# Information Technology for Medical Appropriateness Through Support Algorithms and Recovery of Patients' Clinical History

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Abstract: In the health sector, the current intention of the Ministry of Health and of the Italian Government is to decrease healthcare squandering, to invest in research and to support the NHS. In this context the theme of appropriateness of treatment is essential; in fact the Health Ministry is committed to establish guidelines for the appropriateness of prescription, indicating the "conditions of provision" and "indications of appropriateness". A number of key actors however complain that this approach, along with others (e.g. multifaceted educational programs, electronic systems of frequency filtering, such as limiting the number of available tests to the requesting physicians) lead to uncertain and often ineffective results. This work highlights how the adoption and use of Information Technology (IT) in clinical settings is contributing to the optimization of NHS resources and to the governance of the healthcare delivery activities, in particular for the management and control of appropriateness of care. As an example, the adoption of a computerized alerting system by the University Hospital of Parma has brought out significant results. System integration through standard protocols such as HL7, fully normalized data repositories that univocally identify patients, diagnosis and health service provided are crucial in the healthcare context.

## 1 INTRODUCTION

In recent years the Italian NHS has undergone budget cuts of more than 30 billion, with negative effects on research, on generational turnover of healthcare personnel, on investments in technologies and on the number of hospital beds. In fact, due to the reduction of more than 9000 hospital beds between year 2011 and 2012, the Italian NHS accounts for 3.5 beds per 1000 inhabitants, significantly less than Japan (14 beds/1000 inhabitants), Germany (8,2 beds /1000 inhabitants), or Austria (7.6 beds/1000 inhabitants) .

This factor has led hospitals to adopt a business profile, in which productivity and production costs are key.

It is now a widespread practice to outsource or concentrate services to rationalize resources and improve efficiency. Furthermore the Italian Government plans to reduce squandering through additional healthcare budget cuts, estimated up to 10 billion euro, to be invested in research, in healthcare efficiency improvements or in taxation reduction.

In this regard, the intention is to implement the concept of medical appropriateness, by defining the guidelines for "conditions of deliverability " and "indications of appropriateness". Currently (August 2015) the first draft of the Decree concerning appropriateness of prescriptions foresees constraints on 180 health services in 7 main areas:

- Dentistry, Genetics, CT and MRI, dialysis, nuclear medicine, laboratory tests and allergology.

Health services that go beyond the deliverability constraints indicated by the caring physician will be charged to the patient.

Is this approach appropriate to improve the quality of healthcare?

Many physicians argue that you cannot make cuts to health care indefinitely, nor can further reduce the tools for the collection of a good anamnesis, or to shorten the duration of a surgery. In addition several literature studies show that, educational programs, automatic filtering of prescriptions and generalized budget cuts lead to mixed results, and are hardly ever productive.

Technological development and Information Technology, although increasingly expensive, have on the other hand greatly improved healthcare delivery efficiency and have allowed a more precise definition and monitoring of appropriateness of care,



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through the use of models and algorithms. Proofs abound that these algorithms allow to reduce costs, by highlighting "unnecessary" health services in advance.

In addition, the computerization of the health area, the definition of standard protocols such as HL7, has allowed the hospital information systems to communicate more easily, thus promoting-clinical data sharing. The purpose of this publication is to highlight and demonstrate the benefits achieved in health care by investing in Information Technology.

## 2 MEDICAL APPROPRIATENESS AND INFORMATION TECHNOLOGY

In medicine there is no mathematical definition of appropriateness. The most accredited definition of appropriateness among healthcare authorities is "the measure of how a care delivery system and services are adapted and effective to the clinical needs of patients in accordance with current knowledge and best clinical practices".

The achieved health benefits must definitely outweigh the risks for the patient's health. In this context, we can distinguish two opposite cases:

- "inappropriate" tests that, besides raising anxiety in patients and consuming resources, could generate false positives and lead to additional diagnostic exams or even to inadequate therapy;
- "insufficient" tests, i.e. not performed diagnostic exams that would be needed for a correct diagnosis.

To address the first issue algorithms have been developed to support clinicians on diagnostic prescriptions appropriateness, in particular in the area of laboratory tests and diagnostic imaging. Few studies address the second issue.

