Using Formal Concept Analysis to Design and Improve Multidisciplinary Clinical Processes

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Abstract: - Recent changes in health care have focused attention on new tools for planning and managing clinical processes. Clinical process employ a concept long used in other industries: the explicit design and documentation of a process. However, the knowledge driven perspective is seldom used when modeling or redesigning a process. Using formal concept analysis, we propose a knowledge management perspective to provide a method for modeling and designing a new multidisciplinary clinical process, in which different medical specialist coordinate the treatment of specific groups of patients and improve the medical quality.

Key-Words: - Multidisciplinary clinical process, Formal concept analysis, Process modeling

1 Introduction

A medical or clinical process defines the optimal care process, sequencing and timing of interventions by doctors, nurses and other health care professionals for particular diagnosis or procedure. Clinical process are developed through collaborative efforts of clinicians, case managers, nurses, pharmacists, physiotherapists and other allied medical care professionals with the aim of improving the quality of patient care, while minimizing cost to the patient.

Medical process are continuously reviewed and evaluated in the light of clinical evidence so that they become a method for evaluating the care provided an form an important component of continuous quality improvement in clinical practice. Hospital managers have also used clinical process to minimize average length of stay without compromising the quality of care provided [11].

Information technology started to play an important role in medical organization beginning with 1980s. Due to advances in medical sciences and the introduction of new technologies, medical treatment, and diagnosis, managing all involved processes and related knowledge became a challenge. Medical care has become a complex organization of knowledge and new method is needed to respond these challenges [12-14].

Over the past several years, the management of knowledge is promoted as an important and necessary factor for organizational survival and maintenance of competitive strength. Knowledge management systems (KMS) have been introduced to capture and store knowledge of business and also support the documentation and exchange of knowledge [1]. However, there is no common understanding of how a KMS should look like [2].

Due to the application of information technology and the improvement of changing, the structure in hospital, the processes of hospital need to be reengineered. This approach was coined as business process reengineering (BPR). As more organizations undertake business BPR, issues in implementing BPR projects become a major concern [3]. Changes do occur in the medical environment, the existing process is at risk of becoming antiquated and harmful medial service quality. KM is rarely thought of as a strategy for redesigning hospital medical process. However, several studies [4-6] have investigated the effect of KM can be used to develop and enhance business process. KM can be thought of a strategy of business process redesign. Modeling or redesigning a hospital process involves more than restructuring the workflow. Hospital manager need to learn how to describe, analyze, audit and modify medical process using useful methodologies and tools.

1.1 Basics of formal concept analysis method

This study proposes a knowledge management method for modeling and redesigning a medical process, by using a modified formal concept analysis (FCA). Formal concept analysis has been introduced by Wille [15], and applied in a variety of domains with strong philosophical and psychological supporting, such as psychology, sociology, anthropology, medicine, biology, linguistics, computer sciences, mathematics and industrial engineering [16]. From cognitive and philosophical point of view, a concept is a unit of thoughts consisting of two parts: the *extension* and the *intension* [17]. The extension covers all objects belong to this concept and the intension comprises all attributes valid for all those objects. Therefore, objects and attributes play a prominent role together with several relations like the hierarchical sub-concept with super-concept relation between concepts, the implication between attributes, and the incidence relation an object has an attribute.

Wille further combined objects, attributes and the incidence relation in a mathematical definition, call formal context, to lexically describe the elementary of linguistic. Mathematically, we can construct for each object g its object concept (A, B), where B is the set of all attributes of g and A is the set of all objects with all the attributes of B. In the same way, each attribute m determines its attribute concept (C, D), where C is the set of all objects of m and D is the set of all attributes valid for all objects of C. Fig. 1 is a lattices diagram represents the conceptual hierarchy of all concepts of the context, diabetic medical case served as an example. Fig. 1 consists of circles, lines, the names of all objects and all attributes of the given context. The circle represents the concepts and if an object g has an attribute m if and only if there is an upwards-leading path from the circle named by g to the circle named by m.

