

# Converting Clinical Pathways to BPM+ Standards: A Case Study in Stable Ischemic Heart Disease

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**Abstract**—Clinical pathways (CPs) are structured healthcare plans designed to implement evidence-based clinical guidelines, medical algorithms, and protocols. In recent years, a community called BPM+ Health has worked to establish a shareable and computer-consumable representation of CP, leveraging standard notations. These notations, collectively referred to as BPM+, include the Business Process Management and Notation (BPMN), Case Management Model and Notation (CMMN), and Decision Model and Notation (DMN), which aim to support clinical management and standardized communication between different stakeholders. However, the adaptation of these notations for the existing guidelines has largely been left unexplored. This paper introduces procedural steps and criteria considerations to apply components of BPM+ notations to reconstruct a guideline for Stable Ischemic Heart Disease. This paper describes how each of the three different notations is mapped to a medical guideline and discusses the advantages and limitations of representing CPs with BPM+ as compared with paper-based medical guidelines.

**Index Terms**—clinical pathway, BPM+, BPMN, CMMN, DMN

## I. INTRODUCTION

Clinical pathways (CPs) are guided care maps intend to improve the quality of personalized care, establish cost-effective evidence-based care management, and standardize care procedures. CPs become increasingly important for clinical process optimization and standardized communication between different stakeholders in clinical process management. However, the design, optimization, and execution of CPs are not yet well established, and the complexity of the healthcare process is rapidly increasing.

Health informatics is an information technology that organizes and analyzes health records to improve healthcare outcomes. CP design, execution, and management can become very efficient if they are seamlessly represented in the health informatics system. In recent years, a healthcare community called *BPM+ Health* has established shareable and computer-interpretable CP standard notations to improve the capabilities

and usability of CPs. The standard notations, collectively referred to as *BPM+*, include Business Process Management and Notation (BPMN), Case Management Model and Notation (CMMN), and Decision Model and Notation (DMN), which aim to support clinical management and standardized communication between different stakeholders. However, adapting these notations for the existing clinical guidelines has largely been left unexplored, and numerous guidelines still remain in paper-based forms, such as flowcharts. This is mainly because there are no standard procedures to represent a paper-based guideline in the BPM+ notations. More specifically, no guidelines exist to translate paper-based guideline items into their equivalent notations in BPM+, and most efforts are done in an ad hoc fashion.

The central piece of most clinical guidelines is a medical algorithm, which is a decision support tool represented as a decision tree that improves and standardizes medical decisions. Typically, the guidelines include a sequence of algorithms representing various courses of treatments. Thus, transforming medical algorithms into the three standard notations is the most important part of modeling CPs for the clinical guideline in BPM+. However, it is unclear how each algorithm should be translated into the correct BPM+ notations. An algorithm can be translated as a process, case, decision activity, or any combination of these. This paper introduces procedural steps and criteria for translating a paper-based guideline represented as a flowchart into BPM+ notations and demonstrates the converting process for a Stable Ischemic Heart Disease (SIHD) guideline as an example. The advantages using BPM+ for the guidelines is compared with existing paper-based guidelines.

## II. RELATED WORK

This section introduces previous work, focusing on modeling CPs using BPMN. BPMN has evolved into one of the most established standard modeling languages and notations in business process management tasks. Contrastingly, few papers were found about CMMN and DMN because they were published more recently. Although Zensen and Kuster [1] compared BPMN and CMMN to determine the advantages and disadvantages of both notations, the application of the notations was not for a healthcare domain.

The concepts, steps, and decisions in a business process are modeled in intuitive and flexible graphical notations, and

