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Telehomecare and Remote Monitoring: An Outcomes Overview

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Telehomecare and Remote Monitoring:
An Outcomes Overview

Authors:

Max E. Stachura, MD
Director, Center for Telehealth
Professor, Depts. of Medicine and Physiology
Georgia Research Alliance Eminent Scholar in Telemedicine

Elena V. Khasanshina, MD, PhD
Associate Director, Center for Telehealth
Assistant Professor, Dept. of Medicine

Medical College of Georgia
1120 Fifteenth Street
Augusta GA 30912

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Executive Summary

Management of chronic diseases such as diabetes, congestive heart failure and chronic obstructive pulmonary disease occurs away from health care facilities, requires patient self-management and behavior modification and depends on the regular collection of patient status data in real-life settings (monitoring). Measurements such as capillary blood glucose, blood pressure, respiratory peak flow rate and weight allow patients to self-administer appropriate amounts of medication in response to dietary and activity variations (insulin), adequacy of medication dose (anti-hypertensives) and excessive fluid accumulation (suggesting deteriorating heart function leading to compromised breathing). Electronic data capture and Internet-enabled timely review by clinicians (remote monitoring) can enable immediate and preventative management adjustments between office visits (telehomecare).

Telehomecare and remote monitoring are increasingly recognized as valuable tools for enhancing care quality in chronic disease management. They have the potential to deliver new savings for both patients and providers. For patients, this means fewer office and emergency room visits, fewer and reduced duration of hospitalizations, reduced patient travel time and expense, and increased access (for the elderly, the physically challenged, the homebound, and especially for rural patients). For clinicians, it means more informed decision-making, enhanced patient compliance and more efficient outreach case management.

The results of studies to date are promising and show clear value in remote monitoring and telehomecare. But they also point to technology, infrastructure, access and reimbursement issues that must be addressed for maximal care quality improvement and cost savings. These are multi-faceted issues that will require careful and coordinated evaluation by payors (Medicare, Medicaid and private insurers), government (federal, state and local), care providers (physicians

and nurses, hospitals, home health agencies, and nursing facilities), and employers, as well as an assessment of technology needs (medical technology, infrastructure, and telecommunications).

While most published studies are small, some are contradictory, and the need for large well-controlled trials remains, evidence supporting the value and the potential of telehomecare is clear and growing.

I. Introduction

Timely access to health care in both urban and rural settings is a worldwide challenge. No nation that is committed to the health of its population can afford to replicate, in every community, all the resources required for comprehensive health care. On the other hand, as the potential for universal Internet access approaches reality, consumer access to health information and portals for health monitoring and health care-related services is assuming increasing importance. These facts are changing the health care system and re-defining the roles of its players including patients, clinicians, health educators, hospitals and clinics, public health organizations, and health insurance agencies and companies.

The Internet allows patients and family members to acquire, on their own, large amounts of disease-related information. As a result, clinicians who were previously the custodians of health information are increasingly becoming patient and family advisers about the use, relevance and specific applicability of that health information in individual situations. The combination of information and advice is then used by patients for decision-making and action. Patients are turning from the role of passive recipients of provider instructions and interventions, to the more self-responsible roles of active and knowledgeable participants in the decision-making and management of their own health.

As this happens, consumers seek ways to operate within the realm of their own convenience rather than the convenience of the clinician [1]. In this regard, they report dissatisfaction with inefficiencies and personal inconveniences encountered in the current health care system—such as wait times to get appointments [2], inconvenient physician office hours and long office wait times [2,3], and after-hours care that is currently limited to emergency departments and urgent care clinics [4,5]. Internet- and wireless-linked consumers are coming to expect access on demand [1]. Providers and businesses are responding to these needs by exploring the creation of alternative solutions for off-hour routine and low-level urgent care [6,7].

The aging population provides another important aspect of the growing demand for creative and cost-effective health care solutions. As Baby Boomers approach retirement, they enter a period of life in which they are at higher risk of costly and damaging chronic diseases such as heart disease, diabetes and cancer, among others. With economic strains already obvious in health care—currently chronic diseases constitute roughly 75 percent of all health care spending—management and control of chronic diseases becomes increasingly critical [8, 9,10].

In this environment, the field of telehealth—that is, the use of electronic and communications technologies to enable long-distance health care—may be the only economically viable way to make health care resources available, responsive and convenient for individual consumers, while being practical for providers to deliver throughout communities, regions or nations.

An important component of this decentralization is the disease-relevant monitoring of physiological parameters of patients. Remotely captured data must be available to both patients and providers to facilitate patient on-the-go decision-making, to alert clinicians to unanticipated

needs for treatment interventions and to enable collaborative patient-clinician planning for long-term disease management and health maintenance efforts that take place where the patient wants to be—at home, at leisure, and productively at work and school.

It is, therefore, essential that barriers to universal broadband access be overcome [11], and that obstacles to adequate reimbursement for such telehealth services be removed. The general access to information and health resources that result will contribute importantly to individual and community health, as well as to the health care systems that support it, especially in the realms of chronic disease monitoring and management.

II. Telehomecare and Remote Monitoring

A first-order barrier that many encounter is the broad range of terms and definitions in the entire field of what is often referred to as "telemedicine" or "telehealth."[1] In general, these terms encompass a wide range of services that use electronic and telecommunications technologies to either provide care, or support care provided, electronically over a geographic distance—often between central health facilities and rural locations or homes. This paper focuses primarily on a subset of these services called telehomecare and remote monitoring. (It also later discusses and defines what is known as traditional consultative telemedicine.)

As defined by the American Telemedicine Association's Home Telehealth and Remote Monitoring Special Interest Group [12], "*Home Telehealth* is a service that gives the clinician the ability to monitor and measure patient health data and information over geographical, social and cultural distances" using video and non-video technologies. The objective is to increase patient access to health services, improve disease management including self-care management and

[1] For further explanation and definitions, see Appendix: Contextual Background and Definitions of Terms.

drive "earlier and proactive interventions for positive outcomes." The technology used is driven by clinical need, management objectives and available resources.

