

A more modest estimate is used in a 2007 report from *The McKinsey Quarterly* [2], entitled, "Addressing Africa's health workforce crisis." In this study the goal is to increase the number of healthcare workers (defined as physicians, nurses, and midwives) up to a level of one healthcare worker for every 400 individuals in the population. This is a level that has some correlation with UN Millennium Development Goals for maternal and infant-health targets.

The McKinsey analysis asserts that 820 000 doctors, nurses, and midwives would be needed, requiring 600 additional medical and nursing schools and more than two decades of effort to meet the desired level or healthcare workers. The magnitude of such an effort can be put into some perspective by noting that, in 2007, a total of 16 139 physicians graduated in the United States from the nation's 125 Medical Schools. The McKinsey report concludes that neither the financial or human resources to pursue this goal are available.

Currently, there are fewer than 100 medical colleges in Sub-Saharan Africa, with most countries having one or at most two institutions.

Table I
Most Doctor Deficient Countries in Sub-Saharan Africa

Country	Population[1]	Number in Population per Physician[2]
Guinea-Bissau	1 503 182	7996
Kenya	37 953 838	8423
Cote d'Ivoire	18 373 060	8828
Zambia	11 669 534	9232
Guinea	10 211 437	10 346
Mauritania	3 364 940	10 750
Angola	12 531 357	10 833
Gambia	1 735 464	11 125
Democratic Republic Congo	66 514 506	11 415
Mali	12 324 029	11 704
Central African Republic	4 434 873	13 398
Uganda	31 367 972	14 200
Burkina Faso	14 264 735	21 560
Senegal	12 853 259	21 638
Togo	5 858 673	23 371
Rwanda	10 186 063	23 379
Eritrea	5 028 975	23 388
Lesotho	2 128 180	23 912
Benin	8 294 941	26 672
Chad	10 111 337	29 308
Somalia	9 558 666	30 834
Liberia	3 334 587	32 374
Sierra Leone	6 294 774	37 469
Ethiopia	78 254 090	40 421
Mozambique	21 284 701	41 410
Burundi	8 691 025	43 455
Niger	13 272 679	44 840
Malawi	13 931 831	52 375

[1] CIA World Fact Book; https://www.cia.gov/library/publications/the-world-factbook/.
[2] WHO World Health Statistics, 2008; http://www.who.int/healthinfo/statistics/en/.

More of Malawi's doctors may be practicing in the British city of Manchester than in Malawi.

Exceptions are Nigeria with 16 medical colleges and South Africa with eight. These countries also have the largest number of physicians who are now working in the United States. Physician salaries are low in Sub-Saharan African countries. With the high demand for physicians in the United States, Canada, the U.K., Australia, and other countries, large numbers of Sub-Saharan trained doctors emigrate. This brain drain exacerbates an already dire situation.

A detailed study [3] of African health care professionals abroad concludes that 65 000 African-born physicians and 70 000 African-born professional nurses worked overseas in developed countries in 2000. This represents about twenty percent of all African-born physicians and about ten percent of all African-born professional nurses. More of Malawi's doctors may be practicing in the British city of Manchester than in Malawi [4].

The shortage of health care professionals in Sub-Saharan Africa is even more serious than the numbers suggest because the disease burden in these countries is extraordinarily high. The McKinsey study asserts that Africa bears one-quarter of the burden of disease in the world, yet has barely 3 percent of all health workers. The HIV/AIDS burden in Sub-Saharan Africa is particularly severe. Sub-Saharan Africa has 12 percent of the world's population, yet in 2007, 75 percent of all the deaths from AIDS in the world were in that region [5].

Meeting the Doctor Divide Challenge—A Community Healthcare Model

Given the magnitude of this Doctor Divide challenge, how might this problem be tackled? Applying models of health-care standards in the developed world, and trying to train enough doctors and nurses to satisfy such models, will not be possible in any reasonable time frame. A recent World Health Organization study [6] of healthcare workforce training in a group of Sub-Saharan African countries finds the shortfalls alarming. That report suggests shifting more care-giving tasks than in the past to those who have received less training.

