German Medical Data Sciences 2022 - Future Medicine
R. Röhrig et al. (Eds.)

doi:10.3233/SHTI220797

Development of a Knowledge Base for Chronic Wound Management Using the Decision Model & Notation

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Abstract. Chronic wounds have significant impacts on patient health-related quality of life (HRQoL) and the healthcare expenditures. Various complex decision-making scenarios arise from wound management. Clinical decision-making systems (CDSS) can assist in relieving healthcare providers in these complex decision-making processes and improve the quality of care. In our study, we used the Decision Model & Notation (DMN) standard as a knowledge representation format to implement a knowledge base for chronic wound material recommendation in phase-based therapy. The resulting decision model is theoretically consistent and sustainable. With this study, we also emphasized the need of a semantic interoperability framework. This opens further research possibilities regarding the improvement of the model and the interest of DMN for decision models in clinical fields.

Keywords. Clinical Decision Support Systems, Wound & Injuries, Knowledge Bases, Knowledge Management, Decision Model & Notation

1. Introduction

Clinical Decision Support Systems (CDSS) are tools, which are supposed to assist healthcare providers in dealing with complex clinical decision [1]. A field to develop and explore the potential benefit of CDSS is the one of chronic wound dressing in a phase-based treatment. Wound healing process "consists of four sequential and partially intertwined stages, hemostasis, inflammation, proliferation, and tissue remodeling" [2], [3]. A chronic wound is a wound which is not completely healed after a long time (depending on the publication, this time is stated from four weeks to three months [4]). The increased healing time of chronic wounds is usually due to complex biological processes that correlate with disruption within the four phases of wound healing. A wound has direct and indirect consequences on affected patients and the society [5]. At first, the health-related quality of life (HRQoL) is reduced because it generally decreases their autonomy in addition to decreasing the physical and / or psychological conditions.

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This value is "the value assigned to duration of life as modified by the impairments, functional states, perceptions, and social opportunities that are influenced by disease, injury, treatment, or policy." of the patients. The extension of the duration of the healing process may also affect the patient incomes and / or their healthcare expenses, due to potential repetitive sick leaves and hospitalizations, when it is not caused by a subsequent incapacity (for example, related to an amputation) or an early retirement. For the society, the healing process involves many healthcare professionals from the diagnosis, the treatment and the follow-up; the related costs have an important impact, representing 1 to 5.5% of the total healthcare expenditures (depending on the country and the chosen publications) [5]. Chronic wounds and their financial impact are so important that they are sometimes described as an epidemy due to their high incidence rate (in its epidemiologic meaning) [3], [6]. On the other hand, the selection of wound care material rises to a complex decision scenario due to the fact that the caregiver has a variety of causalities, conditions and options to involve in the decision-making process.

At least one CDSS, which deals with chronic wounds, is the PosiThera project [7], [8]. The research group already implemented a prototype for chronic wound management for the decision-making process diagnosis to treatment. It was developed according to two inference methodologies to compare the benefits and drawbacks of both methods and to choose the one, which would be the most adapted to the project framework. The project implementation and analysis work helped to define the standards, which would be used for the solution itself.

Our study focuses on the research question if the Decision Model & Notation (DMN) of the Object Management Group [9]–[11] would be appropriate to model the chronic wound knowledge in phase-based treatment.

The DMN standard was developed to be the language, notation and knowledge representation format for business decisions and rules. It is one knowledge representation approach which is human interpretable and explainable. Hence, it could be a good candidate to support guideline formalization in the preliminary phase to CDSS development.

There are other knowledge representation formats like HL7 Arden Syntax, petri nets and openEHR GDL. The similarities between the HL7 Arden Syntax and other knowledge representation formats were demonstrated in other study works [7] like and might make the translation from one format to another easy to perform.

Moreover, DMN can be combined with two other standards:

- the Business Process Model and Notation (BPMN) for business process representation,
- and the Case Management Model and Notation (CMMN) for business cases representation.