In general we can distinguish three types of appropriateness:

- Clinical appropriateness: it refers to the efficiency criteria adopted in the diagnostic-therapeutic process and in the request of laboratory tests.
- Prescription appropriateness: more effective clinical approach for the diagnosis (e.g. investigation diagnostic) and treatment (e.g. pharmacological) of diseases.
- Organizational appropriateness: fair and efficient administration of the available resources in relation to the clinical case to be treated.

Prescription appropriateness is perhaps the most debated topic at present, for its legal and economic implications. See for example the allegations and wages reductions to family physicians due to "improper" prescriptions. In this sense the government proposes to adopt the above mentioned "terms of deliverability" and to define clear guidelines, no compliance to which could result in administrative and/or pecuniary sanctions for the clinician, or even the revocation of the employment relationship.

Information Technology provides computer tools that suggest to clinicians the most "appropriate" therapy, improve the clinical approach and decision-making for the use of medications and treatment of diseases. We refer for instance to "therapeutic algorithms" developed by AIFA (the Italian Drug Agency) in collaboration with experts in the field (University of Padua, the Italian association for the study of the liver, an Italian association of diabetology and the association of medical diabetologists).

One such algorithm concerns the management of triple therapy for hepatitis C (HCV algorithm). Born from mathematical models that consider many multiscale parameters, this algorithm is a "guide" in the use of Direct-acting antiviral (Daa) drugs, later replaced by second generation Daa. Access to these new therapies foresees treatment of patients based clinical urgency criteria.

A second algorithm concerns the treatment and therapy of type 2 diabetes mellitus.

The "Diabetes" algorithm foresees three steps:

1. Identification of the glycemic index.
2. Therapy definition (no contraindications).
3. Therapy definition in presence of contraindications or intolerance to metformin.

Two additional algorithms for the management of arterial hypertension and osteoporosis are also foreseen.

The clinical and organizational appropriateness are closely linked. Recently the usage of laboratory resources and the demand for laboratory exams has significantly increased. According to data from British Government, an estimated 70% of clinical diagnosis depend on laboratory data. The main reasons are ageing of population and related increase in chronic conditions.

Given the limited resources of current NHS system the Ministry of Health is considering the option to produce a list of diseases and of related supported diagnostic and therapeutic prescriptions, outside which patients should pay out of pocket.

Thus to comply with clinical appropriateness, lab technicians and clinicians will both need to provide more and more specific and sensitive tests and also achieve a greater clinical competence in the evaluation of the benefits brought by lab tests to address each patient's disease.

IT offers supporting algorithms also for this "educational/diagnostic" process.

The University Hospital of Parma has developed a computerized alerting tool based on re-testing intervals, linked to the order entry system, that generates pop-up alerts when 15 pre-defined laboratory tests violate the criteria of appropriateness.

The criteria are violated when biological plausibility is not respected or tests are repeated before the defined minimum intervals:

- C-reactive protein (CRP, repeat <24 hours);
- Glycated hemoglobin (repeat < 2 months);
- Beta-human chorionic gonadotropin (HCG beta; incompatible with age < 9 and > 60 years);
- Prostatic specific antigen (PSA; incompatible with PSA reflex and female gender; repetition <3 months);
- Thyroid stimulating hormone (TSH, incompatible with the TSH reflection; repetition <6 weeks);
- Protein Electrophoresis (repeat <7 days);
- Total cholesterol, high density lipoprotein cholesterol (HDL-C) and low density lipoproteins (LDL-C) (repeat <2 months);
- Brain natriuretic peptide (BNP; repetition <24 hours);
- Procalcitonin (PCT; repetition <24 hours);
- Ferritin (repeat <1 week);
- Vitamin B and folic acid (repeat <1 year);
- Immunoglobulin and albuminuria (repeat <3 months).

765 (22%) out of a total of 3539 requests generated by the departments of geriatrics of the hospital, between October 2014 and March 2015, have infringed the preset criteria and generated the alert pop-up. After the alarm, 591 requests were canceled (17% of the total and 77% of the alerted tests) allowing the hospital to save € 3387 in six months.
Once applied to the whole hospital, the system will "educate" doctors to the correct and effective use of laboratory tests, freeing up resources to treat those who need it most, besides generating significant cost savings.