Rural clinic in Mozambique.

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We propose using information technology to meet this challenge. However, technology must be appropriate for the context in which it is to be used. A technological solution must be structured within an organizational framework that can effectively implement the technology with a realistically obtainable cadre of healthcare workers.

For Sub-Saharan Africa, feasible solutions must be structured in a tiered fashion in which the available small number of fully trained physicians is strategically engaged. The objective of the technological initiatives suggested here is to increase the productivity of available doctors, not to replace doctors. Every effort should be made to increase the number of qualified doctors engaged in rural healthcare in Sub-Saharan Africa, but it will be impossible to meet even minimum needs with fully trained doctors in the foreseeable future. The largest number of patients will need to be treated by nurses, paramedical personnel, and technicians. These health workers will need to be supported with technology-based systems that facilitate diagnosis and treatment and that provide essential information at the point of care. Most countries in Sub-Saharan Africa have medical care systems that can be organized to incorporate these features.

The community-based clinic is the point of contact with the rural population and a referral hospital with high levels of health care sits at the top of the healthcare pyramid. A key question is, how can community-based clinics most effectively utilize available staff with the creative use of information and communication technologies?

A strategic approach to developing a full model should seek the highest impact from the lowest tier facility, while using the least expensive infrastructure and the lowest possible level of training for the personnel who staff the lowest tier facility. This assumes that more highly trained personnel and higher performance infrastructure are being implemented at the higher tier facilities.

Iranian Rural Healthcare Model

Any application of technology into a service organization must be done with sensitivity to its impact on workflow and the human factors involved. In considering technology at rural clinics in the developing world, these issues are particularly relevant. An example of a village tier approach that has been used in Iran incorporates one of the most successful low tier frameworks implemented in the developing world.

Major improvements in rural health care have taken place during the past 20 years in Iran where an innovative approach was introduced following the revolution of 1979. Additional health care initiatives were introduced in 1989 at the conclusion of the war with Iraq. Infant mortality that was 120 per thousand live births in rural areas of Iran in 1974 dropped to 30 by 2000. The decline from 1988 to 2000 was from 58 to 30. The under-five mortality rate in rural areas declined from 72 to 35 between 1988 and 2000. During these intervals there was also a substantial increase in the percentage of 1-year-old children who were immunized against measles, polio, and tuberculosis (TB) BCG vaccine, Diphtheria, Typhoid, Tetanus, and Hepatitis B. In each case, the immunization rates in 2000 were greater than 95 percent.

Much of this success can be attributed to the establishment of Health Houses [7] (Khane Behdash) at the village level. A Health House is designed to care for 1500 residents who reside in the village where the House is located and in satellite villages, which are within an hour's walk from the House.

Staff of one male and one female is nearly always chosen from the main village where the Health House is located. Where this is not feasible, a candidate is recruited from one of the satellite villages. The selection is typically from among 16- to 24-year-old female candidates, and 20- to 28-year-old males, with direct participation from village authorities, such as the village council or local clergy.

The process of training the staff is an example of using methods that are appropriate to the local society and the task at hand. Candidates are required to have eight years of formal schooling (frequently a high school diploma). Candidates must successfully complete a written exam and interview before enrollment in the training course. Their studies span two years, arranged in a manner dramatically different from traditional pedagogy. Memorization of volumes of written material has been replaced with practical training through group discussion, role-playing exercises, and working at the Health House with an experienced mentor.

At the tier above the Health House level is a system of rural clinics, to which patients are referred as appropriate. Rural clinics would have a minimum staff of trained nurses and a technician who could perform basic laboratory testing and some fundamental diagnostic testing such as electrocardiogram analysis, urine analysis, and sputum analysis. Because rural clinics in developing countries often serve approximately 15 000 residents, implementation of a network would require about 10 Health Houses within the domain of a single rural clinic.

This model, which has been highly effective in Iran, is one that other countries would need to evaluate in light of their own circumstances. It is presented here to provide a frame of reference, and as an example that can stimulate thought regarding the village level healthcare challenge.