In such a combination, it is possible to have a BPMN or a CMMN diagram which refers to a DMN diagram. As the other knowledge representation formats are limited to decision modeling, DMN presents a clear advantage for the development of easy knowledge exchanges in business in general and in healthcare for clinical decision-making and clinical workflows.

2. Methods

2.1. DMN standard

The DMN standard includes several fundamental definitions and representations which define the framework of decision-making modeling [10], [11].

A “decision” is the action of choosing an option among several possibilities. The “input” data are the variables to be considered in the decision-making situation. The “output” is the chosen option. The “decision logic” defines how the input data drive to the output value using logic.

In DMN formalism, these objects are depicted in a form of a flow diagram which is called “Decision Requirement Diagram” (DRD). In the DRD, the decision is displayed as a rectangle box, Inputs represented as horizontal “cartouche” symbols. Outputs are part of the decision box and has no representative icon. When an element requires information from another one, this “information requirement” is depicted with a solid line and a solid arrowhead which points at the information “requester”. Elements of a DRD can be group informally thanks to a group which is represented by a rounded corner rectangle drawn with a solid dashed line.

The standard includes additional elements, but this publication will focus on these fundamentals elements which are the core of the decision modeling.

2.2. Modeling methods

In this study, we used DMN to model the human decision-making in the wound material selection in a phase-based treatment [9]–[11].

Following the steps of Boxwala et al. (2011) [12] which are the unstructured layer, the semi-structured layer, the structured layer and the executable layer, we used a semi-structured guideline which was created through a documentation analysis of the scientific literature. The requirements for an automated decision-making of wound material choice in the form of recommendations was directly waterfalled from the obtained guideline.

Using defined concepts in the DMN standard, it was possible to start modeling the decision-making. The first step was to define the concerned situation in which one or several decisions are needed. This situation can often be described by a question to be answered according to information (given as input data) and the decision logic.

In our case, we concentrated on the decision problem to select the adequate wound material based on contextual wound case information. As inputs, we followed the TIME assessment method (Tissue, Infection, Moisture imbalance, and Edge advancement) [13], [14]. TIME was developed by a wound care consensus group and provides an assessment framework which got high adoption and usage levels amongst healthcare professionals. We defined the outputs as the recommended materials and technics, the retention time, the potential counterindications and additional information which are relevant for the material usage. The materials and technics included different types of dressings, compresses, foams, cream, gels, compression and cleansing technics. For the decision logic, DMN provides three possibilities: literal expressions which can be formal or executable, invocations which list for each defined parameter its corresponding expression, or decision tables.

We to use the decision table method which allowed us to map multiple input values with the corresponding output value in an easy human readable way. As knowledge sources, we used the mentioned rule base in the form of a semi-structured guideline, the associated glossary (the aim of this glossary will be discussed later in this article) and the literature source on which the rule base was created.

To formalize our model, we chose the academic platform of Signavio Process Manager solution [15].

3. Results

We created the modeling with the different element insertion based on the rule base, which could be seen as a wound assessment "questionnaire" with its criteria (each of them associated to a value set). The criteria for patient and wound characterization were set as 17 inputs for the decision (Figure 1).

