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MAPPING THE HEALTHCARE PROCESS IN ORDER TO DESIGN FOR PATIENT SAFETY

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1. Introduction

The demand for improving quality and patient safety of the healthcare provision process has been growing especially since the release of a report "To Err is Human: Building a Safer Health System" in 1999. In this report, the Institute of Medicine in the US estimated that at least 44,000 American die each year from medical errors[1]. As a result, many countries have established national healthcare quality improvement agencies including the Institute of Healthcare Improvement in the US, the modernization agency in the UK, the Dutch Institute for Healthcare Improvement, and the Australian Council for Safety and Quality in Healthcare.

Redesigning healthcare systems has been a key approach in these organizations. Roughly speaking, this approach consists of two basic steps: identifying where potential for error is built into the process; redesigning the process to remove them [2]. In order to identify potential for error, an existing care process has been mapped first. In the healthcare industry, very limited types of process mapping methods have been used such as block diagrams, decision-action diagrams and activity role lane maps [3] [4]. These are all slightly different types of flowcharts representing the sequence of main process steps. As a communication tool, flow charts may be sufficient to enhance consensus decision-making and involvement of people in different groups and disciplines. On the other hand, as an analysis tool for identifying potential for error, there is room for further improvement. In fact, flow charts are not equipped to deal with the complexity and sheer size of processes that span many departments [5]. For this reason, additional process mapping methods are necessary to assist effective identification of potential for error.

When it comes to the process mapping methods, a great variety of approaches have been developed and used in other disciplines including human factors, software engineering and systems engineering. Since each mapping method has different origin and application, the effort to finding appropriate mapping methods to the healthcare process should be based on the understanding of the distinguishing characteristics of the healthcare system.

In this paper, the main characteristics of the healthcare system are discussed in connection with requirements for the additional process mapping methods. Secondly, the process mapping methods used in either the healthcare industry or other industries are reviewed through case studies to identify their applicability to the healthcare system.

2. Characteristics of the healthcare system

First, considering wide variations in patients' conditions and the resulting variations in care, simple flow charts have considerable limitations in representing countless possible care pathways. Second, a complex cooperation of multiple healthcare workers requires clear representation of activity role distribution in a process map. Besides, complex and widely distributed data in the healthcare system show the need for a data-focused process mapping approach.

Flow charts are not sufficient to deal with diversity of the healthcare system. In fact, there is wide variation in physical and mental conditions of patients. Every patient is truly different and therefore each patient has to take a different care process. In other words, although there may be one idealised care pathway of *what should happen*, there are countless *what does happen*. In order to improve the process, *what does happen* rather than *what should happen* should be described first. When a process has been represented in an idealised way, this will make it difficult to improve the process since the process may appear to be operating without unexpected mistakes and delays. *What does happen* in the healthcare system has great diversity and flow charts can hardly represent all that diversity without being cluttered.

Complex cooperation of healthcare workers requires a clear representation of activity role distribution in the process mapping. Such a complex cooperation structure is caused by high specialization in medicine and the high specialization has been excelled by rapid advance in medical technology. Over the last half century, the number of effective medications has increased from a few to hundreds [6]. Surgery covers a much broader range of treatments using new technologies. The effect of the advances in technology and high specialization was to increase the fragmentation of medicine. No longer could a single physician meet all of the patient's needs. The cooperation of healthcare workers became essential and this cooperation needs a clear representation in the process map. By the same reason, there is also complex and widely distributed data in the healthcare system. In this aspect, a data-focused approach is required to represent this situation.

The autonomy in the healthcare system made the data transfer between different roles more complex. Most of doctors are still private contractors, not employees and are pretty much under control of their own rule. For example, hospitals usually request patient's data from community doctors, but the level of data sharing is totally at community doctor's discretion. Even from an organizational point of view, the healthcare process is very lightly controlled unlike all other hazardous industries. There is no equivalent in the healthcare industry of the Civil Aviation Authority, which is the UK's specialist aviation regulator. National healthcare quality improvements agencies mentioned earlier are only advisory agencies and are not as authoritative as the Civil Aviation Authority. So, there is very limited centralised control in the healthcare provision process. Under this autonomous organisational structure, data and role-activity distribution has become even more complex.

