dHealth 2023
B. Pfeifer et al. (Eds.)

doi:10.3233/SHTI230015

Process-Modelling of Cross-Sector Healthcare Quality Indicators

Julia M. KIRISITS[a,1] and Walter GALL[a]
[a] *Section of Medical Information Management, Center for Medical Data Science, Medical University of Vienna, Austria*

Abstract. Background: Quality indicators (QI) are a common method to ensure quality in healthcare. This paper is based on the so-called QI-KA project, which defined cross-sector QI for the Austrian healthcare system. However, to allow for automated conformance checking, the QI must be modelled in a formal way. Objectives: The aim of this paper is to gather requirements on modelling languages and tools in healthcare, create models for one of the QI-KA project's QI and finally evaluate them. Methods: The QI-2 is modelled in the Business Process Model and Notation (BPMN) together with the Decision Model and Notation (DMN) to showcase and evaluate their application and suitability. Results: The generated models show that BPMN and DMN are mostly appropriate for this use case and serve as a basis for automated conformance checking. Conclusion: We successfully showed that BPMN and DMN can be used to model cross-sector QI in a formal way to prepare for conformance checking. The field of application can be extended to other medical areas. To further improve quality in healthcare, outcomes from models and conformance-checking should be discussed in interdisciplinary teams.

Keywords. Healthcare quality indicators, process modelling, secondary data

1. Introduction

As quality often cannot be measured directly, quality indicators (QI) are a commonly used method to ensure healthcare quality. In Austria, the Austrian Quality Indicators (A-IQI) system uses secondary data to ensure and monitor treatment quality nationwide [1].

However, A-IQI only keeps track of intramural treatment quality and lacks quality measures for the outpatient care. But this area is very important as the transition to outpatient care is a challenge for both, healthcare professionals and patients. There is still a lack of information flow [2] and low adherence may lead to higher morbidity and mortality [3]. To address this issue, in the QI-KA project, cross-sector QI for the Austrian healthcare system were developed. The pilot study explicitly covers both, the intramural and the extramural sector and is using the myocardial infarction as a tracer [4]. To automatically evaluate conformance and perform a conformance checking of those quality indicators, it is necessary to 1) design and model the guidelines defined in each QI using a (semi-)formal modelling language, 2) generate process logs based on secondary data and 3) perform the conformance checking itself by re-playing [5, p. 10].

In this paper we focus on part 1) – the (semi-)formal design of the "to-be" processes and guidelines. Our objective was to gather the specific requirements of the healthcare

[1] Corresponding Author: Julia M. Kirisits, Section of Medical Information Management, Center for Medical Data Science, Medical University of Vienna, Austria, E-Mail: julia.kirisits@gmx.at

sector in terms of process modelling languages and tools, to model one QI defined in the QI-KA project and to evaluate the feasibility of the languages and tools used.

1.1. Applications of process modelling and mining techniques in healthcare

It is quite common to transfer methods from the industrial sector to the healthcare sector. Thus, vocabulary like “Business process” and “Customer value” are being translated into “Treatment process” and “Patient value” [6, p. 29]. However, the Austrian healthcare system is also quite different from industrial processes with respect to financial structures, flexible, but complex treatment processes and particularly strict data protection, regulatory and legal requirements [6, pp. 3-4].

To meet these special requirements, there are several approaches in adapting standardized modelling languages to the demands of healthcare, Wiemuth et al. [7] are proposing the usage of the Case Management Model and Notation and the Decision Model and Notation (DMN), which are like the Business Process Model and Notation (BPMN) being developed by the Object Management Group. Scheuerlein et al. [8] have introduced the Tangible Business Process Modelling method to be used together with BPMN to give medical specialists an easy-to-follow introduction to process modelling.

To complete the picture from process modelling to conformance checking, we also considered current research activities in the process mining field. In 2017, Baker et al [9] used process mining to model electronic health record (EHR)-based clinical pathways in oncology. Their results show: almost every patient follows an individual treatment pathway, but there will be a significant overlap of activities, albeit in different sequences.

2. Methods and Data

First, we identified the specific requirements on modelling languages and to what extent these are met by popular modelling languages. We also identified requirements on modelling tools and finally modelled the QI-2 “Echocardiography” in BPMN combined with DMN.

General requirements on modelling languages as described in [10, p. 9] are expressiveness, simplicity and comprehensibility, formalisation and precision, visualisation, developer support, openness, customisation, vendor-independency as well as analysis and simulation. However, healthcare processes differ from generic industrial processes and thus the requirements on modelling languages do as well. For example, in clinical decision support systems, it may be of interest whether a particular treatment path is evidence-based and how its outcome is. Burwitz et al. [11] therefore defined requirements on modelling languages specifically for the healthcare sector. Those requirements comprise among others the clinical state, treatment step, variable and parallel flow, evidence indicators, evidence-based decisions, and time events [11, pp. 1330-1331]. Mulyar et al. [12] compared the main modelling languages for computer interpretable guidelines (CIGs) with the control flow patterns used in workflow systems. They found that most CIG languages don't support even half of the control-flow patterns and CIG languages add little flexibility compared to business process modelling concepts. However, it is emphasised that CIG languages do add flexibility mainly by providing expression languages for the modelling of complex decisions.