The feasibility of such a healthcare model would depend on the financial and human resources that are available. A basic reality, which any model must address, is the insufficient number of fully trained physicians. Alternatives must be found to the developed world model for the deployment of this scarce and expensive health care resource.

> It will be impossible in Sub-Saharan Africa to meet even minimum needs with fully trained doctors in the foreseeable future.

Computer-Based Clinical Diagnosis Systems

In addressing the extremely limited availability of trained doctors, a key question is:

In the absence of doctors in rural areas of Sub-Saharan Africa, can a computer-assisted clinical diagnosis system facilitate safe and effective primary health care?

In addition to the medical efficacy of the system, questions need to be addressed regarding context, cost, and technological feasibility.

The context issue relates to the rural healthcare infrastructure that is established. Currently, in the absence of a physician, a front-line rural clinic will probably have a nurse, whose training could vary from minimal to extensive, along with a paramedic or technician with a 10th or 12th grade education.

Organizational issues that need to be resolved include: at what point in the healthcare system does the patient come into contact with the computer-assisted clinical diagnostic system; what healthcare worker implements the system; which healthcare worker interprets the results of the computer-assisted analysis, and how is the data from the computer-assisted analysis utilized for follow up and integration into a patient data base?

The development of systems for use in rural areas of the world that lack adequate numbers of physicians has been neglected. Almost all computer-assisted clinical diagnosis systems have been developed to provide support for trained physicians to meet special needs. Some examples of the more robust existing computer-assisted clinical diagnosis systems [8] are presented in Table II.

Based on extensive library and web searches [9], discussions with experts in the field, and a review of books [10], the systems described in Table II represent most of the active computer-based decision support systems for medical diagnosis. These systems share certain characteristics. They seek to be comprehensive in their coverage of possible diseases. The number of diseases included is generally of the order of 10 000. They also are designed to provide doctors who are engaged in making a diagnosis with suggestions for other possible diagnoses. Other objectives might be to provide doctors with the latest knowledge relating to treatment options for the disease that they have already identified. These systems are all designed for use by physicians to enhance their effectiveness and to insure greater safety for patients.

Other types of diagnosis systems in healthcare are also available. These are designed to provide general practitioners with advice on treatment for a disease for which they might not have the required special expertise. Various decision support systems have been developed to deal with specialized illnesses. Examples include hypertension (ATHENA), cancer (ERA), and HIV (TherapyEdge).

Table II
Selected Computer-Assisted Diagnosis Systems

DiagnosisPro
http://en.diagnosispro.com
Online free reference tool for physicians. Provides reminders about diagnostic possibilities and reminders to provide comparisons among possible diagnoses. Includes 11 000 diseases.

ASTI
http://www.openclinical.org/prj_asti.html
A computer decision support system for physicians that can operate in two different modes. One of the modes provides reminders, the other develops diagnoses interactively. The Laboratory of Teaching and Research in Medical Data Processing of the University of Paris 13 developed ASTI.

DXPLAIN
http://dxplain.org/dxp/dxp.pl
A decision support system, which acts on clinical findings (signs, symptoms, laboratory data) to produce a ranked list of diagnoses. The Laboratory of Computer Science of Massachusetts General Hospital in Boston, Massachusetts, developed DXplain.

EGADSS – Evidence Based Guidelines and Decision Support System
http://egadss.sourceforge.net/
An open source tool designed to work with primary care Electronic Medical Record (EMR) systems to provide patient-specific point of care reminders. The British Columbia Primary Care Informatics Collaboratory in Canada maintains EGADSS.

GIDEON – Global Infectious Disease and Epidemiology Network
http://www.gideononline.com/
Commercial program for diagnosis and reference in the field of tropical and infectious diseases, epidemiology, microbiology, and antimicrobial chemotherapy. Updated GIDEON CD-ROMs are circulated to subscribers every three months. The online version is updated weekly.

Isabel
http://www.isabelhealthcare.com
Commercial web-based clinical decision support system designed to enhance the quality of diagnosis decision-making. Isabel uses natural language processing to help answer clinical questions. It supports 11 000 diagnoses and 4000 treatments.