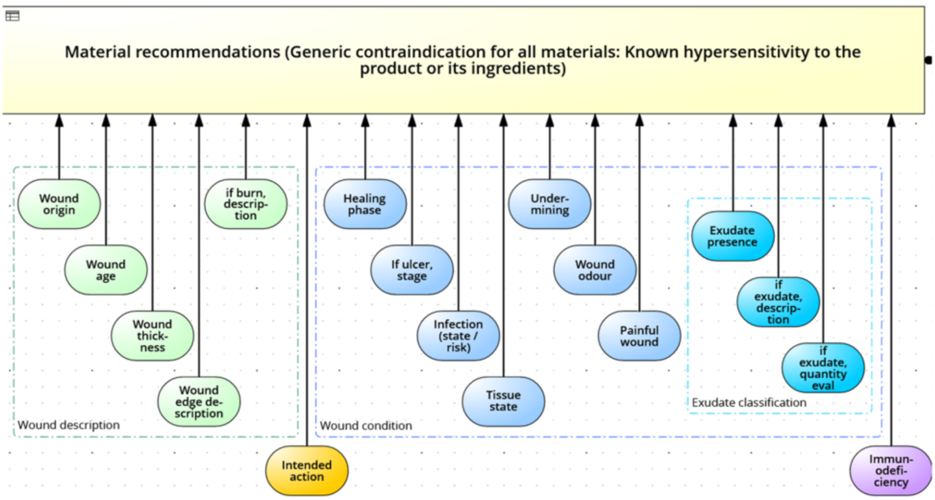

Figure 1. Decision Requirement Diagram of the DMN model for chronic wound material recommendation

The model was complemented by 2 knowledge sources:

- the wound glossary and classifications which was built for this study [16],
- the wound material tables as annexes of the eighth edition of "Moderne Wundversorgung", from Kerstin Protz & Jan Hinnerk Timm (2016) [17].

Fifteen of the inputs were informally grouped in two groups and one "sub-group" describing categories, which could help to create an input form for healthcare professionals. We implemented the first group as the "Wound description" criteria with its origin, its age, its thickness, the description of its edges and its classification if it is a burn. We defined the other group as the one related to the "Wound condition" with parameters providing the healing phase, the stage of the ulcer (in case it would be one), the infection state and risk, the tissue state, and the presence of undermining, odor and pain. Within this second group, we built up a subgroup aiming for the exudate classification. The two last inputs were kept separated because they described possible additional information respectively about the care and the patient. These two last parameters, which were not grouped but are highly important for wound care are the "Intended action" (which could be for example the wound cleaning or draining) and the immune deficiency which addresses misfunctioning of the immune response (predisposing to infection and certain malignancies). With these fundamentals, the Decision Requirement Diagram (DRD) for the wound material recommendation was created. The result of this construction is represented in **Figure 1**.

The Inputs and Outputs were transcribed directly from the two defined groups of the rule base table data. For some rules, the exclusion of a parameter could be a condition of choice for a wound material. The following combination gives a good example for such situation: If a patient presents a wound with the wound description "*Wound age = Chronic wound*" and the wound conditions "*Healing phase = Proliferative phase*", "*Tissue state = no necrotic tissue*" and "*Exudate presence = True*", the recommendation from the rule base would be "*Polyurethane foam dressing / Wound gauze with NOSF (nano-oligosaccharide factor)*". In such a case, the exclusion of a parameter was transcribed with the expression "NOT" (*Criterion A => NOT value X).*

The chosen hit policy could only be a multiple hit policy, because several materials could be recommended for certain combinations of input parameters. Theoretically, the policies **"C**ollect" (C) and "**R**ule order" (R) could be chosen, but the C hit policy would need to be used without an operator ("+", "<", ">", or "#") to get a list of outputs. The hit policy "**O**utput order" (O) could not fit because of the choice to have some of the outputs ("Contraindications" and "Additional information") with text domain (data expressed in natural language) with no value sets. Indeed, no value set caused an impossibility to order the result according to the order in the value set. Before choosing between the two possible policies, it was decided to perform tests to define the most appropriated setup.

When choosing the hit policy, another factor had to be taken into consideration: the completeness of the inputs. In a "*Complete*" decision table, all possible inputs must be considered in the decision table. So, we aimed for the configuration with incomplete data input (option "*Incomplete*") to address real world decision scenarios in which some information might be unknown and/or not filled in by the users.

4. Discussion

4.1. DMN modeling

Through the performed modeling, we managed to show that DMN was appropriate to model the chronic wound material recommendation rule base. A decision table, which was the "heart" of the defined model could be derived for the rule base. The resulting Decision Requirement Graph (DRG) had no decision network but had an important size due to the important number of inputs (17 inputs for 1 Decision element). As we tried to represent the wound assessment process done by professionals, further studies should consider fracturing the model into decision fragments through an iterative process in collaboration with healthcare professionals

The fact Signavio Process Manager only supports DMN version 1.1 [10], [18] could also have been a problem, because the latest version of DMN is the version 1.3 [11]. However, when comparing the two versions, it was shown that this had no impact on the study work, because the changes over the different versions were not on the used level and specifications.

