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Review

# Improving clinical decisions and outcomes with information: a review

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**Abstract**

The clinical information available to clinicians is expanding rapidly. It can enhance clinical decision-making, but it can also confuse the process. To be most useful, information should be available at the time and place it is needed and be specific to the task at hand. In the new paradigm of medicine, one based on continuous quality improvement, useful information must be relevant to both the processes and outcomes of care. Clinical practice guidelines have become increasingly popular for improving the quality of health care. The field of medical informatics can bring cogent information to the point where decisions are being made to augment quality improvement activities in general, and practice guidelines in particular. However, such innovations are dependent on the type, quantity, and quality of information available. This article discusses when guidelines can enhance the quality and outcomes of care and how medical informatics can help achieve these goals. In particular, the barriers to the broad implementation of electronic medical records in a variety of health care settings are explored. 

*Keywords:* Medical informatics; Computer information systems; Quality improvement

## 1. Introduction

There is a rising tide of information available for clinical decision-making. Paradoxically, making clinical decisions is becoming progressively more difficult. We know more about the human body, how it works, and how it fails; we know more about individual patients; and we have more therapeutic options at our disposal. As has been shown in decisions made by military officers [1], having too much, poorly organized information can cause as many errors in decisions as having too little information. This is because: (1) the information we need for making decisions for individual patients is not always available at the time and place when it is needed; and (2) the information is not perfect, sometimes being falsely positive and sometimes falsely neg-

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ative. For example, this author has never seen an MRI scan read as simply 'normal'. There are often signals of undetermined clinical meaning that rarely aid decision-making and often make the clinician nervous that he or she is missing something important. A patient having a panel of 12 blood chemistry tests (in which the normal range of each is defined as excluding 5% of the normal population) has a greater than 50% chance of having a false-positive result on at least one of test. Thus, ambiguous information can lead to uncertainty and additional (and often unnecessary) testing. As a result, most hospitals have arrived at the conclusion that having less information on patients' blood chemistry is better and have established rules against ordering panels of such tests.

## 2. The changing paradigm of medical practice

The structure of medicine is changing. In the old paradigm, decision-making was hierarchical: the physician was at the top of the chain of command, deciding what to do and ordering care from other providers. Physicians were ultimately responsible for patient outcomes and were the final conduit for most information and decisions. The goal of care in this paradigm focused on the health care delivery process: providing high technical quality of care, i.e. 'doing the right thing'. The role of medical informatics in the old paradigm was to help physicians make diagnoses, for example, the likelihood of myocardial infarction among emergency department patients with chest pain [2,3]. The notion was that once the patient's problems had been identified, the physician would be able to make correct therapeutic decisions. Obtaining sufficient and appropriate data was considered a necessary (and even annoying) first step. When he arrived at Indiana University in 1971, Clement McDonald thought it would take a couple of years to establish an electronic medical record system capable of supporting clinical decision-making. Yet, 30 years later, establishing and maintaining the flow of clinical data into the Regenstrief Medical Record System has dominated the time and energies of McDonald and his colleagues [4,5].

The new paradigm of health care delivery consists of a multidisciplinary team of clinician and non-clinician providers whose task is to provide comprehensive and co-ordinated care. Such providers include, but are not be limited to, physicians, nurses, nurses' aids, clerks, technicians, therapists, administrators, and other staff. The goal of care in this new paradigm is to optimize patient outcomes, both objective (clinical) and subjective (patient-centered) [6]. Understanding the patient's problems and making correct decisions (i.e. 'doing the right thing') are just intermediate steps towards this outcome-oriented goal. For example, in the old quality improvement paradigm, the goal of interventions to enhance preventive care included appropriate screening for, and treatment of, cardiovascular risk factors. Under the new quality improvement paradigm, the goal is to reduce the number of adverse cardiovascular events and maximize patients' function and satisfaction with care.

