

Development of an “Alert Framework” Based on the Practices in the Medical Front

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Abstract:

At the University of Miyazaki Hospital (UMH), we have accumulated and semantically structured a vast amount of medical information since the activation of the electronic health record system approximately 10 years ago. With this medical information, we have decided to develop an alert system for aiding in medical treatment. The purpose of this investigation is to not only to integrate an alert framework into the electronic health record system, but also to formulate a modeling method of this knowledge. A trial alert framework was developed for the staff in various occupational categories at the UMH. Based on findings of subsequent interviews, a more detailed and upgraded alert framework was constructed, resulting in the final model. Based on our current findings, an alert framework was developed with four major items. Based on the analysis of the medical practices from the trial model, it has been concluded that there are four major risk patterns that trigger the alert. Furthermore, the current alert framework contains detailed definitions which are easily substituted into the database, leading to easy implementation of the electronic health records.

Keywords: Expert system, Electronic medical record, Alert, Work flow, Ontology

Background:

In recent years, the use of electronic health record systems has been rapidly growing within Japanese hospitals, and digitally stored medical information has been accumulating on a daily basis. However, this vast amount of information has not been effectively utilized for medical support purposes [1]. One of the causes of this is that the amount of information is too overwhelming for a human to process. In addition, we do not have a framework to effectively extract specific information from the electronic health records used in the clinical practices [2, 3].

At the University of Miyazaki Hospital (UMH), the electronic health record system has been implemented since 2006, accumulating a vast amount of medical information during the 10year period. In order to make the database more organized, a semantic structure is introduced and uncategorized entering of information is restricted as much as possible [4]. Furthermore, in this operating electronic health record system, free text is reduced and structured semantically.

Based on the structured medical information, the UMH is ready to implement a highly professional expert system that will be beneficial for our daily medical practice. In order to utilize

the vast amount of medical information accumulated at the UMH for medical support purposes, we have decided to develop an alert system which will notify the doctors about the patients' specific conditions and needs. The purpose of this investigation is not only to construct an alert framework that can be integrated into the electronic health record system, but also to formulate a modeling method of this knowledge.

Research method:

To identify the practical medical needs for the construction of this alert system, we conducted interviews with staff from various departments at the UMH. The target departments were nursing, medical treatment, medical office and pharmacy with the total of 4 personnel. The interviews were conducted between November 2017 and January 2018.

We conducted the interviews by visiting each target department and had the respondents discuss what alert messages were required for their department. We prepared a trial alert framework (Table 1) and let the respondents comment on its items or information, and especially its deficiencies. As this alert framework is intended to generate an alert message for each individual patient based on their electronic health records, we disregarded those alert messages that did not address individual patients.

Based on the findings from the interviews, a more detailed and upgraded alert framework was developed and eventually used to construct our final model.

Results:

Based on practical medical needs, we developed a more detailed alert framework.

As a structural foundation for this framework, we employed the If-Then type structure used for general expert systems. We made the content of the antecedent configurable so that specific criteria can be entered in order to trigger alerts for individual patients. We made the content of the consequent configurable so that treatment details can be entered after an alert has been triggered. We also enabled our system to display detailed alert messages.

Header section:

Alert title, department managing the relevant alert, duty type and summary explanation was set.

Antecedent:

We defined the various attributes of medical treatments on the electronic health records as "treatment objects". Specifically, these are the "order", "documents", "test results", "disease name",

“problem”, “observation items” and “patient profile”. This “treatment object type”, as well as “transition condition”, “condition” and “collateral condition” were also defined. Consequent

We implemented three conditional categories: “Post-treatment Pattern”, “Care which requires post-treatment Object” and “Condition at conclusion of post-treatment”. The “Post-treatment Pattern” has three types: 1) Post-treatment without treatment object, 2) Post-treatment object the same as the antecedent treatment object, and 3) Post-treatment object that differs from the antecedent treatment object.

Message section:

Information required for all the messages are “Post-treatment relative reference date”, “Urgency”, “Scope of message sharing” and “Person responsible for post-treatment”. There are three types of messages: “preliminary message”, “concurrent message” and “supplementary message”. “Timing” and “Contents” are recorded with each message.