In summary, the healthcare system has the characteristics of a collaborative system with distributed roles, complex data transfer, and limited centralised control. In this so-called collaborative system, interfaces among key sub-systems – e.g. how the roles and data interact in the system – have to be designed carefully to provide an incentive to collaborate rather than act independently [7]. In order to deal with these characteristics, the process mapping methods for the healthcare process need to include a data-focused representation and a clear representation of activity-role distribution.

3. Process Mapping Methods for the Healthcare System

A great variety of the process mapping methods has been developed with different purposes and for different applications. Selecting appropriate mapping methods should be preceded by a careful consideration of the characteristics of the process to be mapped and the strengths and weaknesses of various mapping methods. The characteristics of the healthcare system have already been discussed and the strengths and weaknesses of different mapping methods will be discussed.

In Table 1, several mapping methods are classified into two categories such as flow-driven process mapping and data-driven process mapping methods. These two categories can be used with mutual supplement, not with mutual exclusion [8]. The flow-driven process mapping includes various types of flow charts. Traditionally, flow charts have been used to represent the sequence of main steps involved in a process. Block diagrams are the simplest type of flow charts and used to depict a linear process [9]. In decision-action diagrams, decision steps are represented by a diamond symbol with 'yes' or 'no' outputs [10]. In activity role lane maps and role activity diagrams, the information about "who is in charge of the process steps" is represented in addition to the sequence of process steps [4] [11]. Flow charts are mostly used at the level of detail that involves specific actions, and decisions. For this reason, flow charts are unlikely to handle a complex cross-departmental process [5].

The second category, data-driven process mapping methods are aimed at understanding the relationships between data elements. A higher-level data-driven process map shows more clearly the various resources involved in the process without all of the detail of tasks performed. Both data flow diagrams and IDEF0 commonly represent types of inputs and outputs. While a data flow diagram is a simple way of showing the flow of inputs and outputs, IDEF0 describes each process as a combination of inputs, outputs, controls and mechanisms. The sequence of the input and output can be represented in either sequence or collaboration diagrams.

In the healthcare industry, comparatively simple flow charts have been used such as block diagrams, decision-action diagrams, and activity role lane maps. As a communication tool, these diagrams may be sufficient. However, in identifying potential for error, data-driven process mapping methods can be of a significant benefit. For a careful consideration of appropriate mapping methods, the strengths and weaknesses of each diagram are discussed through case studies.

Table 1. Classification of process mapping methods

Category	Focus of representation	Mapping methods
Flow-driven process mapping methods (flowcharts)	Sequence of process steps	- Block diagrams - Decision-action diagrams
	Roles and activities	- Activity role lane maps - Role activity diagrams
Data-driven process mapping methods	Inputs, outputs, and process steps	- Data flow diagrams - IDEF0
	Sequence of inputs and outputs	- Collaboration diagrams - Sequence diagrams

3.1 Flow-driven process mapping methods

Flow-driven process mapping methods mean flowcharts, which basically represent process steps in sequential order. While block diagrams represent single idealised process steps, decision action diagrams represent multiple possible process steps by using decision steps. In addition to the sequence of process steps, role information – i.e. "who is in charge of these steps" – can be represented in activity and role maps and role action diagrams.

3.1.1 Block diagrams

Figure 1 shows a block diagram representing a patient referral process from a general practitioner (GP) to a hospital. The block diagram is the most straightforward process map. It is a single flow line that links a sequence of activities or events. It shows one ideal pathway without considering possible options. It is very easy to understand, but very difficult to see how different roles interact together and how interfaces work. Since the process may seem to be operating without unexpected mistakes, the potential for error can be hardly detected through this map.