Requirements and features of modelling tools are often divided into categories to have a better overview and to put an emphasis on one of the categories where necessary and useful. In [13] for example, they defined the categories “Design and Modeling”, “Analysis”, “Implementation”, “Management and Administration”. The “Design and Modeling” category thereby comprises features like the support of standardized modelling languages, building forms and creating workflows, Drag-and-Drop functionality, the visualisation of processes and attributes, activity and flowchart mapping, process hierarchies and collaborate process design.

Thus, we choose BPMN as it is standardized, providing openness, company independency and a diagram interchange format. Furthermore, BPMN is designed to be executable and is widely supported by modelling tool vendors. As the conditions for the indication check are quite complex, we decided to complement BPMN by using DMN for this task as proposed by [7]. As modelling tools, we used *SAP Signavio Process Manager*[2] and *ARIS 10 Designer and Architect*[3]. We evaluated the appropriateness for our use case regarding Design and Modelling functionality and exchange formats of tools, but also expressiveness, simplicity, and visualisation aspects of the modelling languages.

2.1. Use Case “QI-KA project”

The QI-KA project demonstrates the usage of cross-sector QI by using the acute myocardial infarction as a tracer and defining the event of infarction as index event. Six quality indicators have been developed, of which we took quality indicator No. 2 (QI-2) to design the treatment guidelines in a formal modelling language.

QI-2 was developed to check whether an echocardiogram has been performed within six weeks of the index event (QI-2-echo). In addition, QI-2 verifies if an implantable cardiac device has been implanted only with given indication and within the correct timeframe (QI-2-impl) [4, p. 66].

3. Results

QI-2-echo is the first aspect and specifies that an echocardiography should be performed between 6 and 12 weeks after the infarction. While the index event is usually treated in a hospital, the echocardiography may take place in an outpatient setting or at a rehabilitation clinic. However, intramural documentation is often better than in outpatient care, e.g., by providing encoding in the International Classification of Diseases, Version 10 (ICD-10).

Figure 1 shows a BPMN process diagram for QI-2-impl, which verifies the implantation of a cardiac device took place according to the current treatment guidelines. The process starts with the index event, an acute myocardial infarction (ICD-10 code I21.*). It is necessary to wait 48 hours before assessing the indication for an implant. If there is no indication, an implantation should not be conducted. If the implantation of a cardiac device is indicated, other factors are clarified and the patient gave consent, a minimum of 40 days must elapse from the index event before the surgery can be conducted and it should be performed within one year from the index event.

This BPMN diagram is easily understandable and visually appealing. The process flow can be followed easily, whereas all important treatment steps are described precisely. Therefore, it is well suited to be discussed interdisciplinary with medical

---

[2] https://www.signavio.com/products/process-manager/

[3] https://documentation.softwareag.com/aris/Architect/index.htm

professionals. However, we found some disadvantages of BPMN for our use case. The time-based conditions are not clear enough for automated execution. They are only typed as literal strings and ambiguous in their meaning. E.g., the timer “T40d” could also be interpreted as “wait 40 days after patient gave consent”. Moreover, the swimlane approach might also be a disadvantage, as the boundaries between inpatient and outpatient care may vary from case to case. E.g depending on the patient’s health condition, the consultation may take place in an inpatient or in an outpatient setting.

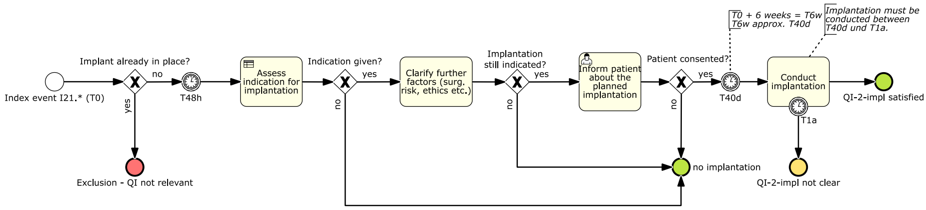

Figure 1. BPMN process diagram for QI-2-impl.

To assess the indication for an implantable device, we complemented our BPMN model with DMN. To verify the indication, the Decision Requirement Diagram (DRD) in Figure 2 defines the decision requirements and the required input, which in this case are ICD-10 codes.. The results of the indication-check for the implantable cardioverter-defibrillator (ICD) and for the pacemaker, formally Cardiac Resynchronisation Therapy (CRT) will flow and thereby determine the top-level decision “Indication for implantation given?”.

