Electronic medical records and quality of care

Exploration of the effects of EMR use on the quality of hospital care

Rube van Poelgeest

ELECTRONIC MEDICAL RECORDS AND QUALITY OF CARE

EXPLORATION OF THE EFFECTS OF EMR USE ON THE QUALITY OF HOSPITAL CARE

RUBE VAN POELGEEST

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De relatie tussen het Elektronisch Patiënten Dossier en de kwaliteit van de geleverde Nederlandse ziekenhuiszorg

(met een samenvatting in het Nederlands)

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In memory of my father Christiaan Cornelis van Poelgeest,

who, more than anyone I have known, demonstrated to me

the importance of learning.

Paranimfen:
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CONTENTS

CHAPTER 1

Introduction

Implementations of potentially transformative eHealth technologies are currently underway internationally, often with significant impact on national expenditure. [1,2] Such large-scale efforts and expenditures have been justified on the grounds that picture archiving and communication systems (PACS), electronic prescribing (ePrescribing) and associated computerized provider (or physician) order entry systems (CPOE), and computerized decision support systems (CDSS) are supposed to help to address the problems of variable quality and safety in modern health care. [3] However, the scientific basis of such claims, which are repeatedly made, remains to be firmly established. [2,4–7] This thesis has the objective to contribute to the scientific discourse on the relationship between the digitalization of hospital care and quality and safety of such care by exploring the experience in one European country with fairly advanced EMR capabilities: The Netherlands. The hypothesis to be tested is: advanced electronic medical record (EMR) capabilities are positively associated with quality and safety of hospital care.

While electronic medical records (EMRs) and electronic health records (EHRs) are used interchangeably, there is a difference between the two terms. EMRs are the digital version of the paper charts in the clinician's office. An EMR contains the medical and treatment history of the patients in one practice. However, EHRs focus on the total health of the patient-going beyond standard clinical data collected in the provider's office and inclusive of a broader view on a patient's care. This thesis focuses on the EMR i.e. the legal record created in medical centers and ambulatory environments. To measure the capabilities of EMRs in Dutch hospitals a specially developed maturity model, the so-called Electronic Medical Record Adoption Model, the EMRAM, is used.

The Electronic Medical Record Systems

The Electronic Medical Record (System) is an application environment composed of the clinical data repository, clinical decision support, controlled medical vocabulary, order entry, computerized provider order entry, pharmacy, and clinical documentation applications.[8] This environment supports the patients electronic medical record across inpatient and outpatient environments, and is used by healthcare practitioners to document, monitor, and manage health care delivery within a care delivery organization (CDO). The data in the EMR is the record of what happened to the patient during their encounter at the CDO and is owned by the CDO. The EMR environment is a complex and sophisticated environment. Its foundation is the clinical data repository (CDR), a real-time transaction processing database of patient clinical information for practitioners.

In the following paragraphs EMR stands for the Electronic Medical Record System as defined in this paragraph.

Maturity models of healthcare information systems and technologies.

The concept of the 'maturity' of information systems has been developed to determine the adoption and use of information systems. Richard Nolan is considered the principal architect of the Information Systems Technology (IST) maturity approach. [9] IST maturity models fit in various types of organizations. There are several examples of maturity models focused on different areas of the organization and IST. [10] This study will use the so-called Electronic Medical Record Adoption Model (EMRAM) of HIMSS (Healthcare Information and Management Systems Society). This maturity model (Figure 1) is specifically developed to measure the maturity of information systems in hospitals.[11]