## 3. Information and quality improvement in the new paradigm

Health care delivery in this new paradigm is being increasingly governed by an organizational scheme of continuous quality improvement (CQI) first championed by Deming and embodied by Japanese industry [7]. In this approach, a multidisciplinary group of providers: (1) identifies a problem ('an opportunity for improvement'); (2) decides how to intervene to overcome it; (3) implements an intervention in one or more care environments; and then (4) assesses appropriate outcomes (clinical and/or patient-centered). With information from one quality improvement activity, the multidisciplinary provider group initiates another quality improvement cycle by identifying subsequent opportunities for improvement. This approach aims to create a sustained upward spiral in the quality of health care by helping the health care team make the best decisions, provide the best (i.e. most appropriate) care, and aim towards optimizing patient outcomes. For example, a renal transplant team of physicians and nurses decided that their outcomes (length of stay, costs, and infection rate) were unacceptable [8]. They first created a set of clinical pathways for the inpatient management of patients post-transplant. They then assessed the effect of establishing the pathways on the above outcomes. There was significant improvement, but they were not satisfied so they developed a computer-based implementation system that further enhanced patient outcomes.

To make the best decisions in specific clinical situations, clinicians must have up-to-date information about their patients. Although comprehensive electronic medical record systems have yet to permeate the practice of medicine, most data are already in electronic format (Table 1). Unfortunately, these data are often in disparate systems. Drawing them together for clinical decision-making often requires co-operation between clinical and administrative departments as well as substantial custom programming. Fortunately, linking data from disparate systems is getting progressively easier with the advent and promulgation of: (1) common schemes for formatting and transmitting data [9] (e.g. HL7 [10]); (2) widely accepted and utilized systems for coding diagnoses and procedures (e.g. ICD-9-CM [11] CPT-4 [12], and LOINC [13]); and (3) presentation formats (e.g. flowsheets [14], feedback reports [15], and reminders, alerts, and other patient-specific interventions targeting providers [16–23]).

Table 1
Data currently available electronically

| Data source | Data likely available |
|---|---|
| Clinical laboratory | Date and time registered/performed |
| | Specimen source |
| | Results |
| | Charges |
| Pharmacy | Date and time dispensed |
| | Prescribing physician |
| | Drug |
| | Dose |
| | Route of administration |
| | Sig, instructions |
| | Amount dispensed |
| | Charges |
| Scheduling systems | Date, time, and place of appointment |
| | Person/site making appointment |
| | Provider to see patient |
| | Appointment type |
| | Reason for visit |
| | Referring person |
| | Insurance information |
| Billing systems | Date and time of transaction |
| | Type of item billed (e.g. procedure, visit, drug) |
| | Charge |
| | Diagnosis code(s) (e.g. ICD-9-CM) |
| | Procedure code(s) (e.g. CPT4) |
| | Insurance code(s) |
| | Cost/revenue center code |
| Dictation systems | Type of report |
| | Person dictating |
| | Date and time of reported activity |
| | Text of the report |

In any clinical situation, providing the best patient care means choosing from a number of potentially appropriate decisions. Optimal decision-making thus requires the following chain of events:

1. selecting the most likely diagnosis,
2. selecting the treatment(s) most likely to be effective for that problem,
3. administering the treatment(s) correctly,
4. performing appropriate monitoring of therapy and follow-up of patient outcomes, and
5. modifying treatment(s) appropriately.

Most of the factors in this chain of events can be expressed as explicit practice guidelines [24,25].

## 4. Practice guidelines

Practice guidelines have been identified as one potential tool for reducing the variability in the processes and outcomes of care [25–29], although many physicians find them intrusive and too general to be useful in making decisions for individual patients [30]. Using the tools of medical informatics can facilitate practice guidelines and make them more applicable to individual patients [16,17,25], but this requires that the guidelines be written as algorithms with explicit definitions of clinical states and branch points. The data necessary to navigate practice guidelines are often missing from even the most sophisticated electronic medical record systems. Most guidelines are written to help clinicians in their everyday practice. They therefore often rely, to varying extent, on having the clinician gather the appropriate information and make clinical judgements. For example, the guideline from the Agency for Healthcare Research and Quality (AHRQ, formerly AHCPR) for managing heart failure [31] contains the following rule: If the patient's heart failure is still symptomatic after maximizing therapy with an angiotensin converting enzyme (ACE) inhibitor, then add digoxin. Executing this rule requires information on patient symptoms and the judgement that the ACE inhibitor has produced suboptimal results. One area in great need of development is to find ways in which electronic medical record systems can record symptoms (and their severity) along with providers' judgements of a therapeutic intervention's success.

