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Pathway-Supporting Health Information Systems: A Review

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Abstract. Care pathways and supporting health information systems (HIS) have been permeate the discipline of Health Information Systems Research (HISR) over years. Traditional objectives of workflow assistance are increasingly extended by interdisciplinary goals from technology, medicine, management and public health research. A systematic literature review is dedicated to this integrating character. It examines the interdisciplinary mesh of objectives associated with care pathways and pathway-supporting HIS in the HISR literature. From 47 identified articles, 6 thematic themes were derived. Their consolidation supports in particular design and development processes as it describes the solution space of future pathway-supporting HIS addressing requirements stated by multiple stakeholders.

Keywords. Care pathways, health information system, pathway systems, review

1. Introduction

In medical practice and research care pathways describe complex sequences of interventions of defined patient groups in defined time periods to support the organization, coordination and decision making of care processes [1]. Different terms are used to emphasize intra-organizational ("clinical pathways"), inter-institutional ("integrated pathways") or patient-centered ("patient pathways") orientations [2]–[4]. Also Health Information Systems Research (HISR) investigates care pathways especially the conception, modeling, realization, and impact of pathway-supporting Health Information Systems (HIS) [5]–[7].

In this context, the research and development work seek to bring original motivations from the process perspective in line with the requirements of innovative disciplines. For example, it is being discussed how patient integration can be intensified along care pathways [7], how data mining methods can describe care pathways retrospectively [8], or how data analytics approaches can contribute to the individualization of care plans [9]. Experiences from practice-oriented digital health projects underline the observation that the objectives of care pathways and pathway-supporting HIS go beyond the traditional process support.

This paper follows up on these observations. If research and development teams want to master the multidisciplinary field of requirements for pathways-supporting HIS, a consolidation of previous work can support them especially in conceptual design and development process. Such a compilation can describe the solution space for pathways-

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supporting HIS, derive design implications, and point to disciplines and professions to be involved. This review paper therefore addresses the question of how the literature discusses scope and challenges of pathway-supporting HIS and which contributions can be used to face the mentioned mission of multidisciplinary requirements engineering. The review thus extends the knowledge from previous reviews on characterization of patient pathways [2] and on support opportunities of clinical pathways by Health Information Technologies [10].

2. Methods

A systematic literature review [11]–[13] for the mentioned research question was conducted in the last quarter of 2020. The following high-quality databases of ISR or HISR were chosen: AIS Senior Basket, Proceedings of the AIS Conferences, recommended eHealth Journals of the AIS SIG Health. The past decade was chosen as the publication period. After abstract and full-text screening, 47 articles were defined as final set for analysis. Only articles that prominently named care pathways as a research context were included. Review articles were not excluded from the analysis set in order to extract implications of their contributions to research and practice. Further details of the search process are given in Figure.1.

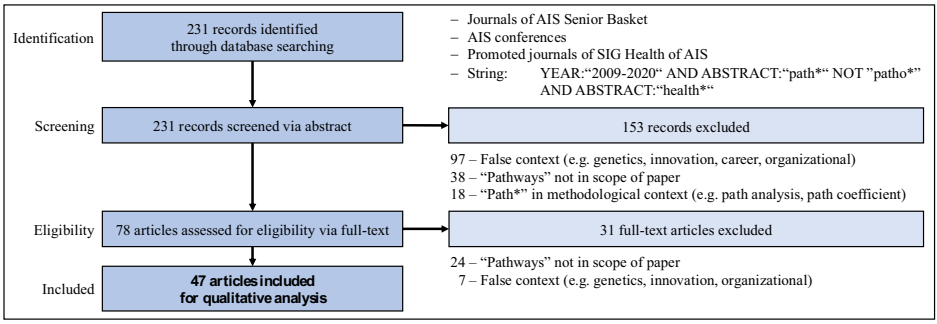

Figure 1. Review process according to PRISMA guidelines [13]

Following the process model of a summarizing content analysis with inductive category formation [14], the analysis material was reduced to those passages in which central goals or contributions related to care pathways or pathway-supporting HIS are described. Paraphrases were constructed and structured interpretatively. Through this structuring step, six themes were identified and validated in group session with three digital health experienced researchers.

3. Results

The 47 identified articles are distributed relatively evenly over the past years. With regard to the distribution across journals or conferences, it can be noted that the majority of the articles found are published in HISR journals recommended by the AIS Health SIG (n=35). Here, 13 articles could be found in the *International Journal of Medical Informatics* and 11 papers in the journal *BMC Medical Informatics and Decision Making*.