Remote monitoring may include video-conferencing, messaging reminder and surveillance questioning, and/or one or more sensors—such as electrocardiogram, pulse oximetry, vital signs, weight, glucose, and movement or position detectors.

These technologies provide information about the patient's condition and support "…post-discharge care, home health, chronic care management, schools, skilled nursing facilities, sub-acute care and senior living facilities…" by providing "…education, monitoring, patient self-directed care and the ability for individuals to have more effective access to health care...." They can also be clinician enablers that "…facilitate quicker assessment and proactive intervention…to improve quality of life" [12] for patients with chronic diseases who may be either homebound or going about the business of their daily lives.

The technologies used in telehomecare and remote monitoring run the gamut of technological complexity, including whether and how they access the Internet (wired or wireless). Historically, free "call-a-nurse" programs have used the telephone to answer patient questions and direct them to health care services. In addition, some communities and practitioner offices provide nurse-initiated and/or automated surveillance systems that use telephone lines to provide patient reminders or confirm basic patient functionality [13]. More sophisticated telehomecare and remote monitoring applications can be accessed from wired, networked workstations where the rapidity of download is not a major concern and where the need for upload is minimal.

Perhaps among the most sophisticated technologies in this field involve monitoring of physiological parameters, such as blood glucose in individuals with diabetes mellitus, and

decision support applications that guide clinical management. These technologies are available in the mobile environment of real life—home, work, school, travel. Data collection from chronic disease-related monitoring of physiological parameters is possible irrespective of patient location and sharable with clinicians, also irrespective of location—assuming adequate Internet connections are available. These monitoring data will have value in many scenarios: for use in patient-clinician discussions at a later time; for connection to an alert system for both patient and provider that warns of deteriorating clinical status; and/or for immediate linkage to databases, decision support systems, and algorithms for mobile patient self-management based on plans and parameters previously decided upon with caregivers.

The clinical conditions that are most commonly addressed by telehomecare and remote monitoring programs include, but are not limited to: asthma, diabetes, chronic obstructive pulmonary disease, chronic heart failure, mental health (anxiety and depression) and wound care.

III. Benefits of Home Telehealth Monitoring and Care

Studies that seek to document the benefits of telehomecare and remote monitoring generally focus on patients and their families, although some examine benefits to providers, communities and the health care system. This paper focuses on the patient/family unit and the responsible clinical providers.

Core parameters addressed and evaluated in these studies include one or more of the following: access, support, education, health outcomes, quality of care, social isolation and quality of life. These parameters tend to be studied in the context of overall cost, cost-effectiveness, health services utilization, acceptability and satisfaction. Available data generally

suggest that telehomecare and remote monitoring have the potential to show benefits in most, if not all, of these topic areas.

It is also important to keep in mind that telehomecare and remote monitoring are usually viewed as supplements to normal in-person care and not as substitutes, except when extreme circumstances (e.g. geography and distance) make telehomecare and remote monitoring the only option.

A. Improvements in Clinical Care

Telehealth remote monitoring technologies have the potential to improve clinical management of chronic diseases. There are many clinical conditions for which telehomecare is being used, and home remote monitoring has been shown to benefit patients with chronic diseases in many research trials. Of these, patients with diabetes mellitus and congestive heart failure have received the most attention [14,15].

In this paper, we focus on three significant public health problems: diabetes mellitus (DM), congestive heart failure (CHF), and chronic obstructive pulmonary disease (COPD). Each has great potential for benefiting from remote monitoring.

Diabetes Mellitus

There are an estimated 20 million diabetic individuals in the United States, representing approximately seven percent of the population (American Diabetes Association, 2007). The goals of intensive insulin therapy in DM are to achieve near-normal blood glucose control and avoid short-term crises, including hypoglycemia. The benefits of intensive insulin therapy for the treatment of DM have been well-established and include both reduced long-term complications [16] and reduced cost to the health care system [17].

DM patient involvement in self-monitoring and intensive blood glucose management can be improved by using telehomecare and remote monitoring technology. For example, randomized trials and meta-analyses were conducted by Canadian researchers [18] to determine where use of these technologies can improve glycemic control—that is, control of blood sugar levels within normal ranges—in Type 1 DM patients. The researchers used wired telephone modem communication between patients' homes and a research computer. In a randomized trial of patients on an intensive insulin regimen that initially had failed to achieve glycemic control, the researchers found better overall glycemic control in patients receiving multiple daily insulin injections or continuous subcutaneous insulin infusion. Telehomecare enhanced adherence to self-monitoring, which is essential for achieving glycemic control. Meta-analyses showed that telehomecare was equivalent to intensive usual care (pooled HbA_{1c} change from baseline: mean difference 0.2%, 95% Confidence Interval – 0.2 to 0.6%).

Columbia University's Informatics for Diabetes Education and Telemedicine project provided videoconferencing and data collection from glucose meters in 400 patient homes [22]. In a randomized trial comparing telehealth case management with usual care in a Medicare population with Type 1 DM, researchers showed an HbA_{1c} improvement[2] over the course of one year in the initially poorly controlled (initial $HbA_{1c} \geq 7$ percent) intervention group. The improvement reflected a reduction in the average blood sugar levels from 8.35 percent to 7.42 percent. This was a significantly better response ($p=0.002$) than was seen in the control group—whose blood sugar levels dropped from 7.42 percent to 7.17 percent.

Several studies document that telehomecare and remote monitoring improve patient knowledge about diabetes self-management, improve patient self-monitoring, and thus can

[2] The HbA_{1c} test evaluates the average level of glucose in the blood during the preceding two to three months. The goal is to keep such levels close to normal levels. The test helps physicians know whether the efforts to control diabetes are working or need to be adjusted.

improve the quality of the ambulatory care for the disease. The result is better physiologic control as measured by daily home capillary blood glucose (CBG) monitoring and office measurement of HbA1c levels to assess average control [18,23-25]. In these cases, the remote monitoring of CBG levels—the values themselves, their patterns and the degree of patient compliance with testing—provide a rich source of information for both the afflicted patient and the clinical caregiver (e.g. responses to dietary intake, activity levels, and the effects of medication).