With the DMN model and its decision table, the resulting recommendations are theoretically consistent and sustainable. The Signavio solution enforces this theoretical possibility as it provides easy access to all parameters and rules can be added and/or updated. A test campaign is the obvious next step for the study to check and improve the decision model.

Moreover, Wasylewicz et al. (2018) [19] stated the interests of applying a validation strategy. In any software development and implementation, the validation of the components is a standard and obvious part of those processes. This does not only help to search and solve failures, but it also participates to the software quality in terms of reliability, sustainability, and consistency [20].

4.2. Semantic interoperability

The variation in the perception and knowledge representation among people is at the same time a strength and a weakness for the knowledge communication [21]. In the scientific literature, all publications, be it articles, reports or books, are written in natural language and contain a glossary listing the terms used in the concerned specialty field.

It seems it is particularly the case for the clinical field of chronic wound. In 2018, Kyaw et al. wrote an article which pointed at the absence of a clear and unique definition for the term “chronic wound” [4]. They concluded their review emphasizing two aspects: on one hand, a unique common definition would help to improve wound management. On the other hand, the related guidelines and a “scoring system” based on the patient info and the clinical case would strengthen the diagnosis and the care quality in a multidisciplinary team.

We faced those difficulties and benefits of the implementation of such a semantic normalization work. Due to the needed multi-disciplinary for wound treatment, several scientific societies provide such glossaries. Hence, no standardized terms and definitions were found. This increased the difficulty to select and apply a “specialty-neutral” term and definition set. We used a dedicated glossary for our study but ideally, we should have used a nomenclature which could both be validated by healthcare professionals. In that regard, establishing the mapping of a dataset for wound routine care (which was obtained through a national consensus) [22] with SNOMED CT [23] would be very interesting but would require a significant time frame.

5. Conclusion

With this study, we created a decision model as a rule base for wound material recommendations, and we managed to represent it in the DMN standard [9]–[11], using the knowledge extraction from a medical education book (Protz & Trimm (2016) [17]. The resulting Decision Requirement Diagram included one Decision element and the associated decision table was directly derived from the rule base. This application of the standard confirmed its relevancy to the healthcare sector. It opened consequently the possibility for a better and more transparent exchange of the Decision models for the chronic wound treatment clinical use case.

Concerning the used value sets, the natural language expression allows too much interpretation possibilities and misunderstandings. We also took into account that wound care involves many healthcare specialties. For these reasons, we used a dedicated glossary and classification set because of a time perspective but keeping in mind that the ideal solution would be to use the SNOMED CT nomenclature in association with a glossary issued thanks to a clinical expert consensus [21], [22].

For future research studies, the rule base assessment should be considered in the global modeling work. The model should not only be further tested but also be assessed. Indeed, the tests and assessments of the rules would increase the trust the users could have in the model as well as its level of reliability, sustainability, and consistency. Moreover, Shortliffe et al. (2018), cited by Montani & Striani (2019) [23], mentioned that any recommendation should be understandable by user. Even if our rule base was built on evidence-based literature, creating an assessment indicator inspired by PRISMA meta-analysis method or AMSTAR 2 method could be a solution to improve the transparency and explainability [23] of the rule base. Through this approach, the idea would be to provide a rational and evidence-based evaluation of each recommendation in regards of the clinical researches which were realized for the associated wound material. This knowledge base check is mentioned in an ongoing study as part of the CDSS lifecycle [24] and would help to minimize the risks and to increase the quality of the CDSS development. This approach might also be interesting to support the scrutiny approach mentioned in the Medical Device Regulation for the conformity assessment of some of the class III and class IIb devices (Section 2, Article 55).

Contributions of the authors

AF and SV did the Work Conception, AF created the knowledge base and wrote the Manuscript. SV did the substantial revision of the manuscript. All authors have approved the manuscript as submitted and accept responsibility for the scientific integrity of the work.

Conflict of Interest

The authors declare that there is no conflict of interest.

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