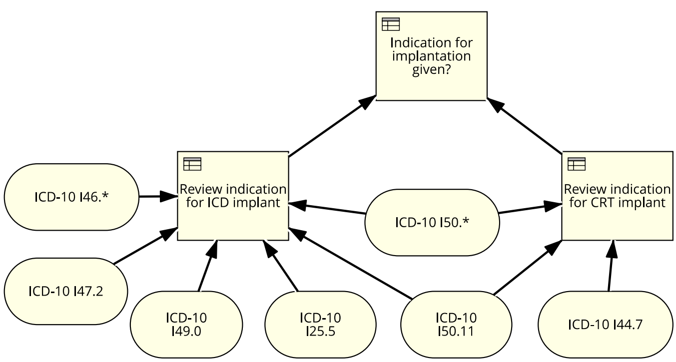

Figure 2. DMN Decision Requirements Diagram to assess indication for QI-2-impl.

First, however, the sub-decision “Review indication for ICD implant”, located at the bottom left in Figure 2, will be discussed.

The decision logic is defined in decision tables. DMN’s Friendly Enough Expression Language (FEEL) aims to be useable by developers, as well as by business users. It offers a simple data model and syntax together with the three-value logic, plus a variety of built-in data types and functions to define decision logic in a simple manner [14]. Figure 3 shows the decision table for the ICD indication check as an example. To answer the question “Indication for ICD implant given?” with “yes” (true), there must be a diagnosis for New York Heart Association (NYHA) Class II-III, ICD-10 I50.* (true), but not for I50.11 AND a diagnosis for ischaemic cardiomyopathy (ICD-10 I25.5) AND the patient must suffer from cardiac arrest (ICD-10 I46.*) OR ventricular tachycardia (ICD-10 I47.2) OR other cardiac arrhythmias (ICD-10 I49.0). In each other case, the decision table will evaluate to false.

We chose hit policy “First (single)” so that the first matching rule is applied.

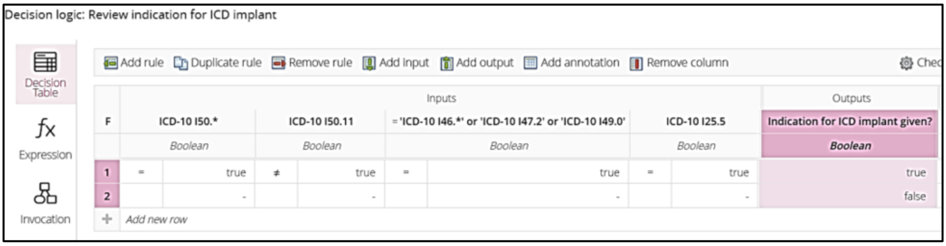

Figure 3. DMN Decision Table to verify the indication for an ICD implant.

The indication for a pacemaker, formally a Cardiac Resynchronisation Therapy (CRT), is given with the following diagnosis: [4, pp. 71-72]

- NYHA Class II-III – ICD-10 I50.* except I50.11
- AND Left bundle-branch block, unspecified – ICD-10 I44.7

The associated decision table is linked to the decision “Review indication for CRT implant”, located on the bottom right in the DRD diagram (Figure 2).

To implant a Cardiac Resynchronisation Therapy Defibrillator (CRT-D) both, the indication for an ICD and for a CRT must be present. The top-level decision “Indication for implantation given?” in Figure 2 checks if either the indication for an ICD, for a CRT, for both or for none is given. If the indication for both, an ICD and a CRT is given, the implantation of a CRT-D is proposed.

We linked this top-level decision with the task “Assess indication for implantation” so that – when correctly implemented – the result of this decision will be transferred to the BPMN diagram and influences the following decisions.

In addition, we compared the tools used, regarding the user-interface, the supported modelling languages, import- and export-functionalities and simulation capabilities. We found that Signavio Process Manager is well suited in terms of BPMN, DMN and UML modelling support. It offers basic simulation capabilities for BPMN models whereas DMN simulation is convincing and intuitive. Unfortunately, for DMN models only an export-option is offered. At ARIS Architect we especially liked the repository capabilities and the broad range of supported modelling languages. However, ARIS Architect itself does not offer any simulation features.

We exported a BPMN model and a DMN model from Signavio Process Manager to import it in ARIS Architect and vice versa. This worked especially well for BPMN models, whereas with DMN models we are not convinced, that the functions of Signavio Process Manager would still be executable in another simulation program. Also, when looking into the code of exported files, the DMN files vary more than the BPMN files.