1.2 Concept lattice of formal concept analysis and the knowledge representation

Formal concept analysis has been successfully developed for more than a decade. Theoretic and practical evidences revealed that its connections to the philosophical logic of human thought became clearer and even consistent connections to Piaget's cognitive structuralism that Seiler [18] elaborated to a comprehensive theory of concepts. Seiler's theory has been proven that there is a closely linking between mind concepts and formal concepts. Therefore, the mathematical of concepts and concept hierarchies used in formal concept analysis opens up the opportunity of supporting mathematically the logical thinking of humans. The support can really take place in the documentary report when apply FCA on it [19-20]. Therefore, FCA will be adopted as the knowledge concept representation method in this study.

In essential, FCA treats knowledge based on actual realities. Text records are one of the examples for presenting the actual realities that relies on the philosophical logic as the science of thought in general [21]. Seiler explains that concepts are cognitive acts and knowledge units, logical thinking analogous patterns of thought, reflexive knowledge, habitual knowledge, have motivational and emotional qualities and have a history and go through a developmental process.

Based on FCA to construct conceptual maps for medical behavior and environment. The lattice structures of these conceptual maps are actually ontology, which reflect the characteristics of medical environment. FCA will establish a set of conceptual relationships and hierarchy of knowledge terms. There are three kinds of relationships that exist among concepts. These are independence, intersection and inheritance. Knowledge is a representation based on these relationships. Knowledge contains all types of signs or symbols either in text form, drawing form, or expressed into mathematical formulas. A person who is able to explain why certain pieces of knowledge belong together possesses theoretical knowledge concerning this specific knowledge domain. People use theoretical knowledge when they are able to answer why questions, and are able to formulate structural relations. Theoretical knowledge is often used to identify causal relations.

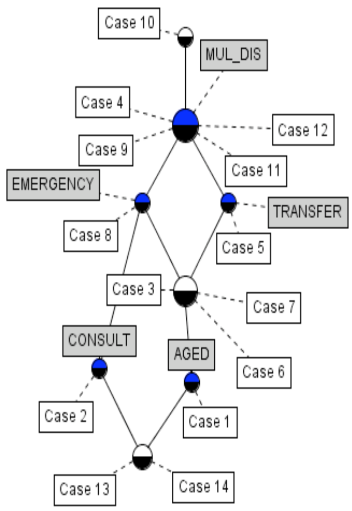

Fig. 1. Example result of clinical process concept lattices.

The reason why this study prefers this knowledge analysis method but not the general tacit-explicit knowledge categorization method is because the later one has an inherent problem. The term 'tacit knowledge' is ambiguous and not concrete experience.

Knowledge management system design emphasize knowledge capture, organization, and formalization are all need explicit knowledge [7] In the process redesign, the creation of new knowledge is limited to the integration of knowledge from multiple experts and sources. The advantage of the method proposed in this paper has the ability to provide complete new knowledge about the business process. In this study, we illustrate the proposed method by investigating medical process of treating patients in one teaching hospital.

Our FCA knowledge management comprises three main steps:

Knowledge creation: Raw data are first converted into code knowledge by FCA method, then coded knowledge is used to provide theoretical knowledge about the medical process.

Knowledge use: The new conceptual knowledge can be use for analyzing, diagnosing, and redesign the medical process.

Knowledge transfer: The new conceptual knowledge can be easily transferred to other people, or from one department of the hospital to another one.

This paper is organized as follows. In section 2, we describe the main steps for knowledge conversion and the creation of new knowledge about the medical process in hospital. In section 3, we illustrate how newly created knowledge can be used, and Section 4 is the conclusion and the directions for further research.