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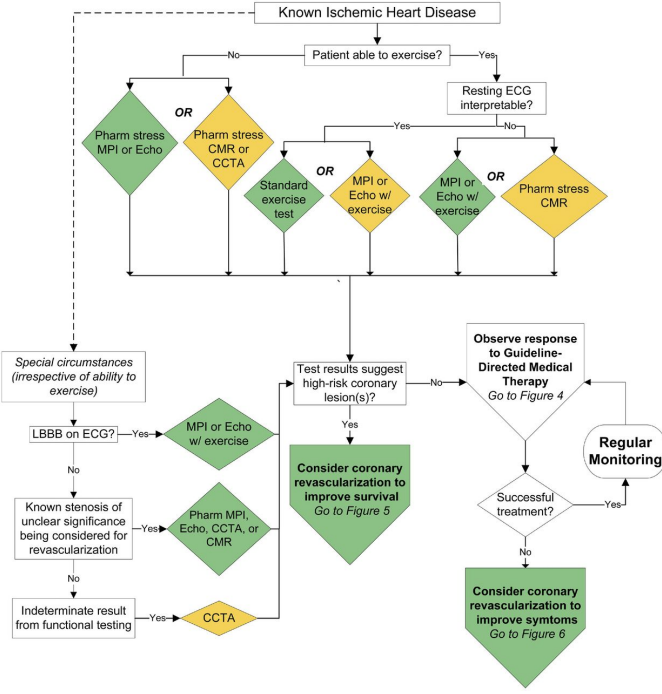


Fig. 1. A medical algorithm for risk assessment of patients with SIHD. [6]

CPs are designed with regard to clinical process management. In recent years, therefore, many studies have focused on modeling CPs based on BPMN [2]–[4]. Scheuerlein et al. [3] converted two different cases of CPs to BPMN by using a heuristic approach to evaluate the applicability of BPMN for CPs. Andellini et al. [4] modeled CPs as a BPMN model to identify the benefits of BPMN using pediatric kidney transplantation as a case study. The results showed that the BPMN method reduced the time of management and provided other benefits that improved healthcare service quality. Although BPMN is suitable as a standard CP language model, there is a gap between BPMN and CPs. To bridge the gap, some models are designed and implemented as extended versions of BPMN for CPs [2]. Few studies focused on converting CPs to BPMN. Hashmian [5] proposed an approach based on ontology mapping to represent CPs as BPMN.

### III. BACKGROUND

This section provides background information about BPM+ Health and the SIHD guideline.

#### A. BPM+ Health

BPMN is a formal graphical language used to create visual workflow diagrams for specifying business processes. BPMN is mainly used for structured and deterministic workflows. Using a well-defined standard helps improve the communication among all types of stakeholders by providing consistent and coordinated workflow steps. CMMN is also a graphical notation, and CMMN complements BPMN with additional capabilities for ad hoc and nondeterministic workflows influenced by the information flowing into the situation. DMN is a standard used to model combinations of factors that must

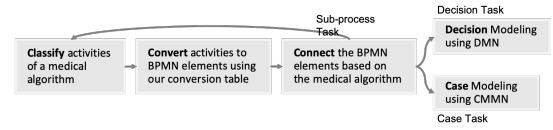


Fig. 2. Procedure for converting clinical pathways to BPMN.

be considered for complex clinical decisions by providing an understandable decision table.

#### B. Guideline of Stable Ischemic Heart Diseases

This guideline is intended to apply to adult patients with stable known and suspected SIHD, and it includes the initial diagnostic approach to patients with SIHD and the assessment of their risk of subsequent complications. The guideline consists of four basic sections. The sections contain a guideline of diagnosis, risk assessment, treatment, and follow-up. The guideline also provides five algorithms that summarize the sections. The medical algorithm for the risk assessment of patients with SIHD is shown in Fig. 1.

### IV. CONVERSION PROCEDURE

This work proposes a conversion procedure that defines a set of ordered steps for converting a clinical guideline to BPM+. Most clinical guidelines provide medical algorithms, which are a clinical decision support tool represented as a decision tree to display possible decisions and conditional control structures. In a medical algorithm, each node (i.e., activity) represents a test on an attribute of a patient or patient healthcare activity. Each branch represents the test outcome. The conversion procedure provides a way to convert medical algorithms to the graphical notations of BPMN, CMMN, and DMN, as in described in Fig. 2.

First, given a medical algorithm, the algorithm activities are classified based on their characteristics, such as operation, decision, and reference. Then, the classified activities are converted to appropriate BPMN elements according to the conversion table in Table I. Next, the converted graphical elements are connected based on the order of activities in the medical algorithm. Finally, specific types of BPMN elements are modeled separately according to each type of elements using CMMN and DMN. The models are associated with each other. Using this procedure, the five SIHD guideline algorithms were transformed as a case study. For example, the BPMN model shown in Fig. 3 was converted from the medical algorithm in Fig. 1.