PAIRS – Physician Artificial Intelligence System
http://www.openclinical.org/aisp_pairs.html
PAIRS helps doctors diagnose difficult cases. Contains 30 000 disease characteristics and reports on 7282 diseases. PAIRS provides a differential diagnosis with probabilities for each disease. Developed by Dr. Roa of Logic Medical Systems in Hyderabad, India; a commercial version is anticipated.

Systems have also been developed to assist with dental practice and nursing care.

The systems described here are designed for use by trained physicians, and require users with specialized knowledge.

In addition to the physician-focused systems, there are also many medical symptom programs available on the Internet to assist the general public in self-analysis. The structure of these programs is useful for knowledgeable people in the developed world, but not appropriate for use in developing countries where the Internet is generally not available. Patients there need easy-to-use tools that can be applied in a uniform fashion by an educated technician who acts as an intermediary for a possibly illiterate patient. A non-physician healthcare worker, with minimal professional training, at a rural clinic in a developing country, would not be able to make use of any of these Internet-based systems.

Certain decision support systems have been designed specifically to help meet healthcare needs in regions that have extreme physician shortages, as described in the following sections.

Sympmed I

In 1988, an experimental computer-based diagnostic system called Sympmed I [11] was developed by the Foundation for Research in Community Health in Mumbai, India. The premise for Sympmed I was that a small number of symptoms account for a majority of the patients visiting rural healthcare facilities. The system was compared with diagnoses for 900 patients who were seen by both Sympmed I and a general practitioner physician. The outcome of this study led to the following conclusion:

> "The results of the evaluation confirm that most problems seen by first level medical personnel in developing countries are simple, repetitive, and treatable at home or by a paramedical worker with a few safe, essential drugs, thus avoiding unnecessary visits to a doctor."

Hemoglobin test in Tamil Nadu.

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It does not appear that Sympmed I has been developed further or utilized in ongoing care programs at rural clinics.

Early Detection and Prevention System

The Early Detection and Prevention System (EDPS) is an example of a more fully developed computer-assisted diagnosis system, designed for use at rural clinics that do not have a staff physician. While there may be other systems in existence for use by non-medical personnel, this is the only system we have identified with these characteristics. Furthermore it appears to be unique in having a track record of more than seven years of satisfactory use, in rural India.

EDPS [12] was developed by Dr. Abraham George in 1998–2000 for application in rural areas of India. Dr. George, who holds a Ph.D. in Finance from the Stern School of New York University, established The George Foundation in 1995 to improve the lives of residents in rural India. The development of EDPS was implemented through eMedexOnline LLC, a software company chaired by Dr. George. Experienced physicians in India and the United States helped develop the system.

EDPS facilitates early detection of diseases and nutritional deficiencies even in the absence of a physician. The system provides a probable diagnosis based on symptoms and signs presented by patients. It seeks to identify individuals who require prompt attention by qualified physicians and to support treatment of those who have illnesses that can be treated without a physician.

EDPS captures an extensive record of patient medical history and other data that assists rural healthcare workers in their outreach to villages. Health workers are assigned to villages to call on women who face high-risk pregnancies and those who need periodic attention, all based on daily "ticklers" generated by the system from the patient database. EDPS provides external reports to health authorities and agencies.

The design of EDPS has focused on ease of use and emphasizes the most common diseases and maladies found in rural India. The analysis is presently limited to 300 commonly found diseases. Data important for follow-up and

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EDPS clinic near Pondicherry, India.

preventative care is included in patient records, such as all aspects of maternal and child health, as well as nutritional and immunization status for children under 5 years old.

Patients interact with EDPS via a dialogue conducted with a technician who has not had prior medical or computer training. At a rural clinic in the Tamil Nadu region of India, EDPS systems operators were educated only at a high school level. The training of the technicians is accomplished during a two-week period with additional observation, monitoring, and mentoring as needed.

When introducing EDPS to the region, operators registered inhabitants into a database that includes their health history, family circumstances, and their source of livelihood. Patients are provided with an identification number for local use.