2 New Knowledge Creation by FCA

Patients who required the medical treatment of different department are become more and more common in modern hospital. The number of these patients is increasing because of the development of modern medical technique. Multidisciplinary patient care is essential in the management of many popular diseases. Concepts of multidisciplinary care continue to evolve. New roles have been defined an the medical profession is now emerging with additional skills to support patients and their families [8]. More and more hospitals now provide special centers in which different specialism work together to provide the whole support. However, the specialisms compounding these centers are based on the specialist's perceptions. In other words, they may have some implicit knowledge about what specialism should provide to patients. In this study, we provide a method that allows medical specialists to use explicit models as base for creating multidisciplinary units, in which different specialism coordinate the treatment of specific groups of patients.

Patients with diabetes are good example of multidisciplinary patients. One medical symptom can have many different causes, one cause can have different manifestations, and there is complexity in cause and effect between pathologies. One of the consequences of the complexity of expressing these patients in medical terms is that the homogeneity of the underlying treatment processes of these patients is low.

A medical treatment process of health service organizations comprises the design, planning, and implementation of patient flows and related diagnosis and therapeutic activities. Patients with diabetes diseases are grouped on the basis of medical homogeneity, but unfortunately this does not result in homogenous process group.

Given some criteria for selecting patients that can be considered diabetic patients, records for 263 inpatients have been collected from a teaching hospital in Taiwan. The collected data refer to personal characteristics, policlinic visits, clinical admissions, emergency or transfer from other hospital, and the complexity of diseases. Using these data, we show in this section how new knowledge about the medical process can be created, employing this type of knowledge conversion.

2.1 Knowledge conversion

We obtain the knowledge needed by performing following main steps:

1. Converting raw data into concept
2. Conceptual relationship and hierarchy construction
3. Knowledge concept lattices building

2.1.1 Converting raw data into concept

Inpatient medical records were composed by different medical specialism, and the underlying clinical process can be discriminated by different data attributes. We can express the concept of clinical process in terms of formal concept.

The important attributes of inpatient medical records are presented below.

1. CONSUL_COUNT: The total count (number) of involved specialisms consultation within a medical case. The more specialisms are involved, the more complex the medical case is.

2. CONSUL_DEPT: The physician or department of involved specialisms consultation with in a medical case.
3. TRANS_COUNT: The number of transfer within the medical case, counted by the total number of transfer to specialisms within the medical case. The more a patient has transferred from one physician to another, counted by the total number of transfer, the more complex the medical case.
4. TRANS_DEPT: The physician or department of transfer within the medical case.
5. OPER_COUNT: Number of operations underwent within the medical case. The more operation a patient underwent, counted by the total number of operation, the more complex the medical case.
6. OPER_CODE: The representation code of operations underwent within the medical case.
7. DISEASE_CODE: The code of diagnosis disease within the medical case. Disease code is represented in International Statistical Classification of Diseases (ICD). The more disease code a patient have, the more complex the medical case.
8. COMBINATE_CODE: The code of combination within medical case.

Table 1 is the example data of a diabetic inpatient. First 5 attributes are patient personal characteristics, and others are medical information.

Table 1 Example data of inpatient medical data.

Data Attribute/ Description	Example data
CHART_NO Patient id	444590
HOSP_NO Hospitalization id	09600139
AGE Age of patient	83
GENDER Gender of patient	2*
MARRIAGE Marriage status	U**
ADM_TYPE Type of admission	1***
ADM_CLI Clinical admission	MW (Medical ward)
CONSULT_COUNT	2
CONSULT_DEPT	OW, OBS
TRANS_COUNT	1
TRANS_DEPT	OW
OPER_COUNT	2
OPER_CODE	211, 211.1
DISEASE_CODE	250.42; 583.81; 250.52 362.01; 785.5; V10.52
COMBINATE_CODE	785.5

** 1: male, 2: female*
*** M: married; S: Single; D: Divorced; W: Widow; U: Unknown*
**** 1: Outpatient; 2: Emergency; 3: Transference*

2.1.2 Conceptual relationship and hierarchy construction

To have better understanding of the treatment process for diabetic, we have to develop the process model for the clinical process. A process model is a description using a formal concept of an actual or proposed process that represents the process elements or process tasks. Modeling an existing process is often providing a prescriptive model that contains what 'should' be done, rather than describing the actual process. Subsequently, models tend to be subjective. A modeling method closer to reality consists in using data representing the actual events that took place. The desired outcome is to have process models that are not biased by subjective perceptions or normative behavior.