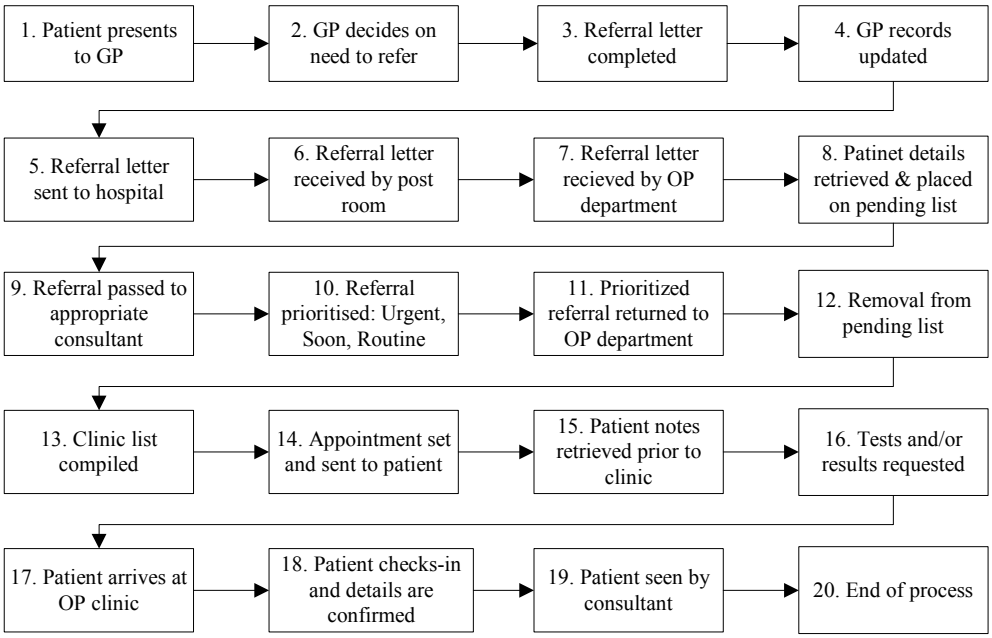

Figure 1 block diagram (arranging an outpatient (OP) appointment) [3]

3.1.2 Decision-action diagrams

A decision-action diagram depicts the processes in terms of the decisions and actions that have to be performed. Figure 2 shows a referral pathway for a specific disease called Otitis Media with Effusion. Boxes represent action elements and diamonds usually represent decision elements. The pathway has several entry points represented by black circles. By showing several possible pathways rather than a single ideal pathway, the decision-action diagram is more comprehensive than block diagrams. However, interactions between different roles are still not represented explicitly.