When patients arrive at the clinic for treatment, a technician makes four measurements: height, weight, blood pressure, and temperature. These measurements are entered into the system prior to the EDPS interview.

The interview is structured such that the EDPS technician is not asked to make up any questions or to engage in any keyboard entry. All of the questions are generated by EDPS software and the patient responses are recorded by having the technician either click on a box or select an entry that appears from a drop-down menu.

After the initial set of questions, successive screens appear based upon the first set of responses. As the interview proceeds, additional questions are again computer-generated as follow-up. The use of drop-down menus and check-off items limits the system. However, the system is not intended to be comprehensive and the fallback position of recommending that the patient see a doctor is always available.

The entire interview takes less than 10 minutes and terminates with the printing of a report that summarizes the interview and identifies one or more possible diagnoses. The report may also request additional information from a laboratory test or measurement. A healthcare worker with training and experience, such as a nurse, reviews the results of the EDPS analysis. The outcomes can be viewed in three traditional "triage" categories.

Some patients do not need specialized treatment. They are sent home with non-pharmaceutical medications such as aspirin and cough syrup along with advice. Complaints stemming from the headache, common cold, simple skin rashes, and malnutrition fall into this category. Experience in India finds that about 34 percent of patients fall into this category. In practice, at least an equal number of additional cases can be diagnosed by EDPS. Thus, a nurse with basic training who is using EDPS can reduce the load on doctors by dealing with approximately 70 percent of patients visiting rural clinics.

The second category is patients who require testing or prescription drugs. Technicians at a front-line rural clinic can perform some simple tests, while others require referral to a more advanced facility. With regard to prescription drugs, it might be possible to get approval from a physician via a telephone call or an email interaction. In some countries, nurses are empowered to prescribe basic drugs such as antibiotics. In such a circumstance, a nurse at the rural clinic can finalize the treatment of the patient.

A third category is patients who require emergency treatment for extreme high blood pressure, high fever, and other life threatening disorders. Such patients are sent to a regional hospital, if one is available, that has the capacity to provide appropriate assistance.

EDPS was not designed to be comprehensive or to provide absolute recommendations. The system provides guidance and recommendations that need to be reviewed by a nurse or an experienced paramedical health worker. The productivity of doctors can thus be significantly increased through computer-assisted diagnosis and preventive healthcare can be greatly enhanced through the use of the EDPS database.

Validation Studies

In 2002, the Kempegowada Institute of Medical Science (KIMS) located in Bangalore, India conducted a validity study [13] of the diagnostic capabilities of EDPS.

Over a period of three and one-half months, 1156 patients were examined by a physician at the outpatient section of the Preventive Medicine Unit of the KIMS Hospital and Research Centre and then interviewed separately using EDPS. Nine hundred and thirty-three patients were consistent in what they reported in each of these two examinations. The EDPS operator did not have any information about the physician examination. For 94% of the 933 patients with consistent interviews, the EDPS and physician analyses agreed. The most frequent complaints were fever, weakness, headache, stomach problems, cough with sputum, vomiting, and skin problems. The overlap varied from 100% for certain diagnoses to 85% for others. The 100% concurrence included renal, ear, nutrition, and fever problems while the 85% concurrence included endocrine system disorder, skin patches/ulcers, and hepatic (liver related) diseases.

A study [14] was also conducted by the Department of Community Health of St. John's Medical College of Bangalore on Process Evaluation. This study examined issues of implementation such as integration of EDPS into the operations of a clinic, human resource needs, cost and maintenance issues, as well as the acceptance of the system by staff and patients.

Of particular interest is the issue of patient acceptance given that about a third of the patients are illiterate and are being confronted with an interview that includes computer interactions. The study found that patient responses were positive, since in comparison with prior visits to a government run health center, the computer asked more questions and printouts made the staff more accountable. Patients seemed to view the EDPS experience as a more accurate and in-depth interaction than they had experienced previously.