This study uses FCA [9, 10] to establish a set of conceptual relationships and hierarchy clinical process concepts. There are three kinds of relationships that exist among these concepts. These are independence, intersection, and inheritance. In order to establish the concept relationships and hierarchy of the different concepts, following steps are designed.

First, produce the binary relation matrix between patients and medical data values. In every medical case, a concept, which comes from values that will best represent the main concept of the medical case, must be obtained in the concept retrieval. Referring to the data set and value set can do this. If a concept appears in a medical case, the corresponding entries of the matrix are labeled as 'X' and generated the binary relation matrix between medical cases and concepts. The initial starting point in using FCA is setting up a context [22].

A context is triple $L = (D, T, I)$ (1)

In this study, the context of the clinical process context is identified as L, the related medical case set of the diabetic patients is represented by *D*, the related data values set of the medical cases is marked as *T*, and *I* is a binary relation between *D* and *T*:

$$I \subseteq D \times T \quad (2)$$

Secondly, generate the concepts set *C*. Let *X* bet the partial set of *D*, and *Y* as the partial set of *T*, that is,

$$X \subseteq D,\ Y \subseteq T \quad (3)$$

The mappings:

$$\alpha(X)=\{t \in T \mid \forall d \in X:(t, d) \in I\} \quad (4)$$

The common medical treatment of *X*, and

$$\tau(Y)= \{d \in D \mid \forall t \in Y:(t, d) \in I\} \quad (5)$$

means the common diabetic medical cases of *Y*. Based on the above definitions, a *clinical process concept* is defined. A concept is a pair of sets: a set of medical cases and a set of data values (X, Y):

$$Y = \alpha(X) \text{ and } X =\tau(Y) \quad (6)$$

Therefore, a concept is a maximal collection of medical cases sharing common data values. Thus, taking concept *c* as an example, it means that the biggest diabetic medical cases set that contains the common data values is in the maximal rectangle by all the relationships *I* in the binary relation matrix. *C* represents the set of all the concepts of *c*.

The third step is to calculate hierarchy relationship of concepts. The set of all the concepts of a given context forms a complete partial order. Thus, we define that a concept (X_0, Y_0) is a sub concept of concept (X_1, Y_1), denoted by

$$(X_0, Y_0) \subseteq (X_1, Y_1) \quad (7)$$

In the event that the medical case set X_1 of a value set Y_1 is contained in the medical case set X_2 of another value set Y_2, denoted by $X_1 \subseteq X_2$, (X_1, Y_1) becomes the sub-concept of (X_2, Y_2), denoted by $(X_1, Y_1) \subseteq (X_2, Y_2)$. For concept C, it means $C_1(X_1, Y_1)$ becomes the sub-concept of $C_2(X_2, Y_2)$.

The last step in the conceptual construction is generating the entire hierarchy of concepts. It is possible for concept *c* to have various father concepts as well as sub concept. For this reason, computing various hierarchy relationships for different concepts is required in order to obtain the entire hierarchy of concepts. Each node in the hierarchy represents a concept. Given two elements (D_1, T_1) and (D_2, T_2) in the concept hierarchy, their supremum or join is define as:

$$(D_1, T_1) \cup (D_2, T_2) = (\tau(T_1 \cap T_2), T_1 \cap T_2) \quad (8)$$

Let $c_1(X_1, Y_1)$ and $c_2(X_2, Y_2)$ be two concepts, the supremum of the two concepts is computed in order to determine their respective positions in the concept hierarchy.

2.1.3 Many-valued contexts process

In Fig. 2 the perception terms with red color such as ‘well’, ‘small’, ‘now’, ‘right’, or ‘have’ do have values. We call these terms perception terms with *many-valued attributes*, in contrast to the *one-valued attributes*.