A total of 11 papers were identified in the proceedings of the AIS conferences, and only one article in the AIS Senior Basket.

Table 1 presents exemplary the results of paraphrasing step of the six articles published in 2020. It primarily shows how paraphrases have been formulated and offers secondly an insight about newest research on or with pathway-supporting HIS. A complete list of the paraphrasing results of all identified articles will be provided in additional material to this paper.

Table 1. Paraphrases examples of article analysis (only articles published in 2020)

Article [reference]: Summary of contribution's intersection to pathway-supporting HIS
Askari et al. 2020 [15]: Study for professional assessment of the effectiveness and efficiency of clinical pathways and path-supporting HIS in medical care
Cho et al. 2020 [16]: Development of a data-driven method for deriving clinical pathways from electronic health records
Gaveikaite et al. 2020 [17]: Case study along a COPD pathway for potential analysis of telemedicine
Kempa-Liehr et al. 2020 [18]: Modeling tool for clinical pathways and prediction models based on data mining methods and machine learning models for individual improvement of recovery time
Trajano et al. 2020 [19]: Process oriented modeling language for clinical pathways
Ye et al. 2020 [20]: Feasibility study on the use of deep learning prediction models for decision support and derivation of optimal, individual hypertension pathways based on electronic health records

Six themes have been inductively identified out of the paraphrasing results of all 47 articles. Some articles refer to up to two different themes due to their complexity (e.g. [18]). Table 2 shows all themes and sub-topics to give a referenced overview of pathway-related HISR of the last decade. The following additions highlight selected findings or implications for future design and implementation activities of pathway-supporting HIS.

I. Design, development and implementation of pathway-supporting HIS: This theme includes generic approaches as well as descriptions of pathway-supporting HIS and application systems for specific care scenarios. Such work has been established for years. The traditional workflow support of clinical processes is increasingly complemented by articles that present solutions for more complex, cross-institutional and patient-integrating care scenarios. Future work of this theme should concisely characterize the care scenario and parameterize targeted improvements to care-related goals or further outcomes in order to increase reusability.

II. Evaluation and assessment of pathway-supporting HIS: Theme II papers investigate the effects of pathway-supporting HIS. Increasingly complex care scenarios require future evaluative papers to consider all involved stakeholders more comprehensive (e.g. multidisciplinary care teams, patients, expanded health care market) and to discuss competing or synergistic effects and measurable outcomes.

III. Modeling and modeling languages of care pathways: Research with a focus on pathway modeling, modeling languages and tools discuss less the design and realization of application systems but address the underlying pathway models and their genesis. The established knowledge base provides already valuable guidance. However, the changing scope to integrated care scenarios with by multiple professional stakeholders and increasing technization may require additional work in this theme to offer appropriate techniques for precise, comprehensive and consistent pathway models.

IV. Data-driven pathway models and integration of data-based prediction models: Recent advances in data science, machine learning, and related disciplines drive articles in this young theme (earliest publication of this review from 2017). It includes articles that discuss the data-based derivation of care pathways from existing data, e.g.

of EHR. Such retrospective pathway analyses provide the opportunity to compare originally defined care plans with de facto care pathways and to investigate deviations. In consequence, those knowledge might be used to optimize individual care pathways or general pathway templates prospectively or to improve medical guidelines (e.g. for care quality or efficiency). On the other hand, this theme also includes discussions of how pathway-supporting HIS can provide the data basis for data-driven medical decision support systems or management-oriented predictive models (linkage to Theme V). Both sub-themes - pathway-supporting HIS as a source and as a sink of data-driven processing of health information - like to merge and are currently of increasing interest.

V. Conceptual integration of the management perspective: Traditional workflow assistance fosters goals directly related to care processes such as accelerated process flow or lower error rates. Articles of this fifth theme investigate how pathway-supporting HIS can support additional short-, medium- and long-term tasks of healthcare management on micro, meso or macro level (e.g. quality management, resource management, health program management). Future work shall explore how pathway-supporting HIS need to be designed to satisfy this information demand and to offer management decision support. It therefore will probably benefit of popular research efforts of Theme IV.

VI. Care pathways as a means for HISR: Pathway-supporting HIS can be a starting point and data source for diverse research questions. Future design and implementation activities should consider the access to and scientific usability of the processed data and integrate validation and anonymization mechanisms in particular.