We designated 34 specific alert items based on the practical requirements of the medical treatment.

Discussion:

After careful evaluation of the medical care practices, we identified four risk-inducing patterns. First is a pattern where risks arise from the patient’s condition itself, such as cases of patients whose white blood cell count may drop during the course of chemotherapy. Second is a pattern where the risks arise from the type of treatment being administered, such as the danger of serving natto (fermented beans) to patients who are undergoing anticoagulant therapy using Warfarin. Third is a pattern that includes both of these factors, for instance the risk of an automated prescription of ionic radiopaque dye for an X-ray CT to patients who are allergic to such dye. Fourth is a pattern where the treatment lacks continuity and/or contingency, which may, for instance, result in a prescription expiring for a patient who needs medication to be continuously administered. In order to accommodate these four patterns, we have designed a framework where multiple conditions for a single patient can be specified in order to trigger an alert.

In the consequent, there were surprisingly many cases where specifics of the post-treatment were not defined, and as such, fell under the category of “no treatment object”. Nevertheless, we feel that in these cases, even a simple message could be of significant value.

To trigger an alert, a threshold value often needs to be set. For instance, for patients undergoing chemotherapy such a threshold may be a platelet count of under 60,000. At present, such thresholds are usually established empirically. Hereafter, a more accurate value will be established through statistical analysis of the clinical data.

An alert message is meant for a specific member of the staff, whereas the person who administers

the posttreatment may be another staff member. The data show, however, that both personnel tended to be the same person, but in order to cater for a more diversified alert system, it will be valuable to differentiate these personnel on the electronic health record system.

We have created three different timing attributes for an alert message. A “preliminary message” gives advance notification about the post-treatment; an “concurrent message” prompts for the immediate carrying out of the post-treatment; and a “supplementary message” gives an alert that post-treatment had not been carried out. In practice, most alerts had been of the concurrent type; however, as there were some occasions where preliminary and supplementary messages were needed, we decided to implement these as well.

Experience accumulated by pharmacists indicates that, as most medicine is either hepatic metabolic or renally excreted, it is important to accurately evaluate the clinical condition of the patients' kidney and liver functions. In order to automatically generate alert messages in this respect, an automated system to evaluate kidney and liver function in real time will be required.

Today, there are many existing expert systems in the medical field [5, 6].

For example, Mycin - developed by the Stanford University - diagnoses contagious hematological disorders and recommends antibiotics for their treatment [7, 8]. Previous expert systems have been limited for use in specific fields [9–11]. However, we have been working to develop a versatile expert system for various practical situations in the clinical field.

Recently, automated learning using artificial intelligence has been widely reported on [11–13]. We have concluded that it would be difficult for automated learning to extract specific experiences in this field. It is more valuable to develop standard rules based on first hand experiences of our medical field experts [14, 15].

Automatic learning could perhaps be used to set trigger values for alerts which require such thresholds [16].

With detailed definition of relevant categories, our newly developed alert framework can effectively be applied to electronic health records. The items on the framework can easily be matched to ones in the data-base and the If-Then type functions thus become effective.

We would like to focus our future efforts on the application of this framework to our electronic health record system and on the improvement of the framework through our firsthand operational experience.

Thus, by automatically generating alert messages based on the vast medical information from the electronic health record system, it will be easier to practice safe medicine without being overly dependent on individual medical personnel, resulting in overall improvement of the quality of medical treatment [17].

Based on the interviews with experienced medical staff, we were able to develop a more detailed framework for the alert system. This single framework was able to accommodate all the relevant

medical knowledge.

Through our studies, we were able to construct an alert framework which effectively applies to the existing electronic health records. In addition, we were able to confirm that our modeling method using interviews to create the alert rules for the framework was valid.

Compliance with ethical standards:

Conflict of interest:

This study was not funded. Author Takuya Sakata, Author Kenji Araki, Author Tomoyoshi Yamazaki, Author Koichi Kawano, Author Minoru Maeda, Author Muneo Kushima, Author Sanae Araki declare that they have no conflict of interest.

Ethical approval:

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors.

Informed consent:

Informed consent was obtained from all individual participants included in the study.