In the short term, as these studies show, systems that notify either the patient or the clinician, or both, concerning CBG values outside a mutually identified target range can stimulate important corrective action. This can include action by clinicians to modify the treatment regimen to prevent acute complications (hypoglycemia or ketoacidosis) and action by patients to make diet or lifestyle changes.

In the long term, information about CBG levels and patterns of response to diet, exercise and medication that are gathered in the course of normal living, rather than in the artificial setting of the medical office appointment, allow the development of realistic baseline management plans and empower knowledgeable and flexible self-management of both unanticipated disruptions and planned variations in the routine of daily living.

As a result, patients make good decisions in real time rather than waiting for clinician advice at the next office appointment. Improved control of CBG levels within physiologic target ranges is the result. Long-term control within these targets is associated with reduced and/or delayed onset of damaging and costly complications known to be associated with poor control of DM. These include blindness, kidney failure, impotence, acute cardiac events and peripheral vascular disease that can result in amputation.

To be sure, not all studies about remote monitoring or telehomecare are unanimous in their conclusions about benefits and improvements in care. For example, British researchers [19] studied telehealth support through a mobile phone-based system that used real-time data transfer. In this systematic review, these interventions to support blood glucose self-monitoring in DM were found to be both feasible and acceptable. However, the evidence for their effectiveness in improving HbA_{1c} levels, reducing costs while maintaining HbA_{1c} levels, or improving other aspects of diabetes management was not strong. In their own trial study, these authors also found equivalent HbA_{1c} changes in intervention and control groups [20,21]

It is not surprising, especially in such a new field, that contradictory findings arise or that the degree of benefit varies. What the studies on the use of such technologies for DM do agree on is the clear potential of remote monitoring and telehomecare in addressing the patient access and clinical care needs noted earlier.

Congestive Heart Failure

In a similar fashion, remote monitoring of patients with congestive heart failure (CHF) and patients using implantable cardiac defibrillators can lead to better management of medications and patient behavior.

CHF is a deadly disease and one of the primary causes of hospital admissions. Once a person has been hospitalized with CHF, there is a 25 percent chance that he or she will die or be re-hospitalized within three months [26]. Nevertheless, careful management of CHF, including careful reporting of changes in weight and symptoms, can extend lives and improve quality of life. Two recent randomized controlled clinical trials show that remote monitoring can be a useful component in achieving these goals.

A study of 426 patients found that remote monitoring—in which an electronic device recorded and reported blood pressure, pulse, heart rhythm and weight and transmitted them via telephone lines to a Web site—substantially reduced the mean duration of hospital admissions and the number of home or office visits when compared to monthly follow-up phone calls from nurses [26]. The duration of each hospital stay for the remote monitoring patients was 10.9 days versus 14.8 days for patients who only received telephone calls from nurses. Office visits were reduced 10 percent and home visits were reduced 65 percent for the remote monitoring group versus the nurse telephone call group.

In another study, a randomized trial of 280 patients from 16 U.S. heart failure centers found that a home monitoring device that captured and transmitted weight of heart failure patients reduced the six-month mortality rate 56.2 percent, as compared with a group of patients who did not use home monitoring [27]. The study concluded that, "Despite aggressive medical management in both arms of the study, this non-drug, daily monitoring technology intervention provided an additional mortality benefit beyond guideline-recommended care for patients with advanced heart failure." According to the authors, daily monitoring and evaluation of symptoms by trained nurses via remote monitoring allowed for rapid assessment and action when warning signals appeared. This included immediate notification and action by physicians when necessary.

These and other applications have produced reductions in hospital admissions, emergency department visits and the overall cost of the CHF patient's care [25,28-31]. A study that tracked data on 281 veterans who received telehomecare found significant reductions in resource consumption. After 12 months, hospital admissions for the usual care group increased 27 percent—in contrast to a 60 percent reduction for the telehomecare group. Emergency room

visits increased 22 percent in the usual care group, while they decreased 66 percent for telehomecare. Also, the usual care group experienced a 37 percent increase in pharmacy utilization, versus a 59 percent decrease for those receiving telehomecare [74].

Another and unique example of corrective remote monitoring includes implanted cardiac defibrillators that monitor the heart's rhythm and apply a corrective stimulus when an aberrant rhythm occurs [75].

***Chronic Obstructive Pulmonary Disease* (COPD)**

Patients with COPD and asthma experience similar benefits from telehomecare and remote monitoring [32-36]. COPD can be successfully monitored in the home with a high quality of clinical service and no increase in cost [37]. Functional status is reported to be improved or maintained more effectively in remotely-monitored patients than in non-monitored patients [38]. When patients with severe respiratory illness requiring long-term oxygen therapy were remotely-monitored, hospital admissions decreased by 50 percent, acute home exacerbations decreased 55 percent, and hospitalization costs were reduced by 17 percent, even after the costs of monitoring were included [25].

Monitoring of this kind can enable more sophisticated home care, detect deterioration prior to symptom development and minimize the need for complicated and cumbersome patient transportation to hospital/office appointments.

Because they can now be reliably monitored at home, home-bound COPD patients may be able to receive better care in other ways. When the home-care program is carefully designed and implemented, early release from the hospital will not endanger patient health, will reduce patient exposure to hospital-acquired infections and will minimize risks associated with return to the hospital/office for routine clinical examinations [36,39,40]. Further, although it is not

possible to make the home environment as safe as the intensive care unit, clearly defined steps can be taken to minimize risk [41].