Table 2. Analytical results –themes on pathway-supporting HIS

Theme (Number of papers that led to theme): Sub-topics [references]
I. Design, development and implementation of pathway-supporting HIS (n=13): - Development and implementation of clinical pathway for specific healthcare scenarios [21]–[28] - Generic conceptualizations and design recommendations [23], [25], [29]–[34]
II. Evaluation and assessment of pathway-supporting HIS (n=16): - Studies on effectiveness, efficiency and user experience [10], [15], [28], [35]–[43] - Usage analyses for coordination and communication [35], [37], [43]–[46] - Maturity model for care pathways and its implementation in HIS [47]
III. Modeling and modeling languages of care pathways (n=8): - Development of process-oriented modeling languages for care pathways [19] - Conceptualization and modeling approaches [30], [48], [49] - Modeling tools for care pathways [18] - Examples of care pathway modeling (process and final pathways) [22], [24], [40]
IV. Data-driven pathway models and integration of data-based prediction models (n=7): - Modeling methods or tools for care pathways from electronic health records [16], [18], [20], [37], [51] - Development of data-based prediction models (Data & Process Mining, Machine Learning, Deep Learning) for medical decision support [18], [20], [37], [52] - Data-based analysis and decision models from data of pathway-supporting HIS for healthcare and hospital management [50], [51]
V. Conceptual integration of the management perspective (n=5): - Intersection analysis of Information Systems, Operational Research and Industrial Engineering to solve problems related to care pathways [53] - Method conception for the embedding of quality management in care pathways [54] - Path-based data analysis for tactical and strategic hospital management [55] - Conceptualization and modeling approaches for aligning evidence-based Clinical Practice Guidelines and Clinical Pathways [48], [49]
VI. Care pathways as a means for HISR (n=7): - Analysis of the Status Quo of the Digital Transformation [56]–[58] - Analysis of technology support across care pathways [10], [17] - Analysis of key areas via patient flow pathway mapping [59] - Studies on personalization of HIS services [60]

4. Discussion

The review results can be used for different tasks by research and development consortia of pathway-supporting HIS and offers an aid for their objectives. Institutions with a need to catch up in IT-based workflow support can draw on the contributions of *Themes I* and *II* to design and implement their own pathway-supporting HIS. The traditional care process support may seem almost obsolete compared to current HISR contributions. However, these themes remain particularly relevant to healthcare actors with low digital maturity. Contributions from *Theme III* should also be considered in this outlined case to enable the creation of the necessary pathway models as a success-critical resource. Theme III can also support consortia with already established pathway-supporting HIS and contribute to improvements of the used pathway models.

From the perspective of HISR and healthcare organizations of high digital maturity, *Themes IV* and *V* are highlighted in particular. Technological advances in data science and related disciplines indicate enhanced potential for both personalized care and learning systems of a macro level for management and medicine. Future work may generate data-based individual improvements in care pathways (e.g., based on patient constitution or resource availability) or address care economic issues at the local (e.g., clinical process improvements) or global level (e.g., regionally adequate care programs). Future contributions will help pathway-supporting HIS to benefit from the technological progress while providing the required valid and consistent data for these mechanisms.

The contribution of this paper is affected by a certain number of *limitations*. For example, the analysis sample from the selected publication organs offers a solid basis for interpretation, but is still restricted. The integration of additional development-focused journals or conferences could provide more differentiation in the design of novel pathway-supporting HIS. Further, the creation of the six research themes is also subject to the limited objectivity of the author, although this influence was counteracted by group sessions with experienced digital health researchers.

How may *future research* stimulate the progress? With the assumption that concrete care scenarios will continue to be main drivers for technological innovation with and for pathway-support HIS, the relationship between care context and system design could be explored in more detail. Such investigations could determine those care scenarios that motivate the development of pathway-supporting HIS in particular or those which benefit only from dedicated functionalities. Therefore, an appropriate description model is required to define characteristics as well as types of care scenarios , which in turn could be linked to concrete care goals on micro or macro level. Those studies should focus on: care setting (outpatient, inpatient, rehabilitation); medical discipline (e.g., oncology, emergency medicine); indications (e.g., COPD, depression); patient's role (autonomous vs. paternalistic); degree of multi-professionality or number of institutions involved.

5. Conclusion

This review identified 47 articles from highly ranked literature on care pathways or pathway-supporting HIS. Through their interpretation, six themes were derived that represent the range of interdisciplinary goals with and for pathway-supporting HIS. Their consolidation supports future design and development processes by describing the solution space for pathway-supporting HIS. In particular, the design of new systems can benefit from this summary and interdisciplinary requirements management of multiple

stakeholders can be supported. Among those themes, articles with a scope on data-driven pathway models, the integration of data-based healthcare prediction models as well as the enhancement to pathway-supporting HIS for management and operations currently represent exciting fields of activity for HISR and seeks to future work.

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