A many-valued context (G, M, W, I) consists of sets *G*, *M*, and *W* and a ternary relation *I* between *G*, *M* and *W* [23].

$$(g, m, w) \in I \text{ and}$$
$$(g, m, w) \in I \text{ always imply } w = v \quad (9)$$

The elements of *G* are called objects, those of *M* (many-valued) attributes and those of *W* attribute values.

$(g, m, w) \in I$ read as ‘the attribute *m* has the value *w* for the object *g*’. (G, M, W, I) is called an n-valued context, if *W* has *n* elements. The many valued attributes can be regarded as partial maps from *G* in *W*. Therefore, it seems reasonable to write $m(g) = w$ instead of $(g, m, w) \in I$. The domain of an attribute *m* is defined to be

$$dom(m) := \{g \in G \mid (g, m, w) \in I \text{ for some } w \in W\} \quad (10)$$

The attribute *m* is called completed, if $dom(m) = G$. A many-valued context is completed, if all its attributes are complete.

Like the one-valued contexts mentioned in section 2.1.2, many-valued contexts can be represented by formal context table, the rows of which are labeled by the objects and the columns labeled by the attributes. The entry in row *g* and column *m* then represents the attribute value $m(g)$.

How can we transform many value contexts into concepts? This study transform many-valued context into a one-valued context in accordance with certain rules, which will be explained below. This interpretation process is called conceptual scaling.

In the process of scaling, first of all each attribute of a many-valued context is interpreted by means of a *conceptual scale*. A scale for the attribute *m* of a many-valued context is a *one-valued* context $Sm := (Gm, Mm, Im)$ with $m(G) \subseteq Gm$. The objects of scale are called scale values; the attributes are called scale attributes.

Actually, the choice of the scale for the attribute *m* is not mathematically process, it is a matter of interpretation and thus will base on the opinion of domain expert. In converting raw data into concept term process, medical record values with multi-value or perception status will be treated with many-valued context and to transform into one valued context. We explain the transform rule by an example as follows.

In Fig. 2, two perception values were observed, 'COMBINATION_CODE' and 'AGE'. For the convenient of data transformation, ordinal scales scale many-valued attributes for these multi-valued terms, the values of these two multi-value terms are ordered, shown as Fig. 2.

2.1.4 Clinical process concept lattices building

After constructing the hierarchy relationships among concepts, the next step is to identify the inter-relationships of these concepts. Let $c_1(X_1, Y_1)$ and $c_2(X_2, Y_2)$ are tow concepts, if $Y_1 \subset Y_2$, and $Y_2 \subset Y_1$, since the two concepts are partially contained by one another, it allows us to identify the inter-relationship between c_1 and c_2.

After the process by the above methods, a matrix table denoting concepts appearing in diabetic medical cases can be done as Table 2. The result of matrix table calculates by formula *(1)* to formula *(10)* constitute the concept lattices as Fig. 1. A fast algorithm was adopted for building the lattice chart. This algorithm was developed by P. Valtchev [24] and has three steps: the first step generates the intents of all least upper bounds (LUBs), the second finds all maximal sets among the intents and the third step finds all nodes in the partial ordered set represented by the structure after the insertion of the node that correspond to maximal intents and then connects the current node to them. Additional effort is necessary to maintain the list of border elements that is independent from the upper cover computation.

```
PROCEDURE Build_lattice
INPUT: C = {c1, c2, …, ci}
OUTPUT: L = (C, <= l)
SORT (C)
L ⇐ {c1}
Border ⇐ {c1}
FOR i FROM 2 TO l DO
      Intents ⇐ ∅
FOR ALL c' ∈ Border DO
      Intents ⇐ Intents ∪ (Int(c') ∩ Int(ci))
Cover-Intent ⇐ MAXIMA(Intents)
FOR ALL Y ∈ Cover-Intents DO
      c' ⇐ FIND-CONCEPT(Y)
      MAKE-LINK(ci, c')
Border ⇐ (Border – upper-covers(ci)) ∪ {ci}
L ⇐ L ∪ {ci}
```

Algorithm 1: Building the concept lattice from formal context.