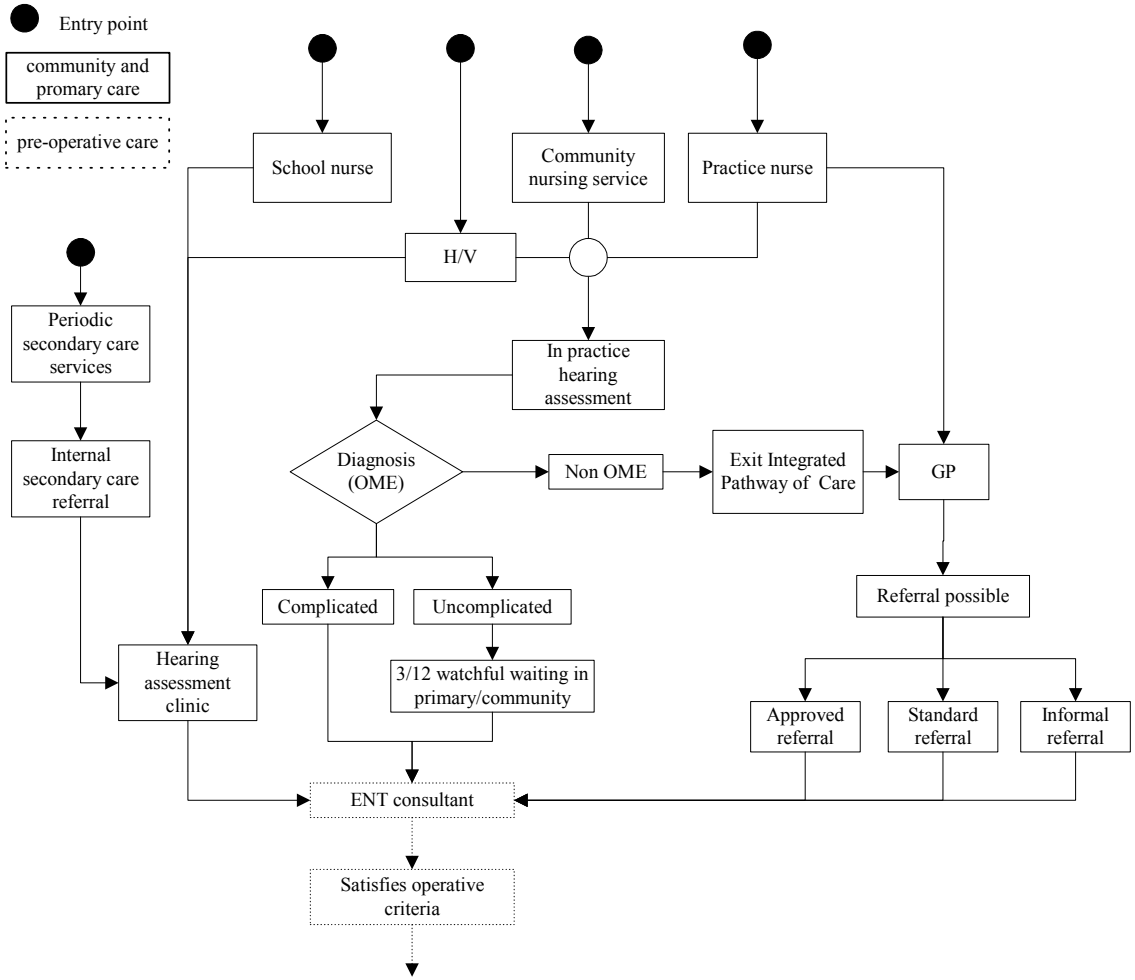

Figure 2 Decision-action diagram (Otitis Media with Effusion referral pathway) [3]

3.1.3 Activity and role lane maps

Activity and role lane maps lists the activities and the roles and links them by asking 'who does this now?' Table 2 shows activity and role relationship of the current activities in outpatient clinic [4]. This map shows how the cooperation in each task takes place. However, since it is limited to a single sequencing process, parallel activities can hardly be represented. It is also difficult to show interactions among the roles.

Table 2. Activity and role lane map (current situation in an outpatient clinic) [4]

Activity/role	Clerk	Nurse	Porter	Doctor
Move patient		X	X	
Record details	X		X	
Record vital signs		X		X
Take history		X		X
Examine patient				X
Write pathology request				X
Write imaging request				X

3.1.4 Role activity diagrams

Figure 3 shows a role activity diagram showing a simplified in-hospital medication process. Role activity diagrams originate from UML (Unified Modeling Language) and are also named as "swimlane diagrams." Activities by different roles are separated by swim-lanes. By arranging activities into vertical zones according to responsible roles, activities for each role and interaction among the roles can be portrayed with clarity. Parallel activities can be described using "fork" as in Figure 3; after an activity "prescribes medication" done by a doctor, "medication dispense" and "drug chart fill-out" go in parallel. The role activity diagrams are particularly useful in describing workflow that has a lot of parallel processing [11]. Role and activity diagrams, which have not been used for the healthcare process mapping, are expected to be especially useful to represent the complex role activity distribution in the healthcare process. Activity links between roles are shown clearly but still more detailed information about link – e.g. what input and output they communicate – need to be clarified to identify potential for error more effectively.