# 3 INTEGRATION AND DATA RECOVERY

The computerization and integration between the different Hospital Information System (HIS) components is essential in order to achieve effective results for medical appropriateness.. The use of an integrated virtual patient record available from any healthcare delivery location, appears a good solution to allow the dematerialization of documents and easy circulation and exchange of clinical information.,.

To this aim the model IHE (Integrating the Healthcare Enterprise) for the integration of health information systems was developed. This model uses communication standards like HL7 and DICOM.

HL7 is now at version 3.0 and allows applications of the systems (HIS, LIS, RIS etc..) to interact based on events such as ADT (admission, discharge, transfer), ORM (request for examination), MDM (transmission of documents or medical reports) etc.

These messages include a header (MSH), followed by the description of the event (EVN), the patient demographic data (PID) and information about administered visits or healthcare services.

IHE has therefore a standard structure and allows easy communication between different health facilities without expensive interventions on the existing hardware and software.

A transmission system for the exchange of messages is also needed to ensure interoperability between the information systems. . The meaning attributed to messages must to be shared by both the sender and the receiver; an application that converts the intermediate information exchanged in a format common to all the health information realities is therefore required (for example from XML -> HL7).

Therefore in a logic-oriented EHR it is crucial to use middleware that ensures a common understanding of the messages and sharing the rules.

Several such middleware systems are available, e.g. Picasso, Spagic or JCAPS. An ideal solution for integration between health information systems.is also the open-source Mirth software, developed in Java.

Mirth supports different formats (such as HL7, queries from the database, EDI / X12, XML, NCPDP, DICOM and Delimited Text) and protocols (TCP / LLP, http, JDBC and FTP ).

It allows you to manage and manipulate HL7 messages according to the needs of listening systems; it makes use of channels that can take two

profiles:

- Router: manipulates messages using filters and transformations according to the demands of the target systems. Subsequently perform message routing.
- Broadcast: the information is sent via broadcast to all listening applications.

Mirth has therefore the advantage of managing the flows of information systems using independent channels. The latter will verify the conformity of messages in order to make them understandable by the listening systems.

Furthermore, as mentioned before, messages don't need to be HL7 compliant; the Middleware is quite versatile and can in theory be used in any language for the exchange of information. It is the channels, via Java libraries or JavaScript commands, that will transform the message.

In the following we show an example of integration for the archive of medical reports from a hospital department of Parma to be sent and stored into the hospital's repository.

In this case the exchange of messages is handled by Mirth via two channels:

1. A channel dedicated to the extraction of patients' data (via T-SQL query) from the department db, required to generate medical reports in pdf format.
2. Another channel used as a web service sender, which associates the report created before (and encrypted) to patients' data and then generates an HL7 message. This message will be added to a SOAP envelope and sent to the web service listener of the Central Repository.

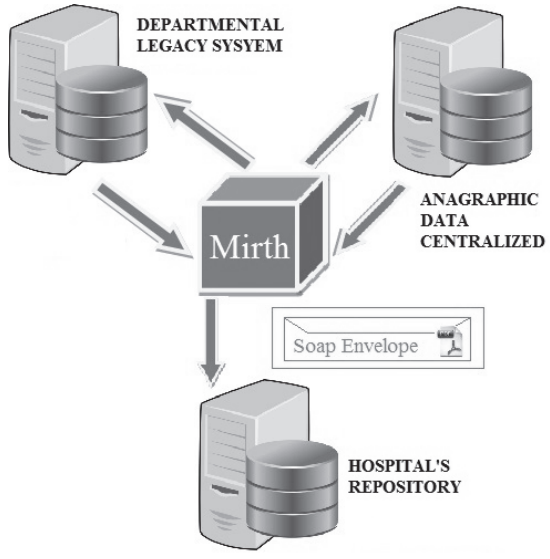


Figure 1: Integration Department-Repository.

The image shows that besides performing an exchange of messages with the department, the middleware also performs an alignment with the anagraphic centralized db. In fact, the existence of univocal anagraphic data is mandatory to achieve a correct integration and to possess unique anagraphic data. Often in hospital realities the patient's anagraphic data coming from the wards, are discordant with those of Central anagraphic system. This happens because often patients arrive at emergency units or directly in departments either unconscious or without identification documents, thus a correct patient's identification is not possible at admission time. In other cases the operator happens to make mistakes in patient's references transcription.