Staff responses included comments that it might be preferable to have Village Health Nurses serve as the EDPS operators. It was observed that perhaps a majority of the Village Health Nurses were interested in doing so provided that it did not involve duplication of records.

Rural Clinic Computer and Laboratory Facilities

Visits by the author to rural clinics in Mozambique and Rwanda revealed that even sites without electricity have reliable computers and printers, which are needed to provide reports to government ministries. Solar energy systems and diesel generators are adequate sources of electrical power. Similar stand-alone computers would support EDPS. Since EDPS requires a Windows operating system and the ability to run SQL database software, some of the new low-cost computers becoming available in the developing world would not be suitable. However, the cost of standard PC technology is falling substantially.

An important capability that should be included in the infrastructure of even the most basic rural clinic is a laboratory analysis facility. A high school graduate level technician with minimal training can process a number of tests that can facilitate diagnoses, whether by computers or by humans.

For example, simple procedures can yield a good estimate of hemoglobin levels in the blood, thus advancing the evaluation of anemia. Straightforward techniques can also provide understanding of various characteristics of urine. A urine test strip can measure glucose, blood, proteins, and other characteristics. Tests are easily implemented as well for HIV, malaria, and other diseases. Results from these and other tests can be fed back into computer-based diagnostic programs or added to the referral documentation that is provided for doctor or hospital use.

Technological Enhancements and Opportunities

While EDPS has been useful and effective in India for more than seven years, its potential use in Sub-Saharan Africa calls for several modifications and enhancements. There are also opportunities for added capabilities.

African Diseases

The first task in adapting EDPS to an African country is the expansion of the disease database and the related diagnostic analysis for diseases that are present in specific African countries, but which have not been included for use of EDPS in India. Given that EDPS focuses on the 300 most common diseases in environments that are rural and poor with malnutrition, inadequate sanitation, and problematic drinking water supplies, the overlap with African settings will be substantial. Candidates for additions to EDPS are likely to be found among the parasitic afflictions of Africa.

Language

EDPS has been developed in India in English. It is used successfully in regions of India where there are various local languages through the ability of implementing operators to translate as needed when engaging in dialogue with patients. It has been found that EDPS operators, with minimal proficiency in English, can quickly learn the meaning of questions prompted by the system to enable them to translate into the local language of the patient being interviewed. If this mode of operation is not manageable in Sub-Saharan African countries, then translation into French and Portuguese will be needed for countries where necessary. Translation will be challenging, since words that meet the criteria of dictionary correspondence may not have identical medical usage.

Internet

EDPS was developed for use with a stand-alone PC Windows environment, and will be effective in that mode. However, as the Internet becomes increasingly available in African countries, a number of advantages are likely to emerge through inclusion of communications capabilities via the Internet. Online consultations, access to external databases and other Web based resources will provide numerous opportunities to enhance the effectiveness of EDPS. The PC Windows environment should make it easy to convert EDPS machines to incorporate Internet functions.

Telemedicine

Internet and Satellite video links have been used for many years to bring medical care to remote locations. Interventions ranging from consultations to remote surgery have been facilitated by those technologies. Rural clinics that employ a computer-assisted diagnostic system and also have telemedicine capability could serve most patients without the need for referral to regional hospitals. As connectivity becomes more economically feasible at rural sites in Sub-Saharan Africa, such technological models should be explored with pilot projects.

Remote Consultation

Numerous telemedicine examples exist in which expert physicians, usually based at medical centers, assist understaffed medical facilities elsewhere. But opportunities for consultations with individual doctors around the world have not been developed on a large scale. As the Internet becomes more common in rural clinics, consultations with such doctors will become possible. Given the history of doctors volunteering for humanitarian service, it is likely that large cadres of MD's will be available. In particular, physicians who are in a given country's diaspora might feel a special obligation to contribute to healthcare in their land of origin. Considering the large number of doctors who have emigrated from countries like Malawi and Mozambique, a significant pool exists for recruitment into remote consultation programs. Note that remote consultations do not need to be synchronous. Data can be sent at one point in time and reviewed by the consultant at a later time provided that the feedback is not in the context of an emergency situation. These remote consultations would be limited to those cases that require the special attention of a trained physician.

