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Development and Implementation of Clinical Decision Algorithms for Oncology

Kees C.W.J. EBBEN[a,b,1], Thijs VAN VEGCHEL[a], Marieke MASSA[a], Matthijs SLOEP[a] and Jurrian VAN DER WERF[a]
[a] *Department of Research and Development, Netherlands Comprehensive Cancer Organization (IKNL), Utrecht, The Netherlands*
[b] *Department of Epidemiology, GROW school for Oncology and Reproduction, Maastricht University Medical Centre+, Maastricht, The Netherlands*
ORCiD ID: Kees C.W.J. EBBEN, https://orcid.org/0000-0003-1069-2357

Abstract. Decision-making in healthcare often relies on narrative guidelines; however, these instruments are poorly accessible for supporting clinical decision-making. This study explores the application of rule-based decision logic in algorithmic modeling, emphasizing its great potential in clinical decision support and research. Integrating rule-based algorithms with existing information systems and real-world data poses a serious challenge. Integrating decision algorithms with information standards increases their effectiveness across various applications. This study outlines a method for constructing clinical decision trees (CDTs), highlighting their transparency and interpretability, using information standards as a design principle. We use the digitization of the Dutch breast cancer guideline through CDTs as a case study to exemplify their versatility and practical significance. The process step 'primary treatment' has been successfully translated from the narrative guidelines format to the anticipated ted computational format.

Keywords. Clinical Decision Trees, Guidelines, Recommendations, Knowledge Representation, Computer interpretable

1. Introduction

Converting narrative clinical guidelines and recommendations into computable knowledge objects like algorithms or executable code has posed a continued challenge in clinical decision support [1]. Additionally, such formats can be utilized to perform automated computational analyses using, for example, real-world data [2]. In this paper we explore the important role of clinical decision algorithms in healthcare and present a reusable methodology for development and implementation of these instruments.

Aligning decision algorithms with semantic information standards (SIS) is strongly recommended for seamless integration into existing health information systems and to ensure future adaptability across a wide range of applications. The advantage of representing knowledge through decision algorithms lies in the enhanced unambiguous interpretability for both humans and computers.

[1] Corresponding Author: Kees C.W.J. Ebben, k.ebben@iknl.nl.

This article is the third of a three-part series, delving sequentially into the applied methodology governing a SIS, clinical reporting, and algorithmic decision support. Together, these elucidated methods serve as a robust foundation for effective clinical information management, essential for a learning health system [3].

2. Methods

In the process of digitizing guidelines and standardizing clinical reporting, the National Breast Cancer Platform of the Netherlands (NABON) and the Netherlands Comprehensive Cancer Organization (IKNL) have jointly initiated the conversion of the entire Dutch breast cancer guideline (version 2022) into CDTs, and the development of templates for standardized, structured reporting. Efforts were undertaken to coordinate authorization from all stakeholders for each product.

In constructing Clinical Decision Trees (CDTs) for healthcare, each CDT represents a distinct decision point. Populations are classified based on relevant combinations of characteristics. Concepts within CDTs are composed from the SIS element dataset [4]. Core elements provide value sets or units, with optional attributes categorized into procedural, anatomical, or temporal contexts, aiding in concept identification. For instance, "differentiation grade" varies pre- and post-surgery, highlighting the importance of temporal context for accurate concept derivation.

In CDT development, the ‘stem’ represents the root node, denoted by a specific step like Primary Treatment. Enriched with metadata, it details the addressed disease, project, responsible working group, version, and time frame. ‘Nodes’, or data-items, within CDTs define patient and disease characteristics. Their values, presented on ‘connectors’, or branches, signify all possible expressions. Logic involves connecting nodes via serial (AND) or parallel (OR) configuration to precisely define relevant subpopulations of patients, ultimately leading to ‘recommendation leaves’. These are provided with a combination of interventions and attributes, which includes the direction and strength of the recommendation. Finally, ‘referral leaves’ indicate when subsequent CDTs apply, serving as root nodes for child CDTs. CDTs are modeled from top to bottom.

2.1. Special CDTs

In healthcare, numerous concepts are significant for providers, with their values intricately determined by underlying factors. For example, in breast cancer, the clinical tumor stage (cT) relies on various factors such as tumor behavior, inflammation, ingrowth, and tumor diameter, as defined in the TNM classification. To simplify complexity within CDTs and enhance decision-making, Value Classification Trees (VCTs) offer context-specific solutions. A VCT's root node represents the base-concept, while its leaves encompass all conceivable values based on the associated classification. Users have two options for determining a VCT value: they can either directly select the value of the VCT base-concept or enter the VCT and select all necessary underlying characteristics contributing to the determination of the concept value. Notably, a VCT may encompass another VCT, providing a hierarchical structure to further streamline the representation of complex patient and disease characteristics and their combinations.