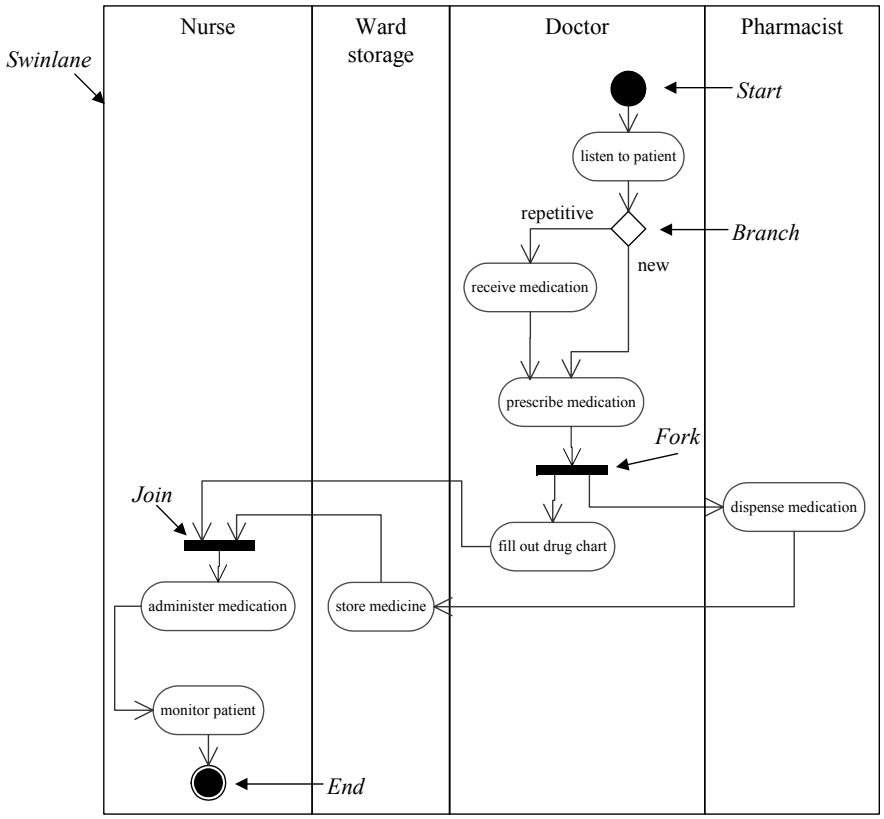

Figure 3 Role activity diagram (in-hospital medication process)

3.2 Data-driven process mapping methods

Data-driven process mapping methods focus on representing data relationships between process steps. We do not see data-driven process mapping methods replacing flow charts but rather a combination of these two methods can realise significant benefits. The first group of these methods includes data flow diagrams and IDEF0, and they concentrate on the content of the interaction between process steps by representing inputs, outputs, controls, and

mechanisms. The second group, including sequence diagrams and collaboration diagrams focuses on representing the sequence of these inputs and outputs.

3.2.1 Data flow diagrams

Figure 4 shows a data flow diagram representing GP's prescription process. Data flow diagrams focus on showing 'what happens to data' 'where the data comes form and goes to', and 'what data stores are referenced or updated along the way.' Data flow diagrams originate from the computing community to describe software system, which are communicating only by passing data [12]. There are some variations in notation. The two most commonly used notations are Yourdan and the SSADM (Structured System Analysis and Design Method) [12]. The SSADM notation, used in Figure 4, consists of four symbols: process by a box with three sections; data flow by an arrow; data store by right-side opened box; and external entity by oval. Data relationships between process steps are clearly described. Data flow diagrams do place some constraints upon the ordering of process execution, but do not completely define process sequence. In addition to data flow, data transfer methods, detailed content of data, and form of data storage may be necessary for the thorough identification of potential for error.