Data Analysis

With a program like EDPS in place at rural clinics in Sub-Saharan Africa, the data gained can help in epidemiological analyses as well as in planning for drug supply management. Systematic data analysis will generate valuable information about disease patterns and the need for critical medications.

Dermatology

The field of remote dermatology is already well developed [15]. Images of skin pathologies can easily be transmitted via Internet and examined remotely. What has not yet been implemented is the matching of such images via automated systems such that a physician is not required to be part of the process.

EKG

Electocardiograms (EKGs) have become a regular component of Telemedicine. Low-cost, simple-to-use EKG equipment is being developed in India for telemedicine applications at rural clinics [16]. However, there is a great deal of information in EKG displays that can be analyzed automatically using computer technology. The EKG data can be of value in a diagnosis without being analyzed at a remote location. Such information could possibly be incorporated into a computer-assisted diagnosis system such as EDPS.

OpenMRS

As already noted, the database provided by EDPS has been used in India to successfully track patients, and to monitor prenatal and postnatal progress, as well as the health status of children under the age of five. Databases used in patient care at clinics are also needed for patient tracking in follow-up care. Sub-Saharan African countries have similar needs in this regard and many are recognizing the advantages of having commonly used open source software for these applications. Many are coalescing their efforts on the implementation of a data base system known as OpenMRS. See: http://openmrs.org/wiki/OpenMRS.

EDPS or any similar diagnostic system will need to have a patient database that is compatible with local usage. Adaptation of the EDPS database to an OpenMRS format will probably be needed.

Need for Comprehensive HealthCare Policies and Programs

In a compelling analysis of global health issues entitled "The challenge of global health," in the Jan./Feb. 2007 edition of *Foreign Affairs* [17], Laurie Garrett states:

> "Today the top three killers in the most poor countries are maternal death around childbirth and pediatric respiratory and intestinal infections leading to death from pulmonary failure or uncontrolled diarrhea. But few women's rights groups put safe pregnancy near the top of their list of priorities, and there is no dysentery lobby or celebrity attention given to coughing babies."

Billions of dollars are being devoted to ameliorating the ravages of HIV/AIDS, malaria, and tuberculosis in Sub-Saharan Africa. For the most part, these efforts are being pursued without concern for primary healthcare issues. Personal behavior, healthcare facilities, personnel, database development, etc., are focused narrowly on these three diseases. While it is imperative that these three devastating diseases receive urgent attention, the long-term health issues for Sub-Saharan Africa will not be resolved until comprehensive healthcare programs are in place in the context of sustainable networks of effective clinics and hospitals. This must incorporate an effective primary health system of local clinics that are within walking distance of the populations that they serve. A major advantage of implementing a program like EDPS is that it is a general program that deals with many aspects of healthcare, encompassing maternal health and early childhood health as well as HIV/AIDS, malaria, and TB.

A small number of symptoms account for a majority of the patients vising rural healthcare facilities.

Appropriate Approach—Computer-Assisted Diagnostic Software

Given the extreme shortage of physicians in Sub-Saharan African countries, computer-assisted diagnostic software to process patients at rural clinics appears to provide an appropriate approach with long-term implications. However, little attention has been paid to the utilization of computer-assisted diagnostic systems for rural environments where fully qualified physicians are not present. Such a system has contributed to improved healthcare for more than seven years in rural India and holds promise for applications in Sub-Saharan Africa. Pilot projects and field tests are needed to determine appropriate implementation strategies for healthcare environments in rural Africa. Both the patient examination process and the use of a patient database in proactive preventive medicine initiatives need study and development. With emerging new technologies for Internet communications and Internet-capable medical instrumentation, new models for healthcare in rural locations in Sub-Saharan Africa are emerging that deserve examination and testing. Any plan for rural healthcare in Sub-Saharan Africa requires a strategic approach to the establishment of a tiered system of first-level health centers, regional clinics, and national hospitals/specialty centers that incorporate the use of technology, while making the best use of human and financial resources.

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