Another specialized tree category pertains to multi-level decision-making scenarios, common in healthcare practice. Intervention Specification Trees (ISTs) facilitate decision-making at both multidisciplinary team and monodisciplinary levels. While regular CDTs typically support decision-making on a multidisciplinary level (e.g. “surgery” or “chemotherapy”), ISTs focus on monodisciplinary oriented recommendations (e.g. “breast preserving lumpectomy” or “Docetaxel”). These specialized tree structures contribute significantly to the reduction of complexity within CDTs, supporting more nuanced decision-making processes aligned with clinical pathways. ISTs, with their elaboration grounded in additional patient and/or disease characteristics, can contain nested ISTs, enabling multi-layered decision-making when necessary. Importantly, ISTs consistently pertain to the same decision point in the patient's care pathway as the corresponding base-CDT, ensuring alignment with clinical processes. By integrating VCTs and ISTs within CDTs, users can navigate complex decision scenarios more effectively.

2.2. Care pathway

Interconnected head-to-tail, CDTs act as parents and children, forming a cohesive ‘care pathway’. Recommendations within a CDT trigger interventions, and the results of these interventions drive the relevant child CDT. For instance, the recommendation “echo and biopsy” not only initiates specific interventions but also provides disease related information, like tumor size and differentiation grade, essential for populating the subsequent child CDT with data.

2.3. CDTs automation and transformation

The implementation of different types of decision algorithms in oncology is efficiently executed within an application named Oncoguide. Oncoguide aims to aid healthcare professionals and patients in treatment decisions by integrating daily scientific insights relevant to personalized care. In the face of growing medical knowledge, the platform consolidates literature, data, and considerations.

The versatility of CDTs in Oncoguide is further underscored by their ability to undergo transformations into various representations while retaining the exact logic. The possible displays of decision algorithms include (structured) text, clinical decision trees, XML, JSON, and more. This streamlined transformation process enhances the interoperability and applicability of decision algorithms across a spectrum of contexts and software environments.

3. Results

We successfully applied our methodology to the Dutch breast cancer guideline and integrated the primary treatment CDT into the Oncoguide platform [5]. This CDT, encompassing 6 nodes (one regular and 5 VCTs), features 11 leaves containing 17 unique recommendations and 12 unique interventions. The tree's complexity is elaborated through 5 attributes (number of unique nodes), and it demonstrates a depth (longest path) of 4. Also, the elements that these concepts are composed from are included in the information standard for breast cancer.

The base-CDT includes 4 unique VCTs: "cN", "cT", "Risk on invasion", and "cN0 risk status," each with varying node and leaf (=value) counts. Moreover, the CDT incorporates 3 distinct ISTs: "Neoadjuvant systemic therapy," "Locoregional policy in metastatic disease," and "Systemic policy in metastatic disease." The first IST is instantiated 5 times, while the other two are implemented once each. The latter IST includes an additional VCT, "Pre-surgical hormone and HER2 status," featuring 4 nodes and 4 leaves (=values).