Each guideline, no matter how carefully and comprehensively crafted, must undergo local translation to be relevant at each practice site and be consistent with local practice standards [32,33]. This is necessary because the guidelines' rules for navigating various branch points may be different from local practice in which thoughtful providers may have taken the same medical evidence upon which the guideline was based and arrived at different recommendations. For example, the AHRQ heart failure guideline recommends angiotensin converting enzyme inhibitors as first-line drugs [31]. Yet many cardiologists and general internists are using the newer angiotensin receptor blockers instead [34] despite limited information to date comparing the two classes of drugs [35]. A guideline must reflect local practice to be effective and useful. Interventions to improve compliance with guideline-based care protocols work best if at all, when providers intend to comply with them [19,36]. Practice guidelines must therefore be accepted as best practice by most clinicians at each practice site to assure any chance that the guidelines will improve the processes and (hopefully) outcomes of care.

The local translation and use of a guideline will also be affected by the availability of objective clinical data. For example, at Indiana University, where echocardiography was born [37], echocardiogram reports do not include an estimation of ejection fraction. Yet ejection fraction by echocardiogram or cardiac scintigraphy is the only objective determinant used by the AHRQ guidelines to identify patients with heart failure resulting from left ventricular systolic dysfunction [31]. Therefore, the AHRQ heart failure guidelines had to be modified at Indiana University to deal with the data provided by local echocardiogram reports [38].

## 5. Practice guidelines and medical informatics

When can the tools and processes of medical informatics support practice guidelines and clinical decision-making? One should focus efforts to develop and reinforce compliance with guidelines when:

1. The targeted clinical problem is common.
2. A straightforward guideline for best practice exists.
3. There is unacceptably low compliance with the guideline.
4. Sufficient electronic data are available to navigate (to a significant extent) the guideline's algorithm.
5. Clinician action is explicit and measurable.
6. The intervention does not require a lot of time or effort (physical or intellectual) from the clinician.
7. The intervention is accepted by clinicians and strongly supported (with appropriate and sufficient resources) by both clinical specialists and practice managers.

An example of a clinical guideline for which support from informatics interventions may be helpful is screening mammography. The need for such screening is obviously common in primary care, guidelines for patient eligibility exist [39], and the evidence supporting the guideline is sufficiently compelling to be acceptable to most clinicians and practice managers. Yet compliance with mammography is often suboptimal (thus supporting its inclusion as a quality of care indicator [40]). Clinical action (i.e. ordering mammograms) is explicit and measurable, electronic medical record systems can support interventions for improving compliance if they contain demographic information (gender and age) and either results of mammograms or physicians' orders, and computer-based reminder interventions and have been shown to increase compliance [15,19,41].

However, informatics interventions are expensive. There are high initial capital outlays for the equipment, software, and programming in addition to the large and often hidden costs of re-engineering the practice environment. There has long been hope (to date unrealized) that the costs of such systems will drop as the cost of computing power and data storage continue to fall and there is more standardizing of system components. The maintenance costs of an electronic medical record system can be quite variable and depend heavily on the efficiency and focus of the system's managers. Fortunately, once such a system is in place, the marginal cost for subsequent individual interventions may be quite small and manageable.

It is especially common to underestimate the time required for training personnel in the use of informatics tools and revamping their practice patterns. One academic family practice got rid of their electronic medical record system because it added almost $5 to the cost of each patient visit [42]. Therefore, administrators and care managers must be convinced that the marginal gains in provider performance and/or patient outcomes are worth the substantial marginal costs. Appropriate outcomes against which to compare the costs of intervening include the processes of care, clinical events, and subjective patient outcomes (Table 2).