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Alert Title	Department	Type of job	Summary explanation	Antecedent			Consequent			General message			Preliminary message			Consent message				
				Type	condition of medical object of the antecedent	Collateral condition 1	Collateral condition 2	post treatment pattern	types of 3	details of 3	definition of treatment for post treatment	relative reference date for post treatment	urgency	Scope of message sharing	Person or group responsible for post treatment	message time	core content	details of content	message time	core content
Responsibility department	Detailed explanation of alert in writing			class of medical object of the antecedent	incident of medical object of the antecedent	other items, types and values of medical object of the antecedent	same as left column; 2 same as antecedent 3 different medical object	1 in treatment pattern 2 same as antecedent 3 different medical object	when post treatment pattern is 1-3 class of medical object of the consequent	defined content of the medical object in the left column	how to check that post treatment has not been conducted	relative reference date for the message	urgency flag	who can access this message	responsibility person or group to receive this message	detailed content of post treatment				
Run out of regular prescription	Nursing	Order prescription	Check the need to continue the regular prescription 3 days prior to running out of regular prescription for hospitalization	Order prescription	regular prescription			1		prescription order in the Antecedent has continuously been ordered	deadline date of department for regular prescription immediately before the prescription runs out.	non	Medical group	Medical group	1 day prior to reference date one day prior of the deadline date of the department for regular prescription immediately before the prescription runs out.	Periodic prescription will expire	regular prescription will run out on date when regular prescription runs out). Please order prescription if required.	Date when regular prescription runs out.	regular prescription will run out.	regular prescription will run out on date when regular prescription runs out). Please order prescription if required.
Restricted food	Nursing	Order meal	Notification to be issued when directions have not been given to restrict diets for patients who are undergoing anticoagulant therapy with Warfarin.	Order food	Netto has not been restricted	Currently taking Warfarin		2		Netto has been restricted for meal order	meal order date in the Antecedent	non	Medical group	Medical group			Meal order date	Netto restricted for patients undergoing Warfarin treatment.	Patient undergoing Warfarin treatment. Please restrict Netto in meal order.	
Restricted food	Nursing	Order meal	Notification to be issued when directions have not been given to restrict grapefruit for patients who are undergoing antihypertensive treatment with calcium antagonist agent.	Order food	Grapefruit has not been restricted	Currently taking calcium antagonist agent		2		Grapefruit has been restricted for meal order	meal order date in the Antecedent	non	Medical group	Medical group			Meal order date	Food caution: Patient undergoing Ca antagonist treatment.	Patient undergoing antihypertensive treatment with calcium antagonist agent. Please restrict grapefruit in meal order	
Discharge guidance	Nursing	Documentation/nursing task	Notification for nurses to support discharges for patients who have had discharge orders by the doctor.	Order discharge				3	Nursing task Discharge support	Discharge support by nursing staff	discharge date	non	Nurses at the patients hospital ward	Nurses at the patients hospital ward	Day when discharge has been ordered	give guidance for discharge	Discharge order has been issued. Please give guidance for discharge. Once completed, please click "done" on the nursing task.	Day before discharge	Give guidance for discharge	It is one day before discharge. Please give guidance for discharge. Once completed, please click "done" on the nursing task.
withdrawal of Antiplatelet agent and treatment	General diagnosis and treatment	Order operation	Once operation has been booked, notify the need to withdraw the antiplatelet agent the patient is currently taking.	Order operation		Currently taking antiplatelet agent		1			Operation order date	non	Medical group	Medical group			Operation order date	Withdrawal of antiplatelet agent for operation	Operation date/operation is scheduled. Patient is currently taking antiplatelet agent. Please instruct patient for drug withdrawal. Once confirmed, please delete message.	
withdrawal of Antiplatelet agent and treatment	General diagnosis and treatment	Order endoscope	Once endoscope has been booked, notify the need to withdraw the antiplatelet agent the patient is currently taking.	Order endoscope		Currently taking antiplatelet agent		1			Endoscope order date	non	Medical group	Medical group			Endoscope order date	Withdrawal of antiplatelet agent for endoscope	Endoscope date/ endoscope is scheduled. Patient is currently taking antiplatelet agent. Please instruct patient for drug withdrawal. Once confirmed, please delete message.	