The Algorithm 1 first sorts the lattice nodes in *C* in order to obtain a liner extension of <= *L*. Then, the nodes are processed in a decreasing order, each time integrating the current node into the partial structure *L* that finally contains the entire lattice. At each step, the intersections between the current concept intent and the intents of all border concepts are computed and sorted in the *Intents* set. The maximal elements of *Intents* are selected and put in *Cover-Intents* (the MAXIMA primitive). These intents correspond to the most specific concepts that are greater than c_i, the upper covers. Next, for each element of *Cover-Intents*, the corresponding concept is localized within the partial structure P_i, (FIND-CONCEPT) and the respective link is created. Finally, the upper covers of a concept are excluded from the border of the partial structure and the current element is added [24].

Fig. 1 is an example result of clinical process concept lattices comes from the matrix table by formal concept analysis.

Table 2. Formal context and attributes process from diabetic medical cases.

	AGED	EMERGENCY	CONSULT	TRANSFER	MUL_DIS
Case 1	X	X	⤢	X	X
Case 2	⤢	X	X	⤢	X
Case 3	⤢	X	↗	X	X
Case 4		↗		↗	X
Case 5		⤢		X	X
Case 6	⤢	X	↗	X	X
Case 7	⤢	X	↗	X	X
Case 8		X	↗	↗	X
Case 9		↗		↗	X
Case 10					⤢
Case 11		↗		↗	X
Case 12		↗		↗	X
Case 13	X	X	X	X	X
Case 14	X	X	X	X	X

COMBINATE_CODE →	Value 1: No combination
	Value 2: With combination
AGE →	Value 1: Child
	Value 2: Adult
	Value 3: Aged

Fig. 2. Transformation of many-valued context.

Clinical process concept provides abstract knowledge express as hierarchy and structural relations. This kind of knowledge is necessary when making important decisions in reorganizing and restructuring hospitals. People need first to know and understand the process and then to be able to teach to other people related knowledge. By using FCA, these medical process concepts are the base for developing theoretical knowledge expressed as rules and concept lattices process models.

2.2 Knowledge about multidisciplinary patients

The obtained concepts provide us with insights into the diabetic clinical process of multidisciplinary patients. The relations of these concepts can be interpreted by calculating association rules as Table 3.

Table 3. Rules derived from characterize concept lattices.

```
1 < 3 > AGED =[100%]=> < 3 > EMERGENCY TRANSFER MUL_DIS;
2 < 2 > EMERGENCY CONSULT TRANSFER MUL_DIS =[100%]=> < 2 > AGED;
3 < 8 > EMERGENCY =[100%]=> < 8 > MUL_DIS;
4 < 3 > CONSULT =[100%]=> < 3 > EMERGENCY MUL_DIS;
5 < 7 > TRANSFER =[100%]=> < 7 > MUL_DIS;
6 < 14 > { } =[93%]=> < 13 > MUL_DIS;
7 < 7 > TRANSFER MUL_DIS =[86%]=> < 6 > EMERGENCY;
```

As general characteristics, ‘aged’ diabetic patients show higher values for the transfer and multidisciplinary characteristics, while patients from ‘emergency’ visited more different specialists. Patients who are ‘transferal’ from other hospital also show visited more different specialists.

As a summary, the concept knowledge we discovered corresponds to some points. First, by analysis diabetic medical data, we obtained new clinical process knowledge in terms of formal concepts. Second, we obtained new knowledge expressed as rules that distinguishes patients belonging to different clinical process from the different attributes of medical data. Moreover, this characterization provides knowledge about the relative importance of the involved clinical process dimensions. By discovering formal concept lattices, we obtained new knowledge at an abstract level. The formal concept process model provided both structural and behavioral insights about the process.