In all these contexts, studies have demonstrated health benefits in terms of reduced hospitalization days, reduced clinic visits, enhanced quality of life and satisfaction with technology. Cost benefits have been demonstrated for patients, home care agencies and the health care system. [42]

B. Cost, Cost Benefit and Cost Avoidance

As with the clinical benefits of telehomecare and remote monitoring, studies also have shown cost-savings in DM, CHF, and COPD. Schiller, Bondmass, and Avitall (1997) combined daily monitoring and educational reminders about diet and symptoms on a device that allowed CHF patients to transmit data on weight and other physiological measures to a central workstation via a telephone line [43]. They found that such remote monitoring saved approximately $8,000 per patient because telehomecare reduced the need for conventional visits (which cost about $100, versus $15-$40 for a tele-visit).

In a telehomecare research project conducted in Sacramento, California, 212 home health patients were randomly assigned to an intervention or control group [44]. The intervention group received video visits in addition to home visits. The average direct cost for home health services was $1,830 for patients in the intervention group and $1,167 for the control group patients. However, because patients in the intervention group experienced less re-hospitalization, the cost savings were $63 per patient in the intervention group. The researchers concluded that telehomecare is capable of maintaining quality of care while producing cost savings.

In a Pennsylvania telehomecare project, 171 diabetic patients discharged from the hospital were randomly assigned to remote monitoring intervention or traditional care control groups [10]. Per patient cost in the control group was $2,365, versus $1,668 in the remote monitoring group. Based on these study data, hospitalization costs were estimated at $87,327 for telehomecare patients and $232,872 for control group patients. The authors concluded that telehomecare can provide home monitoring services to the same number of patients at lower cost than in person.

In a Canadian study, daily information from COPD patient homes (peak flow rate, symptoms) was transferred by an electronic device and reviewed by nurses [45]. The device had the capacity to analyze the data transferred and provide alerts when data were outside established parameters. Patients were then advised by a preprogrammed device on the recommended response. The results included fewer nurse home visits and hospitalizations for patients in the experimental group. In summary, six months of remote monitoring saved $355 per patient (15 percent of total cost for this service) compared to traditional home care in the control group.

In Minnesota, in a randomized controlled trial, a control group (C) received traditional nursing care at home. In addition to traditional nursing care at home, one intervention group (V) received virtual visits using videoconferencing technology and a second group (M) received both virtual visits and physiologic monitoring [46]. Within six months of study participation, 42 percent of group C patients were sent to a higher level of care (hospital, nursing home). Only 21 percent of group V and 15 percent of group M patients required that higher level care. There was no difference in mortality and morbidity among the groups. The average visit costs were $48.27 for group C, $22.11 for group V, and $32.06 (CHF) and $38.62 (COPD) for group M

patients. The authors concluded that telehomecare can improve patient outcomes at a lower cost than traditional care.

Department of Veterans Affairs. Speaking before the House Committee on Veterans Affairs [47] in April 2007, Acting Principal Deputy Under Secretary for Health Dr. Gerald M. Cross explained that the Department of Veterans Affairs (VA) served approximately 5.4 million patients in FY 2006, 41 percent of whom lived in rural areas. The primary challenge in serving rural veterans is access to quality care. New technologies and treatments have changed the service focus from inpatient to outpatient and in-home services, and telemedicine capabilities (including telehealth and home-based primary care) play an important role. VA telehealth programs are of an unparalleled size and complexity. In FY 2006, about 25,000 veterans received in-home tele-support for chronic diseases such as DM, CHF, COPD, post-traumatic stress disorder (PTSD) and depression, with a 50 percent increase projected by the end of FY 2007.

The multi-faceted VA program is publishing cost-effectiveness data. For example, Agha, et al, reported [48] that the delivery of pulmonary care to a rural VA population on-site or using routine ambulatory care cost, respectively, $1,166 and $585 per patient/year, while telemedicine cost only $335 per patient/year. In addition, Schofield, et al, found [49] that a telehomecare program for elderly veterans with CHF produced significantly improved blood pressure and fewer shortness of breath complaints, improved medication compliance and improved weight control. In addition, the total number of inpatient hospital days for veterans on the home telehealth program was reduced from 630 in the previous year to 122, with only one third of those hospitalizations being related to heart failure.

However, as the latter authors [49] and others [50] caution, "The findings of this study cannot be generalized because they were not based on a randomized clinical trial." [49]

C. Telehomecare and Remote Monitoring: Potential for Growth

Historically, telemedicine began as a means of connecting patients to expertise not available in their local community. This approach to networking resources is no longer an experiment. It is successful and employed to a variable extent in every state. The potential for telehomecare and remote monitoring was recognized early in the course of telemedicine's development, but its practical application required the recently deployed advances in telecommunication technologies by the communications and Internet-related industries and the development of appropriate remote sensor technologies by medical innovators and device manufacturers.

It is believed that this increased intensity of disease monitoring and management will create improved patient health with resulting reduction of acute and chronic complications, and that these will translate directly into decreased consumption of expensive emergency health care resources (emergency room visits and rehospitalizations) and decreased long-term disease complications. This, in turn, should translate directly to decreased consumption of expensive medications, personnel, equipment and hospitalization days required to manage those long-term complications [25,30,33,51,52].

This belief is increasingly supported by data emerging across a wide range of diseases and in various treatment venues. For example, one study of frail, elderly veterans in the VA Connecticut Healthcare System who suffered from CHF, COPD or DM found that those who received home telehealth services used fewer nurse visits at home, bed-days-of-care, urgent

visits, and transportation to facilities—yet had equivalent outcomes—in comparison to the participants who received standard care. Though telehealth added $1,666 to the costs during the six-month study, the overall health care costs decreased by 58 percent for the group receiving telehomecare. [30]

At the same time, the true potential of telemedicine as described throughout this paper is by no means assured, particularly in light of what economists might call a potential market disconnect. That is, when one examines the entire health care spectrum—from patient, to provider, to infrastructure, to payor, to local community, to the nation at large—it becomes clear that the sectors that pay most of the costs for remote monitoring and telehomecare are not necessarily those who receive most of the benefits.