Adverse effect	General diagnosis and treatment	Chemotherapy	Notification for patients undergoing chemotherapy with low number of white blood cells	examination history	white blood cells below 1000 $\mu\text{g/l}$	hospitalization profile currently undergoing chemotherapy		1			reporting date for examination history	urgent	Medical group Nurses at the patients hospital ward	Medical group Nurses at the patients hospital ward			reporting date for examination history	Low number of white blood cells	examination date:white blood cells have dropped to white blood cell numbers	
Adverse effect	General diagnosis and treatment	Chemotherapy	Notification for patients undergoing chemotherapy with low number of platelets	examination history	platelet count below 8000	hospitalization profile currently undergoing chemotherapy		1			reporting date for examination history	urgent	Medical group Nurses at the patients hospital ward	Medical group Nurses at the patients hospital ward			reporting date for examination history	Low number of platelets	examination date:platelet numbers have dropped to (platelet number)	
Adverse effects of Radioactive dye	General diagnosis and treatment	Order radiation	Notification for the need to check kidney function within three months of patients who will undergo radiographic examination with radioisotope dye	Order radiation CT	Use of radioisotope dye			1			date of CT examination	non	Staff who ordered the examination	Staff who ordered the examination			timing of CT order	Kidney function test within three months of radiographic examination	A CT examination with radioisotope dye has been ordered. Please conduct creatinine test within three months of the examination date.	
Adverse effects of Radioactive dye	General diagnosis and treatment	Order radiation	Check duration of test and whether steroids have been ordered for ionic radioisotope dye contrasted patients who will have radioisotope dye administered	Order radiation CT	Use of ionic radioisotope dye	Patient profile ionic radioisotope dye contrasted patient		1			date of CT examination	non	Staff who ordered the examination	Staff who ordered the examination			timing of CT order	Prescribe steroids for radioisotope dye usage	Patient is contraindicated for ionic radioisotope dye. Check whether steroids have been ordered and duration of test.	
Plan for hospitalization	Medical	Documentation	Notification to be issued when hospitalization plan has not been filed in within three days of hospitalization	Order of hospitalization				1		hospitalization plan has been stored	Date of hospitalization	non	Medical group Attending nurse	Medical group Attending nurse			Three days after hospitalization	Please make hospitalization plan	Hospitalization plan has not been made. Please make immediately.	
Discharge summary	Medical	Documentation	Notification to be issued when discharge summary has not been made within 1 week of discharge	Discharge order				1		Discharge summary has been stored	1 week after discharge	non	Primary doctor Attending doctor	Primary doctor Attending doctor			1 week after discharge	Please make discharge summary	Discharge summary has not been made. Please make immediately.	
Discharge summary	Medical	Documentation	Second notification to be issued when discharge summary has not been made within 12 days of discharge	Discharge order				1		Discharge summary has been stored	12 days after discharge	non	Primary doctor Attending doctor	Primary doctor Attending doctor			12 days after discharge	Please make discharge summary	Discharge summary has not been made. Please make immediately.	
Tumor marker management fee	Medical	management fee order	Order the tumor specific substance treatment management fee and document the findings from the results of the tumor marker test results.	examination history	includes tumor marker examination			3	order management fee	order tumor specific substance treatment management fee	tumor specific substance treatment management fee has been ordered. requires link to the tumor marker examination	reporting date	non	Personnel who ordered for examination	Personnel who ordered for examination			reporting date	tumor marker results are available	tumor marker results are available. Please order the findings and order the tumor specific substance treatment management fee.
Pediatric contraindication for prescription	Pharmaceutical	Order prescription	Pediatric contraindication for Tarivid and Cravit	Order prescription	Tarivid or Cravit are included in the prescribed order	Pediatrics (under 14 years of age)		1			Timing of prescription order	non	Prescribing doctor	Prescribing doctor			Timing of prescription order	Patient is contraindicated for this prescription	Tarivid and Cravit are contraindicated for pediatric patients (under 14 years of age). Please change the prescribed medication	