3 The Application of New Knowledge

How to apply the new medical service knowledge is another important issue in multidisciplinary patients care. The obtained concepts provide us with insights into the diabetic clinical process of multidisciplinary

3.1 New knowledge, innovation, and improvements for the organization

Today’s health care environment is experiencing unprecedented, intense reformation. Unlike traditional medical service requirement for stabilization and growth, today’s medical service are required to transform knowledge. Strong medical leadership, empowered professionals, and exemplary practice are essential building blocks for medical organizations, but they are not the final goals. Medical organizations have an professional and ethical responsibility to contribute to patient care, the organization, and the profession in terms of new knowledge, innovations, and improvements. Current systems and practices of hospital need to be redesigned and redefined if hospitals are to be successful in the future. The Application of new knowledge includes new models of care, application of existing evidence, new evidence, and visible contributions to the science of medical service process.

Today’s medical service process primarily focuses on structure and processes, with an assumption that good outcomes will follow. Currently, outcomes are not specified, and are minimally weighted. In the future, having a strong structure and processes are the first steps. In other words, the question for the future is not ‘What do you do?’ or ‘How do you do it?’ but rather, ‘What difference have you made?’ Medical service is in a unique position to become pioneers of the future and to demonstrate solutions to numerous problems inherent in our healthcare systems. Hospital may do this in a variety of ways through innovative structure and various processes, and should be recognized, not penalized, for hospital's inventiveness. Outcomes need to be categorized in terms of clinical outcomes related to medical service; workforce outcomes; patient and consumer outcomes; and organization outcomes. When possible, outcomes data that the organization already collects should be utilized. Quantitative benchmarks should be established. These outcomes will represent the achievements of an organization, and a simple way of demonstrating excellence.

3.2 The application of new knowledge from this study

In this section, we illustrate the use of newly obtained knowledge from this study. For a better coordination of patients within hospitals, there is the need to create new multidisciplinary units, in which different specialized physician coordinate the treatment of specific groups of patients. According to the results of this study, it seems that for patients with diabetes, three multidisciplinary units can be created. In case of 'aged' cases, a unit can provide emergency, transferal, and multidisciplinary service would suffice. The 'emergency' and 'transferal' cases would only need to provide multidisciplinary service.

The management team of the future for medical service organization will enter an environment requiring facilitation, participation, clinical, and empowerment skills. Those individuals who possess a clinical orientation as well as business expertise will be sought to manage multidisciplinary units. The rapid changes in the health-care environment have forced hospitals to restructure their operations. To achieve quality care, customer satisfaction, cost effectiveness, and efficiency, service integration across the organization will be required. As the knowledge we gained from this study, this demand will evolve until all levels are managing patient care'. Some of the restructuring trends occurring in the health-care industry have been collaboration service integration, management consolidation, and job elimination. The emphasis for the multidisciplinary manager of the future will include integrating the professional and clinical services, managing information, building community partnerships, promoting physician collaboration, and managing the change process. A model hospital in the next century will move toward a patient-oriented system with inclusion and empowerment initiatives. Service integration will affect all medical organizations [25].

Because of the increased complexity of the diagnostic-therapeutic approach to diabetic patients, these patients should be managed in specialized multidisciplinary units. The application of this new knowledge is to evaluate the efficacy and efficiency of a multidisciplinary service unit (MSU) in the diagnostic-therapeutic management of diabetic patients. This improvement took place despite an increase in clinical workload, but MSU increase the efficacy and efficiency of the management of diabetic patients [26].

Another requirement is the existence of adequate criteria to select new patients for treatment in a patient service center. In this study, rules were developed to identify multidisciplinary patients using medical records and primary diagnosis for validation [27]. Our intent was to refine the multidisciplinary patient selection criteria for diabetic because various hospitals have different criteria and not all patients benefit from the procedure. The most important selection criteria for multidisciplinary patients are identified. After patients have been selected on the basis of heterogeneous pattern of admission condition, clinical factors and disease combination to further refine patient selection criteria. Interventions to inform patients about medical care options and to involve them in decisions about their care are now became possible. The question of which criteria should be used to judge the effectiveness of such interventions is also clear after the application of related knowledge. The provision of research-based information about health care effectiveness to multidisciplinary patients and the promotion of greater patient-oriented in health care decision-making are likely to have a complex range of effects on: the information provided to patients; the quality of decision; professional-patient relationships; the use of health care; the healthy of patients; satisfaction; and the organization and cost of health services [28].