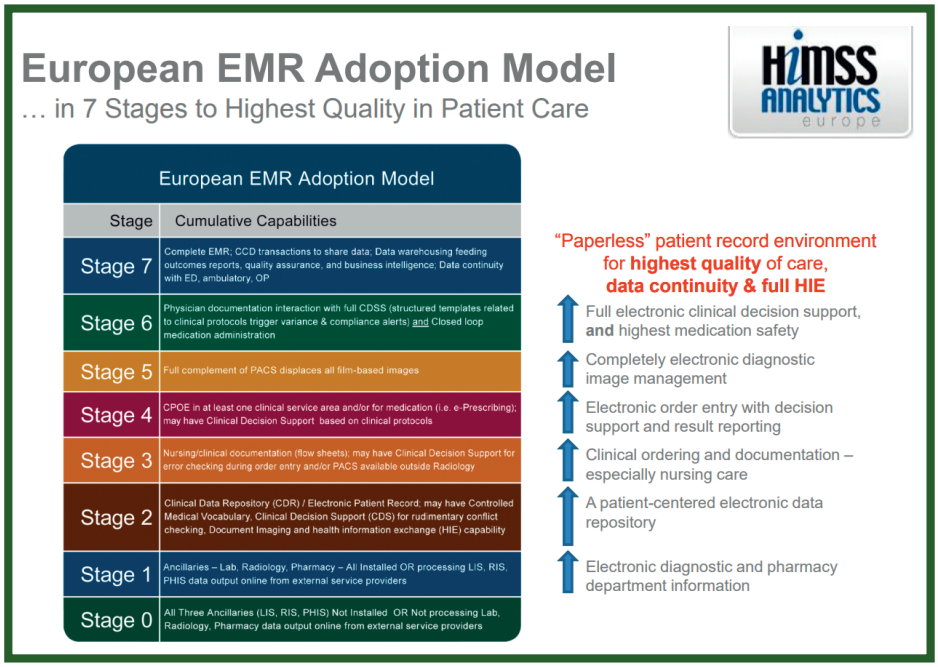

Figure 1 - The EMR adoption model of HIMSS for hospitals.

It is important to mention that this EMRAM model explores which software the hospital has installed and whether the hospital actually uses the functionality offered by this software. HIMSS calls this 'adoption and use'. The model has the advantage of being an accepted model for hospitals in the USA, Canada, and Europe. More than 15.000

hospitals, with all their key organizational figures, are measured, which makes it possible to compare hospitals with each other. At the lowest level, the hospital is at the beginning and has not even automated the ancillary departments like the pharmacy, radiology, or laboratory. At the highest level, the hospital no longer uses physical paper or images, but has everything stored and encoded electronically. Clinical Decision Support Systems (CDSS) are used to analyze clinical information and thus improve the quality of care and patient safety. Clinical data are exchanged electronically between all parts of the hospital. Computerized Provider Order Entry (CPOE) systems are used and refer to the process of providers entering and sending treatment instructions, including medication, laboratory, and radiology orders, via a computer application rather than paper, fax, or telephone. Physician orders are standardized across the organization and maybe individualized for each doctor or specialty by using order sets. Orders are communicated to all departments and involved caregivers, improving response time and avoiding scheduling problems and conflicts with existing orders. And the hospital uses analytic tools and thus also has, from a management perspective, a view of all parts of the hospital. Only hospitals on the highest level (stage 7) are ready to communicate fully digitally with other healthcare providers, the patient, insurers, and other stakeholders.

The scoring process is done by identifying the software used in the different functional areas of the hospital. Depending on the level of maturity, each hospital is presented with approximately 150 questions to focus on varied issues to include demographics, software functionalities, processes, integration standards, and usage in percentage by physicians and nurses. In order to monitor the quality of the scoring process, site visits or telephone interviews are conducted on selected hospitals. Validation is done by the quality assurance department of HIMSS Analytics Europe and the scoring by a proprietary scoring algorithm (HIMSS Analytics North America). If a hospital receives an EMRAM Stage 6 score, an additional 59 questions are asked by a validation team of international peer inspectors mostly from Stage 6 or 7 hospitals in the EU (see appendix 2 for example of results). Stage 6 hospitals can apply for a Stage 7 validation, consisting of a 2-day visit of peer inspectors (see appendix 3 for example of results). EMRAM scores lower than Stage 6 are not publicly shared by HIMSS Analytics and are confidential. See chapter 2 for more details of the model.