Stated more specifically: (a) the beneficiaries of health care services delivered through telehealth and remote monitoring (e.g. patients) are frequently not the sector responsible for the financial burden of providing and maintaining the infrastructure required to make those services available, and (b) the sector responsible for the financial burden (e.g., public and private payors, as well as providers and medical professionals) of providing the short-term monitoring and management services aimed at reducing long-term complications and costs may not be, or may not perceive itself to be, the sector that benefits financially from the prevention of long-term complications of chronic disease.

This may create the market disconnect referenced above that could threaten the emergence of these forms of telehealth and realization of their true potential. That is why it is critical that the potential economic and clinical benefits of telehomecare and remote monitoring are clearly identified and their value more fully understood by all parties.

To that end, the following outlines the array of benefits from telemedicine and its various manifestations that accrue to various elements—local communities, providers, and, of course, patients. It also identifies, in this same context, potential costs.

Traditional Consultative Telemedicine

Traditional consultative telemedicine provides an excellent example of both potential costs and potential benefits. Traditional consultative telemedicine differs from the telehomecare and remote monitoring discussed throughout this paper. Whereas telehomecare and remote monitoring involve transmitting information to or from the patient or the patient's home, consultative telemedicine connects patients and physicians at a local medical facility—a physician's office or a remote clinic, for example—to medical experts and expertise at distant medical locations, such as academic health centers or hospitals. This may be through direct video links, Web-based video, digital image transfer or data and images conveyed over the Web. A variety of medical specialties use consultative telemedicine, including radiology, ophthalmology and cardiology.

Consultative telemedicine connects patients to medical expertise not available in their local communities. Rather than replicating all potentially required resources in all communities where they are needed, it is a model for projecting resources that are currently physically concentrated—usually in urban locations—to where and when they are needed, frequently in rural or remote locations. This type of telemedicine use supplements locally available care and thereby increases the level of sophistication that can be delivered by clinicians practicing in the local community.

Associated expenses for this type of telemedicine include the one-time cost of acquiring and installing the necessary equipment, the on-going costs of telecommunication line charges associated with the clinical encounter, maintenance fees for the equipment, technical personnel necessary to operate the equipment, administrative personnel to handle appointment scheduling, and clinical personnel to present the patient to the distant consultant. The equipment is generally located in a health care related facility, sometimes in or near its emergency room. The patient comes to the telemedicine appointment just as he or she would to an in-person medical appointment, sometimes accompanied by the local primary care provider.

In addition to the costs, of course, there are very clear benefits—some obvious, others less so. Direct patient benefits include (a) access to medical expertise not available locally; (b) timeliness—the consultation appointment usually occurs more quickly than would be possible at a distant facility and, as a result, appropriate treatment can be initiated sooner; (c) convenience—travel time to a local venue is much less than travel time to a distant site; and (d) cost avoidance—both indirect and direct.

The latter can be substantial, potentially including lost income from time away from work; travel expenses (transportation, lodging and meals); and expenses for child care—either because children were left at home or because this option was unavailable and they had to be brought along.

As for benefits to physicians, the primary care clinician receives the benefit of the consultative advice just as she or he would if the patient traveled to a distant physician consultant. The clinician can choose to attend the tele-consultation and discuss the patient with the consultant directly (some telemedicine programs also offer Continuing Medical Education credit for this encounter). As a result, both in the short term (the particular consultation) and in

the long term (as a result of discussion with the consultant) the primary care clinician can learn to provide more sophisticated care to patients than he or she could previously deliver, and community resources are thereby enhanced [53].[3]

Communities benefit as well from hosting a telemedicine connection to external specialty resources and academic medical centers. This is particularly important in rural or underserved areas. Employers certainly experience less loss of employee work time due to travel avoidance and may actually experience reduced employee downtime as a result of more timely and effective patient care. This can result in both a perceived and an actual increase in workforce health that can assist communities to both retain existing employers and attract new ones. In addition, patient expenditures for medications and medical self-management devices recommended by the distant physician are more likely to be purchased locally rather than in the distant community.

Telehomecare and Remote Monitoring

Delivering remote monitoring and telehomecare will have its own associated costs in terms of equipment, supplies and personnel time. This must be accounted for in the context of both the overall cost of care and the business expenses of the individual physician office or agency delivering the care.

Of course, providers will continue to be the final source of care in this environment of telehomecare and remote monitoring, but a new and potentially time-consuming function is

[3] In the past, some programs tied consultant reimbursement to the presence of the primary care provider in an attempt to reassure the local provider that the consultation would not result in the patient leaving the local provider's practice. In that scenario, primary care provider dissatisfaction with tele-consultation arose, even when he or she was also reimbursed for the visit. The dissatisfaction originated not in terms of the value of the consultation but in the loss of productive primary clinician time involved traveling to and from the tele-consultation site – time that could have been used to see other patients in a busy office.

added to their workload—that of real-time advisor. This emerges from the fact that patients will monitor themselves during the course of daily living at home, at work or at school. Real-time or bundled data uploaded to databases to which both the patient and the provider will have access require manual or automated review and interpretation by the medical provider, and may require action.

In particular, providers will likely experience some increased costs because of their responsibility to monitor the in-coming data. Wherever possible, they will want that monitoring to be automated so that normal monitoring results can be recorded and filed for future reference, but out-of-target-range data will be brought to their attention. In the best case, these latter data will require cautionary messages to patients that can be automated and copied to the provider. However, the data may signal a need for an intervention, a preventative change in management, a follow-up call of further inquiry, or the need for an earlier in-person appointment. These responsibilities will add to the workload of the provider office, whether that is the office of a physician, a community health center or a home health agency.

At the same time, it is clear that many benefits come from remote monitoring and telehomecare, with the potential for many more. They accrue to the patient, the community and the health care system.

Patients using telehomecare and remote monitoring can remain in their homes and communities, thereby avoiding travel, job interruption and inconvenience. This is particularly important for Medicare patients, who may need family members to drive them to doctor appointments.