This requires a process for the reunification of personal data ("Patient's Demographic Reconciliation"). A reference database of anagraphic univocal data, MPI (master patient index), is important not only to reconstruct patient's health data and patient's anagraphic data, but also for all the alignments with the accessories db of common use (medical services, regional or national encodings, general practitioners data).

The MPI anagraphic registry is therefore essential in patient-centered architectures and the patient's relative code idMPI is the unique identifier from which all patient's clinical or administrative events can be recovered.

However the concept of MPI is not sufficient to solve the problems of integration between different information systems. Frequent problems are caused by:

1. Duplication: Mickey Mouse has two codes (for example, 001 and 100) in the same building Disneyland Clinic.
2. Overlapping codes: the same patient has multiple codes in two or more structures (001 at the Disneyland Clinic and 100 at the Disneyworld Clinic).
3. Errors of transcription in individual hospital departments: incomplete or misspelled names or surnames, birth dates where the day and month are reversed (e.g. 10/01/1900 → 01/10/1900).

Several algorithms have been developed to solve these problems and prevent the occurrence of false positives (the record is assigned to the wrong patient) or false negatives (a patient has multiple records) in a matching.

In a recent integration test between a legacy information system of a department and the central repository of Parma University Hospital a

middleware (Mirth) was used that was interfaced with the central demographic registry in order to extract the MPI code of patients (not present among the fields of the departmental system). In particular, the matching algorithm used as keywords:

1. The date of birth of the patient
2. The patient's last name
3. The patient's name

They were the only fields in the legacy system of the department that could guarantee the uniqueness of the patient.

The algorithm is actually a step-by-step procedure; from the first matching, mentioned above, the MPI code for about 73% of patients was recovered.

In the next step we made a matching targeted to transcription errors. In particular, we used substrings starting from the same search keys used earlier. To ensure uniqueness in this case, in addition to the surname, name and date of birth, the fields "address" and "telephone number" (when they were present and complete) were used. At the end of this process the MPI code of more than 90% of patients was recovered (67664 of 74971 initial patients ).

Through this system, so it was possible to store medical reports and patient records of that department in the central repository, without any false positive or false negative.

# 4 CONCLUSIONS

Usually Hospital Information Systems are rather fragmented and consist of isolated computerized structures including heterogeneous hardware equipment and software applications. Consequently the concept of medical appropriateness cannot be separated from the computerization of hospital activities and from the integration of these different health information systems.

The access to a central repository that provides information from different departments (e.g. laboratory, radiology, anatomy pathology etc.) can facilitate patient's data retrieval and sharing. It can allow a Medical Doctor to know the patient's medical history, the clinical exams of performed by different structures and provide proper diagnosis with minimal requests for improper medical exams. These information can also be used both as variables by the algorithms supporting physicians on evaluating the appropriateness of requests and also to better investigate on exams (for example, diagnostic images such as CT and MRI) through operations such as chiaroscuro, zoom etc.

Obviously the use of middleware is essential to "standardize" the exchange of data and reduce risk factors related to the circulation of information between the different legacy systems and the central repository.

We have assessed how Mirth, in addition to providing an open source solution, ensures the easy and independent interoperability between applications, providing transparency in the flow of data and adapting to changes in hospital structures, IT infrastructures and in clinical data.

Thanks to the use of anagraphic MPI, the middleware can access a separate centralized anagraphic registry (but related to the anagraphic registry of the hospital) and can make available to all the different hospital systems a number of functions via the web for the management of demographic data.

Moreover the idMPI, in addition to connecting the patient ID with that related to any other access at any hospital structures, adapts to different logics and hospital settings and ensures adherence to the requirements of the Italian Health System (uniquely identifying the patient, avoiding homonyms and unifying double anagraphic positions).

In summary, it is therefore essential to invest in information technology, in order to improve the management of health resources, to integrate the multiple clinical information, in the optics to provide an adequate health care to each patient (personalized medicine) reducing improper requests, as well as to obtain reliable information about medical exams through a simple Web browser.

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