Quality of healthcare

The World Health Organization (WHO) definition of quality of care is "*the extent to which health care services provided to individuals and patient populations improve desired health*

outcomes. In order to achieve this, health care must be safe, effective, timely, efficient, equitable, and people-centered" [12]. Central to the definition is the provision of health care by the health care provider to the individual patient or client. Quality monitoring [13] is becoming an accepted method for insurers, patients, and providers to evaluate the value of health care expenditures. Significant advances in the science of quality measurement have occurred over the past decade. Still, many challenges remain to be addressed so that quality monitoring may realize its potential as a counterforce to the demands of cost containment. In the next paragraph the quality and safety measures as used in this thesis are explained in more detail.

Objective and outline of the thesis.

This thesis has the objective to contribute to the scientific discourse on 'the relationship between the digitization of hospital information and processes and the effect on the quality of care'. This aim is translated into the central research question:

What is the relationship between the maturity of hospital information systems and the quality of care?

This question is divided into three sub-questions:

1. How mature are the information systems of the Dutch hospitals and what are the influencing factors (determinants) for this degree of maturity?
2. What is the association between the degree of maturity of information systems of hospitals and the quality of care?
3. Which positive or negative aspects influence the relationship between EMR use and the quality of medical care according to medical specialists?

The purpose of the first subquestion is to identify organizational and environmental factors that are associated with the adoption and use of hospital EMRs as determined using the EMRAM model as described (see chapter 2).

The second subquestion (chapter 3, 4, 5) concerns the effects of the degree of maturity and its consequences for the quality of care. Relevant is to investigate the link between the EMRAM-score and the quality of care. The maturity concept assumes that this relationship exists in a positive sense: a higher score also translates to a higher level of

the quality of care.[14] The question is whether this association actually exists and to what extent especially in Dutch hospitals.

To investigate this relationship, at first (chapter 3) we compared the quality and safety measures as used in Elsevier's annual publication 'The Best Hospitals'. Elsevier used select data from the publicly available basic quality and the safety set of the Health Care Inspectorate (IGJ) and the Dutch Health Care Transparency Program 'Zichtbare Zorg' (ZIZO) program.

The next step (chapter 4) of this part of the study was to compare the adverse events and unplanned readmissions as measured by the Netherlands Institute for Health Services Research (NIVEL). NIVEL conducted three patient safety measurements with patient records from 2004, 2008 and 2011/2012, to keep track of changes in patient safety at a national level. As the EMRAM study took place in 2012-2014 we used the last study in 2011/2012 of this study of seventeen hospitals shared in the NIVEL study as well in the underlying EMRAM studies.

For the last part (chapter 5) of the second sub question to examine the relationship between the EMRAM score and the quality of care we used the postoperative length of stay (LOS) as measured by the Dutch surgical colorectal audit (DSCA). DSCA is a nationwide audit used to monitor, evaluate and improve quality of care of primary colorectal cancer surgery. It provides feedback to all hospitals in the Netherlands on a set of quality measures and indicators.

The purpose of the third sub question (chapter 6) is to examine the relationship between EMR use and the influencing factors according to the medical specialist. As there are indications that the role of the medical specialist is a particularly important factor in the 'adoption and use' of EMR systems in hospitals [15], we conducted a study of the role of the medical specialist toward the adoption of electronic medical records. Physicians are a main frontline user-group of EMR systems. Hence, it requires physicians to actively support and use EMR systems to benefit optimally from their use. To optimise EMR use, it is essential to understand what physicians perceive to be key factors that either support or hinder the use of EMR systems to positively impact the delivered medical treatment and care. The aim of this study was to examine how, and by which aspects, the relationship between EMR use and quality of care in hospitals is influenced according to medical specialists.

The last chapter (chapter 7) encompasses the conclusions and implications of the findings in the previous chapters. It discusses the main findings, it summarizes the answer to the central research question, the scientific and policy relevance of the thesis and the strengths and weaknesses of the study. The perspective of the results for the digitization of hospitals in the Netherlands and beyond are also discussed apart from recommendations for practice. Finally, angles for further research are explored.