4. Discussion

We show that BPMN and DMN could successfully be used to model the treatment guidelines of the QI-KA project in a formal way. The resulting models provide a clear, sustainable documentation and may also serve as a guideline for treatment processes or as a basis for conformance checking tasks. BPMN clearly proved as an established standard for process modelling, particularly in terms of tool support and exchange formats. However, BPMN lacks some specific requirements of healthcare – in our case mainly flexibility in task sequence and responsibility areas, as well as complex or time-base conditions. For the latter one, DMN convinced as a well-suited complement by separating decision requirements and decision logic. However, tool support for DMN less mature. Although these results are very promising, research should be extended to other medical areas. Moreover, the outcome of the designed models and of conformance checking should be discussed in an interdisciplinary team – consisting of IT professionals, data engineers, physicians, caregivers, and funders.

5. References

[1] Bundesministerium für Soziales, Gesundheit, Pflege und Konsumentenschutz, *Austrian Inpatient Quality Indicators (A-IQI). Report 2021.* Accessed: Jan. 28 2023. [Online]. Available: https://www.sozialministerium.at/dam/jcr:e682b113-fa01-4d78-9c0f-93e247818a87/A-IQI_Bericht_2021.pdf

[2] S. Ludt *et al.,* "Die Patientenperspektive jenseits ambulant-stationärer Sektorengrenzen - Was ist Patientinnen und Patienten in der sektorenübergreifenden Versorgung wichtig?," *Gesundheitswesen (Bundesverband der Ärzte des Öffentlichen Gesundheitsdienstes (Germany))*, vol. 76, no. 6, pp. 359–365, 2014, doi: 10.1055/s-0033-1348226.

[3] P. Sulzgruber *et al.,* "Adherence to cardiac rehabilitation after acute coronary syndrome and its impact on patient outcome," *European Heart Journal*, vol. 41, Supplement_2, 2020, doi: 10.1093/ehjci/ehaa946.3104.

[4] W. Gall *et al.,* "Projekt „QI-KA".: Sektorübergreifende kardiologische Qualitätsindikatoren für das österreichische Gesundheitswesen," Endbericht, Arbeitsgemeinschaft Medizinische Universität Wien, Wien, May. 2019. Accessed: Jan. 9 2023. [Online]. Available: https://www.sozialversicherung.at/cdscontent/load?contentid=10008.738745&version=1599468242

[5] W. M. P. van der Aalst, *Process Mining: Discovery, Conformance and Enhancement of Business Processes*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2011.

[6] A. Gadatsch, *IT-gestütztes Prozessmanagement im Gesundheitswesen*. Wiesbaden: Springer Fachmedien Wiesbaden, 2013.

[7] M. Wiemuth, D. Junger, M. A. Leitritz, J. Neumann, T. Neumuth, and O. Burgert, "Application fields for the new Object Management Group (OMG) Standards Case Management Model and Notation (CMMN) and Decision Management Notation (DMN) in the perioperative field," *International journal of computer assisted radiology and surgery*, vol. 12, no. 8, pp. 1439–1449, 2017, doi: 10.1007/s11548-017-1608-3.

[8] H. Scheuerlein *et al.,* "New methods for clinical pathways-Business Process Modeling Notation (BPMN) and Tangible Business Process Modeling (t.BPM)," *Langenbeck's archives of surgery*, vol. 397, no. 5, pp. 755–761, 2012, doi: 10.1007/s00423-012-0914-z.

[9] K. Baker *et al.,* "Process mining routinely collected electronic health records to define real-life clinical pathways during chemotherapy," *International journal of medical informatics*, vol. 103, pp. 32–41, 2017, doi: 10.1016/j.ijmedinf.2017.03.011.

[10] R. Laue, A. Koschmider, and D. Fahland, *Prozessmanagement und Process-Mining*: De Gruyter, 2020.

[11] M. Burwitz, H. Schlieter, and W. Esswein, "Modeling Clinical Pathways - Design and Application of a Domain-Specific Modeling Language," *Wirtschaftsinformatik Proceedings 2013*, pp. 1325–1339, 2013. [Online]. Available: https://aisel.aisnet.org/wi2013/83

[12] N. Mulyar, W. M. P. van der Aalst, and M. Peleg, "A pattern-based analysis of clinical computer-interpretable guideline modeling languages," *Journal of the American Medical Informatics Association : JAMIA*, vol. 14, no. 6, pp. 781–787, 2007, doi: 10.1197/jamia.M2389.

[13] B. Zuhaira and N. Ahmad, "Business process modeling, implementation, analysis, and management: the case of business process management tools," *BPMJ*, vol. 27, no. 1, pp. 145–183, 2021, doi: 10.1108/BPMJ-06-2018-0168.

[14] *Decision Model and Notation, Version 1.4 Beta,* Object Management Group, Dec. 2021. [Online]. Available: https://www.omg.org/spec/DMN/1.4/Beta1/PDF