Using Technology to Manage Chronic Illness

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Chronic Illness in U.S.

Incurable, but often manageable, e.g.,

- Hypertension (50M), asthma (17M), diabetes (16M), heart failure (5M), Alzheimer's (4M), epilepsy (2.5M), HIV (1M)

Affects all age groups, 1/3 of total U.S. population

- 57M working age (18-64) Americans
- Roughly 100% of elderly

Enormous impact on quality of life

- People lose independence and give up activities

1.7M deaths/year (70% of total deaths), many preventable

- E.g., ~88k deaths/year from nosocomial infections
And Its Expensive

3% of population accounts for 40% of cost

Chronic illness accounts for 75% of total cost
Chronic Disease Not Just an American Problem

35% of Beijingers suffer chronic disease *(Xinhua 7/03/05)*

76% of Taiwanese over 65 have more than one chronic disease

*(Home Health Care Management & Practice, Vol. 15, No. 6, 2003)*

Managing Chronic Illness Is a Control Problem

1. Get Information About State of Patient
2. Make Diagnosis Based on Information
3. Choose Intervention
4. Perform Intervention
A Simple Control System: Your Morning Shower

You get in and turn on shower
You notice that water is too cold
You turn the faucet a little
Water gets warmer, but not warm enough
You turn faucet more
Water now a bit too warm
You turn faucet other way
You enjoy shower
Length of loop should be governed by rate of change of patient. More often by access to physician.
A Shower, per Medical Loop

You get in and turn on shower
You notice that water is too cold
Telephone plumber You wait (and shiver)
Plumber arrives, adjusts hot water heater
Plumber leaves
Minutes later, water becomes scalding hot
You telephone plumber
You stand in shower waiting (in pain)
Plumber arrives, notices burns, take you to
E.g., Management of Congestive Heart Failure (CHF)

Cardiac output cannot keep up with cardiac input
- Effects 6%-10% of Americans over 65
- Blood backs up into lung, leading to congestion & respiratory distress

Managed using some combination of nine kinds of drugs

Appropriate combination and dosages should vary dynamically, e.g.,
- Cardiac output low => increase blood thinner
- Fluid accumulating => increase diuretic

In most cases adjustments haphazard
- Not done often enough
- Done with poor information

Resulting in millions of unnecessary days in hospital
- And uncounted unnecessary deaths
Improving the Control Loop

Reduce length of loop

Replace infrequent large adjustments with frequent small adjustments

Base adjustments on better information

More accurate
More timely

Improve quantity and quality of controllers

Supply of high quality physicians grossly inadequate

Need to help patients and family members be better controllers

If nothing changes by 2020,

Americans > 65 years will consume > 90% of physician time
Leaving < 10% for 75% of population
Improving the Loop

Shift locus of care out of “medical” environments
  Empower patient and family members
  With technology, they can do better than most physicians

Monitor people outside clinical environments
  Physiological signals, behavior, and environment

Capture “narrative” information
  Speech and natural language processing

Use sophisticated techniques to process information
  Build and refine person-specific models
    Personalized medicine is not mostly about genetics
  Provide digests of time series data
  Detect problems and alert appropriate individuals
E.g., Hypertension

Medication interventions made between the initial and dismissal visit (baseline) and then in response to home blood pressure data after dismissal from the hypertension clinic. (from Canzanello, et. al., Mayo Clin Proc. 2005;80:31-36)
Non-physiological Data

Changes in physiologic state often driven by external factors
   E.g., stress

Capturing this information is critical
   Event-stimulated natural language diary
   Spoken language dialog system, perhaps mimic dialog with a caregiver
   Preserve information for analysis, possible immediate alerting, and subsequent trending

Key technologies
   Speech and language understanding
   Conversational interfaces
   Summarization

...
Physiological Data

**Better sensors**
Smaller, more reliable, easier to use
This is the easy part

**Better software**
Signal processing
Communication
Storage and access
Interpretation
Presentation
But What Do We Do with All that Data?

Possible to get continuous physiological data for long periods
(24 hours X n sensors)/24 hours

But what does one do with it?
Patient data hours/Available physician hours is very large
What Should People Do?

What they can do better than machines
- Conversing with patients and family members
- Observing patients
- Dexterous tasks
- Using common sense
  “Common sense is the collection of prejudices acquired by age eighteen.” -Albert Einstein

What does it not include?
- Remembering things
- Being vigilant
- Evaluating large amounts of data

Glut of data is pushing clinicians in the wrong direction
What Do We Do with All that Data?

Look for known alarming conditions in realtime and route alert

Use abstraction mechanisms
  Can provide abbreviated but useful views of data
A Short Example: Viewing EKG Data

Possible to get continuous physiological data for long periods
But what does one do with it?

Look for known alarming conditions in realtime and route alert
Use abstraction mechanisms to provide abbreviated but interesting views of data to experts

Consider 10 minutes of EKG

![Raw EKG data graph]
Ten Minutes of EGG

Random Sample

Interesting Sample

Automatic Clustering
Example 2: Controlling Epileptic Seizures in Realtime

Prevalence of 0.5 – 1%; all ages
Characterized by recurrent seizures
Usual treatments are drugs, taken daily
  Often with side effects
  Not well controlled in 30% of patients
Vagus nerve stimulation (VNS)
  Can abort seizure
  Two modes of use
    On demand
      Rarely timely
    Open loop
      Lower current
Example 2, Controlling the VNS in Realtime

Capture electrical activity on scalp
Transmit signal to DSP system
Detect seizure **onset**
Turn on stimulator
Detection the hard part
  Build patient-specific detectors
  Wavelets + machine learning
Building a Patient-Specific Detector

Seizures

EEG Signal

Feature Extraction

Artifact Library

Learning Algorithms

Patient-specific Detector

SVM (radial basis kernel)

Tested on > 50 patients, highly effective
Proof-of-concept hardware ready
Expect live trials of system soon
Wrapping Up

We can do well, by doing good

IT can change the paradigm for managing chronic illness

- Shorten the feedback cycle
- Acquire and use better information
- Personalize treatment
- Empower non-professional care givers

100’s of millions of people suffer from chronic disease

We have the opportunity to help these people

- Live better and longer lives