#### A. Classification Step

The first step is to classify the activities of a given medical algorithm. The algorithm in Fig. 1 consists of many different types of nodes and edges. The nodes represent specific activities, and the edges show the flow between activities. The activities are classified based on their characteristics into three types: *Operation*, *Decision*, and *Reference*. **Operation activities** are the work that a hospital performs in a clinical workflow (e.g., lab test, medical order, treatment). **Decision activities** are the tasks that comprise a clinical assessment



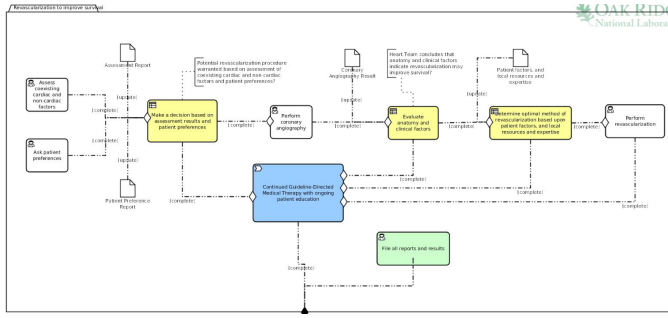


Fig. 4. CMMN model of revascularization of improve survival.

model for the case of the revascularization of improve survival is shown in Fig. 4.

A Decision Task is designed as a DMN model encapsulating a decision logic that is applied to a collection in inputs to determine the appropriate output. The logic is expressed as a *Decision Table*. The Decision Table in Table II shows a subset of synthetic rules depicted as rows for making a decision of coronary angiograph. Each row contains a set of input conditions and a corresponding output.

TABLE II  
DECISION TABLE FOR MAKING A DECISION

Input			Output
Cardiac Factor	Non-cardiac Factor	Patient Preference	Decision
High	High	Yes	Perform coronary angiography
Low	Low	Yes	Direct Medical Therapy
Low	High	No	Direct Medical Therapy

## V. DISCUSSION

This section discusses the advantages and limitations of representing CPs with BPM+. First, BPM+ is a collection of standard notations, making it easier for different stakeholders to understand and communicate. Although medical algorithms in existing guidelines have flowchart forms, they do not have standard rules or notation. For example, the medical algorithm in a guideline of coronary artery disease [7] in Fig. 5 clearly uses different notations than the algorithm in Fig. 1. Therefore, BPM+ provides more consistent, refined, and conformable expressions than existing guidelines. Also, traditional medical algorithms do not primarily consider nondeterministic healthcare procedures. However, CMMN in BPM+ can support ad hoc and unstructured processes in response to evolving situations. DMN in BPM+ efficiently identifies required clinical activities and determines requirements to make decisions.

While BPM+ is specified as a general purpose language, it lacks in modeling domain-specific concepts of CPs. For example, the method for illustrating the involvement of many roles that participate in one Task in BPMN is unknown. Although a few works [2] focused on extending the language to improve the suitability of the standard for the processes of medical practice, there is no well-standardized guidelines for extensions.

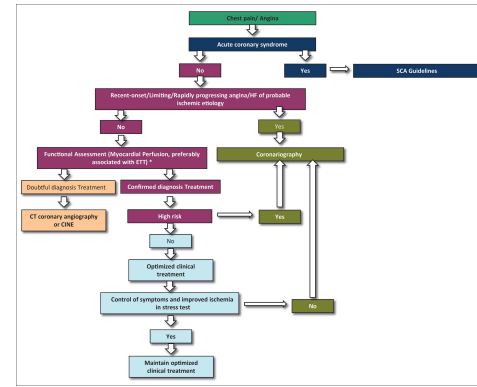


Fig. 5. Diagnostic algorithm and stratification of Coronary Artery Disease [7].

## VI. CONCLUSION

A structured procedure is proposed for converting CPs to BPM+ Health notations. This work demonstrated how the medical algorithms can be reconstructed in the SIHD guideline using the three notations. Lastly, this work discussed the advantages of each standard notation compared with existing medical guidelines. As future work, a more systematic and semiautomatic transition module will be implement for robust and efficient conversion.

## ACKNOWLEDGMENT

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