As noted earlier, it is believed that increased disease monitoring and management will lead to better patient health, along with reduction in complications and less need for

hospitalization and emergency room visits. That such results are occurring in costly chronic diseases, such as diabetes and congestive heart failure, holds promise for reducing long-term costs of chronic disease. With such costs currently at about $1.5 trillion annually, better management of chronic disease through careful monitoring, prompt intervention/adjustment and better patient adherence to treatment regimens represents clear economic benefits for patients, public and private payers and the U.S. health care system.

An important benefit often not recognized is the value of greater convenience and time for patients. Because patients will want to minimize the effect of their illness on their productivity at home, work and school, they will want to minimize any disruption in their day that the condition might cause. Thus, patients will use data from remote monitoring and telehomecare to make chronic disease management decisions on-the-go. Real-time questions will arise. Patients or their family caregivers will want answers sooner rather than later, preferably at a time and location that is convenient for them. In essence, this provides the clear value of convenience and rapid response from telehomecare and remote monitoring. New and more flexible levels of access to their providers [54] mean more value.

The following section outlines several examples of telehomecare and remote monitoring in operation. They reflect early, intermediate and more mature examples of how these technologies are influencing care and costs. Also, they demonstrate how the cost and clinical benefits accrue across the broad spectrum of health care delivery.

IV. Early, Intermediate, and Mature Representative Case Studies

A. Englewood Hospital and Medical Center, [55], **Home Health/Hospice Services, Englewood, New Jersey; Katherine P. Clark MSN, RN, BC, Manager, Telehealth Department**

The telemedicine/remote monitoring component of Englewood Hospital's Home Health/ Hospice Services is a relatively new program, having begun 2½ years ago with grant funding. It deploys 40 home telemedicine monitors as needed among the approximately 350 patients followed by the home health/hospice service with a clinical focus of CHF. Currently, patients are followed both by home visit nurses whose case load is approximately 25 patients and two tele-nurses who perform all the monitoring. Both the visit nurses and many of the patients' physicians have password access to the tele-visit data. As a result, remote monitoring supplements in-home visits rather than replacing them. Tele-visits collect data that can be used to focus in-home visits or doctor office appointments. Data collected through remote monitoring and tele-visits are also used to schedule earlier nurse home visits or doctor visits when developing difficulties are identified. This activity has succeeded in reducing re-hospitalization rates and ER visit frequency, but has not yet increased home nurse case load efficiency.

Nurse buy-in to the program has developed more slowly than anticipated because the tele-visits may be perceived to be additions to the work load associated with an individual patient rather than a way to increase the efficiency of care by reducing the number of actual home visits that must occur. In addition, local physicians have not yet perceived the tele-visit to be a tool for either earlier discharge from the hospital or reduced re-hospitalization. As a consequence, their contributions to driving the system are limited. However, now that data concerning clinical success in these arenas have begun to accumulate, the Telehealth Director perceives aggressive

marketing with these health professionals as the immediately appropriate mechanism for reversing this attitude.

On the other hand, patient satisfaction with home telemonitoring and the supplemental health professional contact is high. Patients perceive more immediate support for problems as they arise and more access to necessary in-person care when it is required.

According to the program's manager, telehomecare is not reimbursed by Medicare or Medicaid in New Jersey, and the program has not yet secured a commercial contract. Therefore, in the absence of direct support from the hospital, program sustainability will depend upon grant funding until documented decreases in re-hospitalization rates and emergency room use are coupled with increased efficiency of staff utilization to convince hospital leadership that savings and cost avoidance will offset implementation costs. Much like other programs, current patient benefit is dependent upon the commitment of a visionary program leader holding together clinicians who are themselves initially neutral.

B. University of Tennessee Telehealth Network, Graduate School of Medicine, Knoxville, TN, Sam Burgiss [56]

This program created an integrated telehealth network (three hospitals, one six-site federally qualified health care clinic, one county dental health clinic and multiple patient homes), with the goal of delivering ten different health services to a rural community. Improved DM self-management and CHF care are presented here. Various combinations of videoconferencing, simple telephone conversation, and remote monitoring were used. Home videoconferencing employed a 13-inch video monitor, patient camera, speaker phone and electronic interface. In addition to this equipment, CHF patients used a remote monitoring system to transmit blood

pressure, pulse rate and blood oxygen saturation. DM patients used videoconferencing or telephone to communicate with certified diabetes educator nurses at least twice weekly, but all used a glucometer to transmit daily capillary blood glucose values electronically over telephone lines. In addition, HbA1c tests were obtained twice each year. The diabetes program was designed to provide a longitudinal view of the impact of aggressive self-monitoring and diabetes management on blood glucose levels over time [57].

The Scott County Telemedicine Program began in May 1999, when private funding was provided to initiate a program of health care that targeted persistent health and medical problems in the county and thus to expand access to medical care. There is a high incidence of diabetes mellitus in the community.

Patient blood sugars were forwarded to a proprietary software program that charted trends – daily, weekly and monthly. Patients could see a pie chart of their blood sugars to show their level of control after each meal and for the day. The clinic nurse monitored these forwarded blood sugars. The patient's plan of care and medications were modified as dictated by the results.

Clinical outcomes for DM: Outcomes were monitored using HbA1c tests, which reflect the average amount of glucose present in a person's blood during the previous three months. In the study, 66 percent of patients demonstrated a decline in HbA1c levels, indicating better glycemic control over time. This is important in light of the fact that a seminal study of diabetes control, the Diabetes Control and Complications Trial, showed that lowering HbA1c can delay or prevent the development of eye, kidney and nerve disease in diabetic individuals.

In addition to clinical improvement, the project produced cost savings. Telehealth patients were followed weekly by either videoconference or telephone consultation. Average per

visit cost savings of $49.33 over 444 visits were documented when transportation, nurse time, and benefits were taken into account. Telehealth data were compared only to nurses' costs that would have been accumulated for the in-person visit. The data do not include the additional value of nurse productivity during the time saved by avoiding travel.

Patients, family caregivers, and providers were satisfied with this low-cost, user-friendly telehealth program that used the plain-old-telephone system. Mileage and nurse drive time were reduced and nursing productivity was improved during this demonstration project of the Knoxville telehealth program.