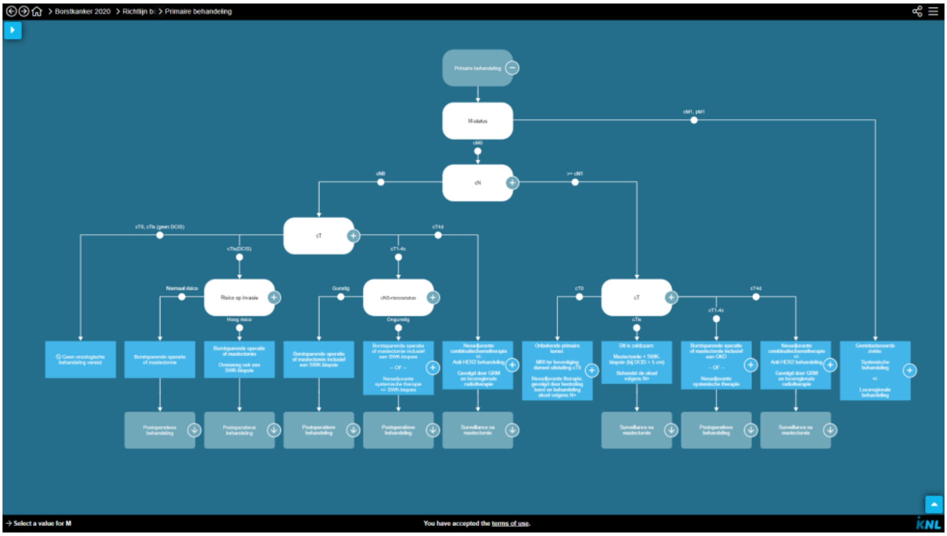

Figure 1. Shows a guideline-based Clinical Decision Tree for the primary treatment of breast cancer. The 'stem' at the top is followed by six white 'branch' nodes representing disease or patient characteristics. Users input values for these nodes, leading to a blue 'leaf' with the corresponding recommendation, based on multidisciplinary guideline recommendations. The lowest blue/green 'leaves' represent the subsequent decision tree in the breast cancer care pathway.

4. Discussion

This structured representation of guideline knowledge is accessible in a format interpretable to both humans and computers, presenting opportunities for application in clinical practice and research [6].

Integrating the developed CDTs into daily healthcare applications empowers them to function as decision support tools. This instantaneously incorporates guideline knowledge into the decision-making process. Moreover, this representation proves valuable in research, facilitating computations to measure guideline utilization or document reasons for deviations from recommendations [7].

Importantly, the method's utility extends beyond guidelines, encompassing all rule-based documents and instruments. This adaptability allows for structured comparisons between guidelines and regulatory documents, including reports from the FDA and EMA. Effective coordination of the content within these resources enhances the clear and unambiguous application of the instruments, providing a significant quality advantage.

5. Conclusion

This study presents the development and application of a method for translating guidelines into a format interpretable by both humans and computers, and aligning with current clinical practices to ensure optimal care for the target population. Ultimately, the vast potential of computational guidelines and other rule-based knowledge representations holds the key to advancing healthcare in a future-ready fashion.

References

[1] Scott P, Heigl M, McCay C, Shepperdson P, Lima-Walton E, Andrikopoulou E, Brunnhuber K, Cornelius G, Faulding S, McAlister B, Roward S, South M, Thomas MS, Whatling J, Williams JW, Wyatt JC, Greaves F. Modelling clinical narrative as computable knowledge: The NICE computable implementation guidance project. Learn Health Syst. 2023; 7(4):e10394, doi: 10.1002/lrh2.10394.

[2] Ebben KC, Hendriks MP, Markus L, Kos M, de Hingh I, Oddens JR, Rothbarth J, De Wilt H, Strobbe LJ, Bessems M, Mellema CT, Siesling S, Verbeek XA. Using guideline-based clinical decision support in oncological multidisciplinary team meetings: A prospective, multicenter concordance study. International Journal for Quality in Health Care. 2022;34(1), doi: 10.1093/intqhc/mzac007.

[3] Friedman CP, Lomotan EA, Richardson JE, Ridgeway JL. Socio-technical infrastructure for a learning health system. Learn Health Syst. 2024;8(1):e10405, doi: 10.1002/lrh2.10405.

[4] Ebben KC, Vermeulen L, Swinkels A, Sloep M, van der Werf J. Development and Implementation of Semantic Information Standards for Oncology. Ebook series: Studies in Health Technology and Informatics (in press).

[5] IKNL. NABON Breast Cancer Guideline for Primary Treatment in digital format [Internet]. [Accessed May 18, 2024]. Available from: https://oncoguide.nl/#!/projects/7/tree/10543/101.

[6] Hendriks MP, Verbeek X, van Vegchel T, van der Sangen MJ, Strobbe LJ, Merkus JW, Zonderland HM, Smorenburg CH, Jager A, Siesling S. Transformation of the National Breast Cancer Guideline Into Data-Driven Clinical Decision Trees. JCO Clin Cancer Inform. 2019;3:1-14, doi: 10.1200/CCI.18.00150.

[7] Keikes L, Kos M, Verbeek XA, Van Vegchel T, Nagtegaal ID, Lahaye MJ, Méndez Romero A, De Bruijn S, Verheul HM, Rütten H, Punt CJ, Tanis PJ, Van Oijen MG. Conversion of a colorectal cancer guideline into clinical decision trees with assessment of validity. Oxford University Press (OUP); 2021 Apr 3;33(2):mzab051, doi: 10.1093/intqhc/mzab051.