Prescription warning due to kidney disorder	Pharmaceutical	Order prescription	Warning to be issued in dosage of prescribed medication for patients with kidney disorders	Order prescription	Prescription ordered for medication with careful dosage required for kidney disorder patients. Furthermore, the dosage of the medication has not been reduced.	Patients who have automatically been determined to have kidney disorders through their clinical profiles.		1		Dosage of medication has not been reduced	Timing of prescription order	urgent	Prescribing doctor	Prescribing doctor			Timing of prescription order	Prescription may assist in reduction of kidney function	Medication which require reduced dosage for patients with declining kidney function has been prescribed. Please recheck kidney function and change dosage of medication.	
echocardiogram conducted in the same month	Medical	physiological function examination	Notification to be issued for an echocardiogram order when the same examination has already been conducted within the same month.	physiological function examination (echocardiogram)		echocardiogram has already been conducted within the same month		1			Timing of physiological function examination (echocardiogram)	non	Staff who ordered the examination	Staff who ordered the examination			Timing of physiological function examination (echocardiogram)	echocardiogram conducted in the same month	Echocardiogram has been conducted in the same month. Please check and reconsider the examination for justification	
Preventive medicine for hay fever	Pharmaceutical	Order prescription	Notification to be issued between January and February to prescribe patients who have had anti-allergic drugs for hay fever prescribed the previous year between February and April.	Order prescription (last year's prescription order)	Anti-allergic drugs for hayfever have been prescribed between February and April the previous year.			1		Anti-allergic drugs have already been prescribed.	Timing of first medical visit of the year in January or February	non	Doctor who previously examined the patient	Doctor who previously examined the patient			Timing of first medical visit of the year in January or February	Anti-allergic drugs for hay fever	Anti-allergic drugs for hay fever have been prescribed in previous year. Please consider whether the patient needs anti-allergic drugs prescribed this year.	
Fever examination	General diagnosis and treatment	Flow sheet	Notification to be issued when patients have had a fever over 38°C for two consecutive days and have not yet had their sample examined.	Flow sheet (body temperature)	Patients with a fever over 38°C for two consecutive days.	sample examination has not been ordered in these two days.		3	sample examination order	White blood cell count and CRP examination to evaluate the fever	Already conducted	urgent	Medical examination group	Medical examination group	At 24 o'clock when patients have been confirmed to have a fever over 38°C for two consecutive days in the flow-sheet		At 24 o'clock when patients have been confirmed to have a fever over 38°C for two consecutive days in the flow-sheet	Continuous Fever: sample examination required.	Patient has had a fever over 38°C for two consecutive days. Please consider the need for a white blood cell count and CRP examination. Relevant orders have been attached to this message.	
Fever prior to operation	General diagnosis and treatment	Flow sheet	Notification to be issued for in patients scheduled for an operation with a fever over 37°C, two days prior, one day prior and the day of the operation.	Flow sheet (body temperature)	Patients with a fever over 37C two days prior, one day prior and the day of the operation.	operation order (operation date confirmed)		3	Operation order	Operation order which has become an incident of the antecedent	scheduled operation date	urgent	Medical examination group, anesthesiologist	Medical examination group	two days prior, one day prior and the day of the reference date (operation date)		two days prior, one day prior and the day of the reference date (operation date)	Patient scheduled for an operation has a fever	Patient scheduled for an operation (operation date) has a fever. Please determine whether the operation is feasible.	
Fever prior to cardiac catheterization	General diagnosis and treatment	Flow sheet	Notification to be issued for in patients scheduled for a cardiac catheterization with a fever over 37°C, two days prior, one day prior and the day of the cardiac catheterization	Flow sheet (body temperature)	Patients with a fever over 37C two days prior, one day prior and the day of the cardiac catheterization	cardiac catheterization order		3	cardiac catheterization order	cardiac catheterization order which has become an incident of the antecedent	scheduled cardiac catheterization date	urgent	Medical examination group	Medical examination group	two days prior, one day prior and the day of the reference date (cardiac catheterization date)		two days prior, one day prior and the day of the reference date (cardiac catheterization date)	Patient scheduled for cardiac catheterization has a fever	Patient scheduled for cardiac catheterization (cardiac catheterization date) has a fever. Please determine whether the operation is feasible.	