Clinical Outcomes for CHF: An historical database was developed on each patient for comparison to data collected after six and 13 months of CHF program participation. Patients used two standardized scales to measure functionality and mood. Remote monitoring information included BP, EKG, and pulse oximeter readings. Results included reduced and shorter hospitalizations and reduced cost. In comparison to a national 30-day readmission rate of 23 percent for CHF complications, only 14 percent of CHF program participants were hospitalized during the program's first six months. Further, their length of hospital stay was reduced from the national benchmark 6.2 days to four days, and their hospitalization rate for CHF was reduced from 1.7 to 0.6 per patient per year.

Nursing labor cost in the program was $2,353 per patient per year. Equipment cost (amortized over three years) was $833 per patient per year. Based on hospital days per patient per year—with and without tele-intervention and the cost of the tele-intervention—the cost of CHF hospitalizations was reduced by 47 percent [58].

C. The Health care Alternatives Group, Ellen B. Bolch, RN, MSN, President and CEO, South Carolina and Georgia [54]

The Health care Alternatives (THA) Group is the parent organization of Island Health Care, Inc., a home health company with agencies in the southeastern coastal areas of Georgia and South Carolina, including Island Hospice, Inc.; Vital-Linc (a home telecare company); and Independent Life at Home. [59]

THA Group recognized that the US spends more on health care than any other industrialized nation but has a significant population of unserved or underserved citizens and rising health costs. The company's hypothesis was that technology must achieve in health care what it has done in other industries: change the labor-intensive health care model that currently exists. Calling on her previous in-hospital experience, the firm's president argued that home health (and hospice) care faced the challenge of monitoring vital signs and other physiological parameters of multiple geographically-scattered patients from central bases by remote data collection. THA Group perceived this problem to be similar to what hospital critical care units accomplished decades ago when technology freed nurses from sitting at one bedside—technology allowed them to monitor multiple patients simultaneously, providing individual patient care when electronic monitors indicated need [60].

Pressure to reduce the cost of home and hospice care and the Medicare prospective payment system demand clinical efficiency. This could be accomplished by daily remote patient assessment, with home visits only when hands-on intervention and in-person teaching are necessary. Continually reported diagnostics would be used to determine the intensity of required nursing intervention instead of scheduling staff to make regular home visits without knowledge of whether they were needed. The challenge was not simply to monitor physiological parameters

in the home. The goal was to combine trended data with clinical judgment to make informed decisions that drive clinical action. The purpose would not be to replace nurses, but to decrease resource utilization while continuing direct personal contact.

Island Health Care, Inc., decided to invest in telehomecare and remote monitoring and to commit to (a) achieving clinical efficiency with high quality, (b) increasing referrals through technological sophistication, and (c) achieving more with increasingly scarce nursing resources. THA Group activities would be focused on diabetes mellitus and cardio-pulmonary disease (including congestive heart failure, coronary artery disease, arrhythmia, chronic obstructive pulmonary disease and asthma) by establishing partnerships that included the patient, the primary care provider and Island Health Care nurses.

An investment of $600,000 acquired equipment and service contracts for five years. This investment debt was retired in three years together with cost savings and an increased margin of $1.3 million. Twenty-one home visits per 60-day Medicare episode at the onset of the endeavor were reduced to 11 in 2006.

Hospitalization rates for all South Carolina home health agencies exceed 32 percent and are about 21 percent for the top 10 South Carolina agencies. The national average hospitalization rate is 28 percent while the national goal has been set at 23 percent. Island Health Care was experiencing a 27 percent hospitalization rate at the onset of its remote monitoring program. In June 2006, 23 months after the program began, hospitalization rates had been reduced to 18.9 percent. Simultaneously, hospitalization rates for Georgia patients were reduced by 50 percent and emergency room utilization by 70 percent.

An additional year-long study was conducted (01/05 to 02/06) to compare hospitalization rate changes with and without telehomecare and remote monitoring. During the baseline period

(01/05 to 06/05) before these telemedicine technologies were introduced for the test group, hospitalization rates were 22.9 percent in the group that would not get remote monitoring and 22.8 percent in the group that would later receive remote monitoring. For the test period (07/05 to 01/06), hospitalization rates without telemonitoring were 21.2 percent while rates with telemonitoring were 16.2 percent.

As a consequence of these successes, Island Health Care has experienced a more than 60 percent increase in the number of referring physicians, and its care managers more than doubled the number of patients that they could comfortably handle to 45 or more.

THA Group perceives that while other health care industries may experience increased costs with technological advances, telemonitoring in home health represents a health care industry in which the "value equation"—improving quality while simultaneously decreasing costs—has been met [54].

V. Conclusion

Comprehensive implementation of telehomecare and remote monitoring require: (a) the cost of accessing adequate broadband services; (b) the reimbursement of nurse and physician fees; and (c) the cost of acquiring, maintaining, and regularly updating the facilities and medical technologies necessary for the telehealth services described in this paper and elsewhere.

As Christensen points out [61], payment affects health care delivery. The way we pay for telehealth will have a significant impact on the ultimate form that telehealth takes and how it is used by both patients and clinicians. Evidence is accumulating that consumers are willing to pay many of these expenses out-of-pocket if they receive services that provide quality and are delivered conveniently [1,62,63,64,65].

The issue is not cost. The issue is value. Consumers, customers, and patients will pay reasonable costs so long as they perceive that their received value equals or exceeds that cost.

It is essential that public and private sector leaders who can influence payment policy recognize the potential for telehealth and its many forms to improve care and efficiently manage resources for an aging population, as well as for productive citizens with chronic diseases. Evidence of the clinical and business success of this innovative form of care is emerging. The evidence suggests that telehealth, telehomecare, and remote monitoring may be one of the only economically viable ways to manage an aging population, the prevalence of chronic disease and the growing constraints on health care spending.

Without universal broadband deployment, access to these services is not assured. Without adequate payment mechanisms for these facilities and services by public and private insurers, their potential to improve health care and reduce the cost of providing that care may not be realized.