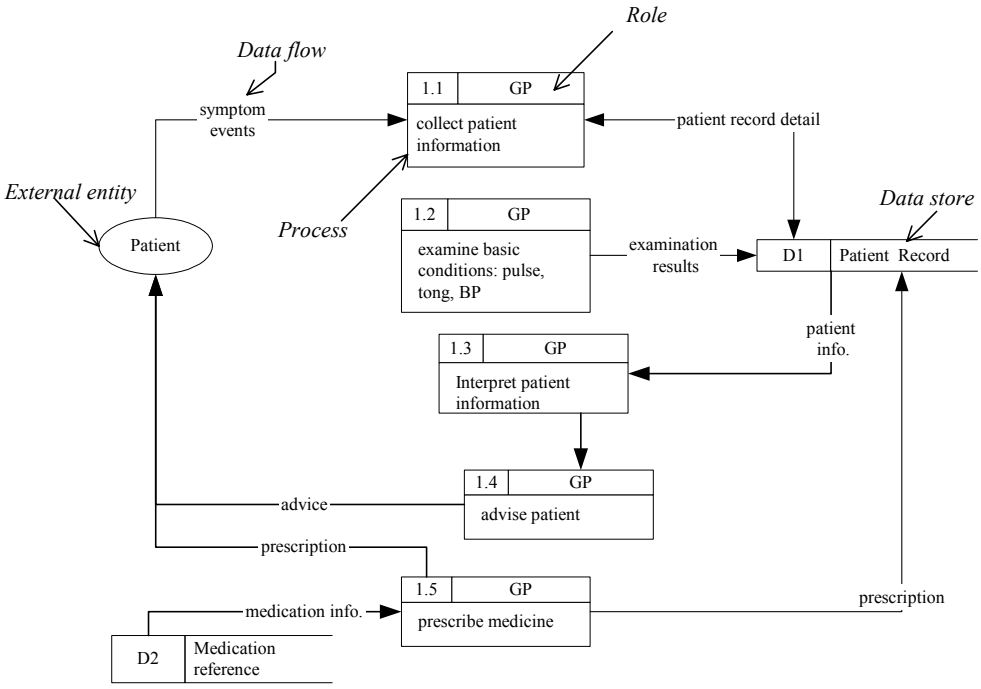

Figure 4 Data flow diagram (GP's prescription process)

3.2.2 IDEF0

The extension of the data flow diagram is advocated via reference to IDEF0. IDEF0 originates from a US Air Force program for Integrated Computer Aided Manufacturing (ICAM) and is aimed at mapping systems generally [9]. Figure 5 shows the basics of an IDEF0 diagram. IDEF diagrams consist of rectangular boxes and arrows. The relationships between activities include controls, inputs, outputs, and mechanisms [9].

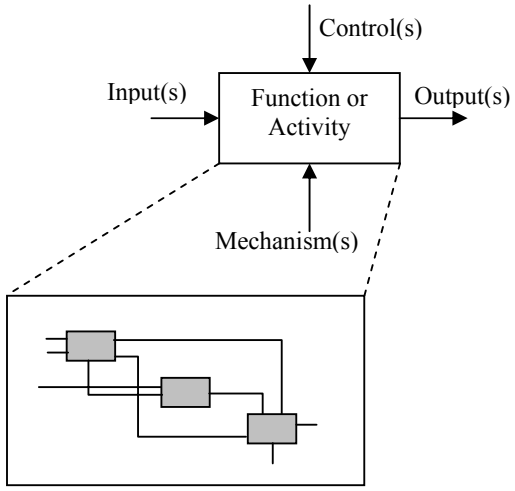

Figure 5 Breaking down a process using IDEF0

3.2.3 Sequence diagrams

Sequence diagrams represent a number of example objects of interest and the messages that are passed between these objects. Sequence diagrams and the following collaboration diagrams originate from the UML (Unified Modelling Language). Figure 6 shows interactions of a GP referral process. The vertical line called lifeline, represents the object's life during the interaction. Each message is represented by an arrow between the lifelines of two objects. The order in which these messages occur is shown top to bottom. An activation box is included to show when an object is active [11]. As in Figure 6, a sequence diagram is very simple and has immediate visual appeal.

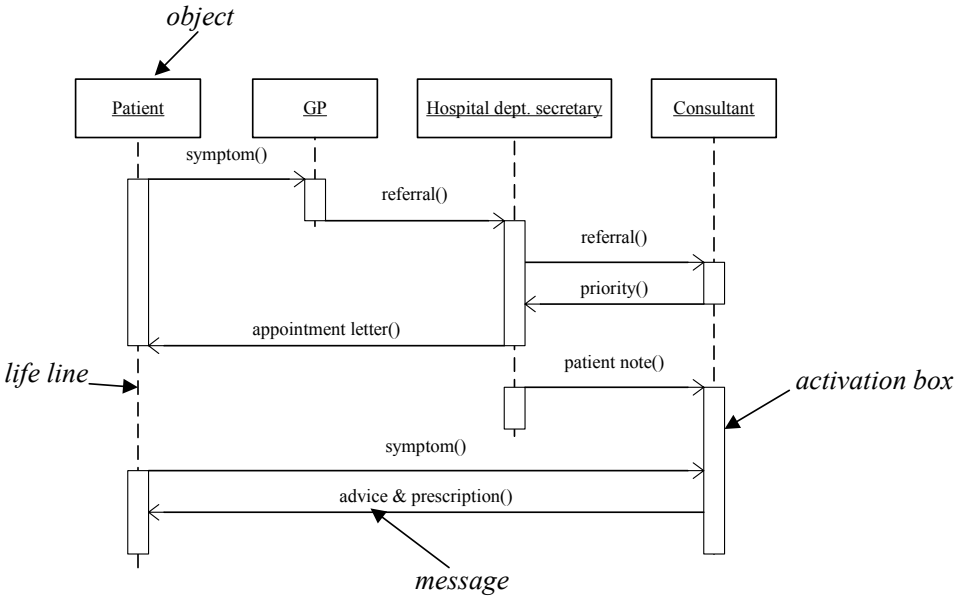

Figure 6 Sequence diagram (GP's referral process)