Table 2
Outcomes to assess in evaluating innovations in medical informatics

| Category of outcome | Examples of outcome measures |
|---|---|
| Clinician actions | HEDIS measures [40] and other report cards<br>Compliance with practice guidelines |
| Clinical events | Emergency room visits<br>Hospitalizations<br>Acute events (e.g. myocardial infarction)<br>Death |
| Costs of care | Total health care charges<br>Total health care costs (estimated or measured)<br>Indirect costs (e.g. time lost from work) |
| Health status, quality of life | Generic measures (e.g. Short Form 36 [47])<br>Condition-specific measures (e.g. CRQ [48]) |
| Patient satisfaction | With physician<br>With a visit<br>With health plan |
| Provider satisfaction | Physician<br>Nurse |

The effects of medical informatics interventions on both costs and quality improvement outcomes should be formally evaluated [43]. The potential study designs vary widely in their susceptibility to bias and confounding, difficulty in implementing, generalizability, and costs (Table 3). Unfortunately, many (if not most) clinical information systems have not been formally studied; purchasers most often make their decisions based on demonstrations and untested promises about performance and effects. Academic health care institutions and non-academic venues with well-developed CQI programs should see concurrently controlled trials as the most desirable method for testing informatics interventions [43] unless the intervention is just not amenable to such a trial or the clinical venue cannot support such controlled investigations.

## 6. Future directions

Although knowledge is power information is effectiveness. Raw knowledge applied ineffectively to individual patients (e.g. screening for rare conditions with non-specific tests, resulting in many false-positives) could cause inefficiency, increase costs, and even harm patients. Information, and the means to apply it to specific clinical conditions, brings the promise of improving health care without increasing clinical costs. In fact, costs can decrease [44,45]. Although wonderful things have been accomplished in the field of medical informatics, they are currently being developed and used in isolated centers of excellence. For most hospitals, physicians' offices, and other practice venues, the promise of medical informatics has simply not been realized. Few practice venues have permanent electronic medical records of any kind, other than billing systems to which clinicians do not have access, and even fewer practices have clinical decision support services. The budding use of the Internet as a platform for electronic medical record systems offers the hope of reducing the costs, time, and difficulty of implementation through use of standard data structures and browser interface programs in desktop computers and hand-held devices [46].

Advances in informatics will be realized first in the larger venues which can support the initial capital outlays: hospitals, hospital-based physicians' offices, managed care organizations, and large practices with many providers. It is the hope of this author that, as computer technology continues to advance and standardization in data formats and coding become disseminated, electronic medical record systems that capture data from laboratories, hospitals, pharmacies, etc. will be available and affordable by the average practising physician. Hopefully, such systems will allow providers to program their own care protocols, guidelines, etc. Those office-based systems that do exist often contain reminder capabilities that are limited only by the initiative of the providers and the availability of sufficient data. To be most effective, such systems must have efficient mechanisms for capturing and processing accurate, reliable, and valid data on patients' symptoms and history. For those making purchasing decisions for clinical practices, the key will be performance. They must have evidence that the ends (improving patient care and outcomes) will justify the costs (dollars, time, and effort). Most of the pieces of the puzzle

Table 3
Methods of assessing the effects of innovations in medical informatics

| Study method | Relative rigor | Strengths | Weaknesses |
|---|---|---|---|
| Randomized controlled trial | Very high | Least bias<br>Least confounding<br>Can select outcomes | Most difficult<br>Most expensive<br>Most time-consuming |
| Randomized prospective cohort study | High | Low bias<br>Low confounding<br>Can select outcomes<br>More generalizeable | Difficult<br>Need supportive environment |
| Non-randomized prospective cohort study | Moderate | Easier to perform<br>Can select outcomes<br>More generalizeable | Selection bias<br>Confounding by concurrent changes in health care |
| Retrospective (historical) cohort study | Moderate | Easier to perform<br>Use available data (electronic, chart)<br>? Inexpensive | Selection bias<br>Confounding by concurrent therapy<br>Confounding by concurrent changes in health care |
| Descriptive study | Low | Very easy to perform<br>Inexpensive<br>Can use a convenience sample | Bias and confounding greatest<br>Not generalizeable<br>No comparison group |
| Demonstration | Very low | Easiest to perform<br>Inexpensive<br>Easy to manipulate data<br>Can be slick | Provides no useful data in ease of use<br>Provides no useful data on effects on care or outcomes |

are available, but we cannot expect each provider to be a puzzle master. An effective and affordable integrated system is still a dream for most clinicians.

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