Appendix: Contextual Background and Definitions of Terms

A. Telemedicine, Telehealth, e-Health, and Remote Monitoring

Telemedicine: The American Telemedicine Association (ATA) defines *"telemedicine"* as the use of medical information exchanged from one site to another using electronic communications for the purpose of improving the health status of patients [66].

Telehealth: The ATA defines the word *"telehealth"* as a closely associated term, often used to describe a broader definition of remote health care. The activities encompassed do not necessarily involve direct clinical services [66]. They include, but not limited to, patient education and the monitoring of patient physiological parameters that assess chronic disease management and progression.

On the other hand, the United States Office for the Advancement of Telehealth (OAT) takes a more general approach to the term, including what others call "telemedicine" within its definition of the word "telehealth": "…the use of electronic information and telecommunications technologies to support long-distance clinical health care, patient and professional health-related education, public health, and health administration." [67]

e-health: The third commonly used term, *"e-health"*, is very broad. It tends to encompass many non-direct but still health care-related activities that use the Internet such as administrative functions and the education of patients, their families, and professionals. The term is most succinctly defined in the Journal of Medical Internet Research [68]: "…e-health is…in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies. …[T]he term characterizes…a technical development,…a state-of-mind, a way of thinking, an

attitude, and a commitment for networked, global thinking, to improve health care locally, regionally, and worldwide by using information and communication technology."

Telehomecare: The use of technology to deliver patient care in the home or place of residence, providing patient-provider contact without either having to travel. Importantly, telehomecare tools (see "remote monitoring") enable patient data to be transmitted from the home and patient-centered information to be sent into the home. The simplest telehomecare technology is the telephone. Its objective is enhanced chronic disease management, but it is especially valuable for patients with conditions that make travel physically difficult.

Remote Monitoring: The use of devices designed to collect patient data such as vital signs, electrocardiograms, and capillary blood glucoses when they are away from health care facilities and transmit them to a monitoring station for interpretation. Typically conducted in the home, data can, however, be collected from any patient location, and can provide real time, around-the-clock evaluation in real-life settings.

B. Telecommunication Infrastructure

Internet: The *Internet* is a worldwide, publicly accessible network of interconnected computer networks. A "network of networks," it is comprised of countless smaller domestic, academic, business and government networks. Together they carry information and services used currently by more than one billion people worldwide [69]. It is defined technically by its interconnections and routing policies. The Internet is becoming so basic a feature of global civilization that the world's "civil society" has been equated with an "information technology society" defined by Internet use [70].

According to the Pew Internet and American Life Project, 55 percent of Internet-connected Americans used it in 2000 to access health information, and almost half acknowledged

that they were influenced by that information [62]. By 2003, 80 percent of adult Internet users had searched the Web for health information [63].

Internet Connectivity for Telehomecare and Remote Monitoring: The usefulness of a telecommunication connection, such as to the Internet, is a function both of the applications that users run over it and the telecommunication infrastructure over which information can be transferred rapidly in both directions. Also essential is the ability of patients and clinicians to share access to remote monitoring data and to receive "alerts" concerning "out-of-target-range" values that indicate need for behavioral change, clinical intervention or both. Thus access, relevant and useful applications, bandwidth, privacy and security are critical and inseparable elements of connectivity for telehomecare and remote monitoring.

Access: Traditional telemedicine programs designed to deliver specialty expertise to communities in which it is locally unavailable usually require expensive work-stations and dedicated telecommunication linkages. These activities tend to use high bandwidth, point-to-point connections located in health care- and health care-related facilities.

However, recent technology and software developments permit improved video and audio quality—sufficient for consumer telehealth applications—from the desktop using home broadband connectivity to the Internet [1] (e.g. cable; DSL – digital subscriber line, ISDN – integrated services digital network; cellular and satellite wireless broadband services; data over power lines, and POTS – plain-old telephone service).

Broadband: Data transmission speed is a function of the bandwidth available to transfer the information – the size of the pipe through which the data bits must flow. There is inconsistency concerning when transmission achieves "broadband" status. The U.S. Federal Communications Commission defines broadband as Internet services at speeds of at least 200

kilobits per second (Kbps) in one direction. TechNet, an industry group, quotes 100 megabits per second (Mbps) as true broadband [71]. Other estimates fall between. In general use, the term "broadband" has come to mean high capacity, always-on, interactive services [72]. The more technically sophisticated the application and its associated software, the more bandwidth is necessary.

The U.S. leads the world in broadband subscribers (84 million in March 2006). However, the U.S. recently fell from 17th to 20th place in broadband penetration with 16+ broadband lines per 100 inhabitants compared to 26+ for world leader Denmark. U.S. broadband penetration among active Internet users grew to 73.1 percent in June 2006. At current growth rates U.S. broadband was predicted to reach 80 percent of active Internet users by the end of calendar 2006 [73]. These figures help to frame the potential for telehomecare and remote monitoring.

Applications: For the purposes of this paper, we use the term "applications" to refer to the clinical, monitoring and educational Internet sites and programs that patients, their families, and clinicians use to accomplish their health care, monitoring and information-gathering goals. Applications with different purposes or levels of technical and software complexity will have differing access and consumer usage requirements. A discussion of the telecommunication service providers, software and other support that makes those clinically-relevant applications useable and useful is beyond the scope of this paper.

For many years, discussions about the lack of penetration of telecommunication technologies into consumer homes centered on who was providing the services and why more people were not subscribing to it. It was said that there was no "killer application" to drive consumer subscription. In fact, there is likely never to be a single health care-related "killer

app." On the other hand, what has developed in health care, health maintenance and health education is a growing number of focused and valuable discipline- and topic-specific applications. In terms of health-related issues, the emerging "killer app" is the ability of individual patients to assemble a personal library of these application, information and education sites that are specifically relevant to their own concerns.

"Telehomecare" and "remote monitoring" are two application groupings that are of particular value to individuals juggling the often conflicting requirements of chronic disease self-management, home, family, school and job.

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