3.2.4 Collaboration diagrams

A collaboration diagram indicates the sequence by numbering the messages instead of by vertical position of the arrow. Figure 7 describes the same process as Figure 6 in different representation. As shown in Figure 7, numbering messages makes it more difficult to see the sequence than putting the lines down the page. However, the spatial layout allows you to see how objects are statically connected.

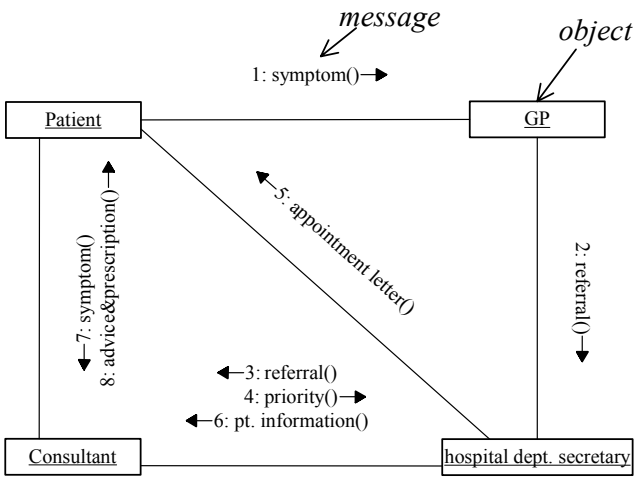

Figure 7 Collaboration diagram (GP's referral process)

3.3 Summary of findings

When it comes to the process mapping, there is always a dilemma between simplicity and adequacy; while a map should be rich enough for you to say what you need to say, it should be simple enough to understand easily [13]. The simplicity is related to how easy it is to generate and read maps. The adequacy is about how well the characteristics of the process are represented.

The process mapping methods are compared with regard to both the simplicity and adequacy in Table 3. The first row shows the aspects of the process mapping such as the simplicity and several features of the process. The first four diagrams are flow-driven process maps and the last four are data-driven maps. Out of four flow-driven maps, role activity diagrams in the fifth row explicitly represent parallel processes and role activity distribution, which are one of the important characteristics of the healthcare process. Data-driven mapping methods are generally more complex than flow-based mapping methods. While data flow diagrams and IDEF0 are focused on type of inputs and outputs in connection with process steps, sequence and collaboration diagrams are more on the sequence of inputs and outputs. In the healthcare process, there are some cases when the sequence of inputs and outputs are a key issue to be taken care of. For example, medication data updating sequence among different care groups – e.g. community doctors and nursing homes – is a key issue to be mapped out. Therefore, according to the key issues of the process, the most appropriate mapping methods need to be used. Besides, since a single diagram cannot accommodate all the important features of the process as in Table 3, multiple diagrams need to be used to see different features of the process.

Table 3 Comparison of process mapping methods (●: high, ⊙: medium, ○: low, -: none)

Aspects / Mapping methods	Simplicity	Sequence of process steps	Parallel processes	Role-action distribution	Type of input/output	Sequence of input/output
Block diagrams	●	●	-	-	-	-
Decision-action	⊙	●	⊙	-	-	-
Activity role lane maps	●	●	-	⊙	-	-
Role activity diagrams	⊙	●	●	●	-	-
Data flow diagrams	○	⊙	○	⊙	⊙	-
IDEF0	○	⊙	○	-	●	-
Sequence diagrams	○	○	○	⊙	○	●
Collaboration diagrams	○	-	-	⊙	○	⊙

4. Conclusion

The healthcare industry has been trying to improve quality and safety of the care provision processes based on flow charts. In order to overcome the limitations of the flow chart and identify potential for error more effectively, additional process mapping methods are necessary. Considering the characteristics of the healthcare provision process, a clear representation of activity and role distribution and a data-focused representation are additionally required. Role activity diagrams and four data-driven process mapping methods, originated from software and systems engineering, are expected to assist the flow charts to facilitate the identification of potential for error.

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