Knowledge about which effects are most important and how these knowledge should be measured and valued will be influenced by variety of factors, including the rationales and motives underlying interest in patient involvement in decision-making; the forms of patient involvement envisaged; and the types of interventions being considered. In the context of health care systems that aim primarily to improve health status, health outcomes should take priority over process variables such as decision-making behavior and patients' knowledge [28].

In this study, predictive rules can be developed, based on the demographic information of patients (aged, gender, and type of admission) that assign a patient to the most suitable clinical process, e.g., 'aged' or 'emergency'. We may find a rule specifying that if a patient has specific diagnosis ICD9 code, and is likely to be identified an emergency patient. This fact should be consistent with the formal concept lattices model from Fig. 1. Thus, assigning the patient to the specific process, it is also possible to know more about the patient's future clinical pathway and to estimate what departments are likely to be visited and in what order. Without modeling patients in different concept process, it would be difficult to distinguish between patients, which lead to unnecessary resource spending.

4 Conclusion

In this study, we have proposed an application of formal concept analysis for modeling and redesigning a medical clinical process. Our method focuses on three import knowledge management activities: knowledge creation, knowledge use and knowledge transfer. We illustrated our method by considering the clinical process of diabetic. This is an example of multidisciplinary patients who require the involvement of different specialized physician for their medical treatment. Consequently, this leads to more efforts regarding the coordination of care for these patients. The problem is to provide knowledge for reorganizing the care for multidisciplinary patients in order to increase the care efficiency that is to eliminate the redundant and overlapping diagnostic procedures. The proposed solution is the creation of patient service center; in which different specialized physician coordinate the treatment of specific groups of patients.

The first step of this solution is to identify patient groups in need of multidisciplinary medical care. In this study case of multidisciplinary diabetic patients, we analyzed medical raw data and found that diabetic patients can be divided into different groups, 'aged', 'emergency', and 'transferal' groups, which can be treated as a new discovery of knowledge.

The second step of our solution is to find those relevant health care professionals for particular diagnosis or procedure that will constitute the components of the multidisciplinary service center. In such service center, the care for multidisciplinary patients is not constrained within single units. For identifying the specialisms that form the multidisciplinary service center, we build process models for the treatment of 'aged', 'emergency', and 'transferal' diabetic patients, by employing concept lattices. We came to the process models by formal concept analysis on the medical data containing the medical treatment record of patient's visit to different specialisms, for example, surgery operation counts, consultant department, functional investigations, and radiology department etc. By constructing the process models for 'aged', 'emergency', and 'transferal' patients, we do not focus only on the order in which different departments are visited. The new discovery of knowledge express in concept lattices of formal concept analysis can be effectively used for constructing multidisciplinary units.

The theoretical knowledge expressed in concept lattices and rules provides relevant suggestions into the improvement of clinical process and may support the redesign of care process of diabetic patients. Our study try to be more patient oriented, in the sense of reducing redundant and overlapping diagnostic activities, which will consequently decrease the cost spent in the hospital and improve the medical quality.

We consider several directions for future research. First, patient personal information and medical history are known the first time when he or she enters the hospital. Based on this information, a first prediction could be made and patients could receive the proper treatment faster. Information within these data structures can be used to inform the patient better about the medical problems and about the sequence of treatments. This means that when more information becomes available through time, more precise prediction can be made. Second, the clinical concept process model obtained from formal concept analysis can be improved by provide weighted value between concepts. Lastly, the new technology of combining sensory equipment, e.g., radio frequency identifier sensor, might provide real time information to complement the old rule based reasoning approach in artificial intelligence with the case based reasoning approach.

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