In Figure 2 the conceptual relation between the different chapters of this thesis is schematized. Centrally displayed in this diagram is the measured EMRAM score (chapter 2) in relation to, respectively the influencing factors of EMR maturity in hospitals (also chapter 2), the quality measures as used by Elsevier best hospitals publication (chapter 3), the adverse events and unplanned readmissions of the NIVEL study (chapter 4), the LOS of the DSCA audit (chapter 5) and finally the results of the study of the role of the medical specialist (chapter 6). Chapter 7 encompasses the conclusions and implications of the findings in the previous chapters.

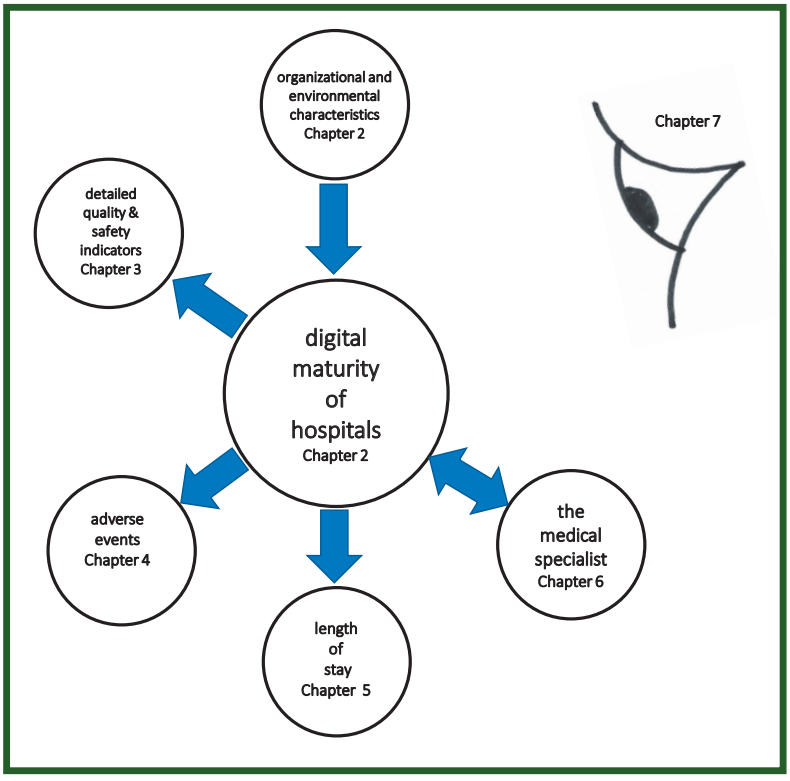

Figure 2 - Outline of the thesis: chapters and associations.

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CHAPTER 2

Profile of the digitization of patient medical records in Dutch hospitals.

Rube van Poelgeest
Lorren Pettit
Rob J. de Leeuw
and Guus Schrijvers

Published in J Healthc Inf Manag. 2015;(Fall 2015):38-46.

ABSTRACT

Background

Much research has been conducted on the organizational and environmental factors associated with the adoption and use of electronic medical records (EMRs) in hospitals. With much of these studies focused on U.S. hospitals, there are limited studies at this time surrounding the adoption of EMRs in Dutch hospitals. The purpose of this study is to profile the organizational and environmental factors associated with the adoption and use of EMR technologies in Dutch hospitals.

Methods

Using the HIMSS Analytics Electronic Medical Record Adoption Model to define a hospital's EMR capabilities, acute care hospitals in the Netherlands (NL) were surveyed regarding their EMR capabilities. From this data, we determined the proportion of hospitals that had a comprehensive EMR system in use in various clinical areas of the hospital and then examined the relationship between the hospital's EMR capabilities and various intervening variables to include environmental factors, hospital characteristics and information and communications technology (ICT) characteristics.

Results

The results of this study indicate that Dutch hospitals reflect a varied array of EMR capabilities. Of the 72 hospitals surveyed between 2012 and 2014 (77.4% of all NL hospitals), 15.3% had a comprehensive EMR system present in at least one clinical unit. The findings also revealed notable EMR capability differences by organizational and environmental characteristics. Larger hospitals and academic affiliated hospitals were more likely to have advanced EMR systems. There also appears to be a positive association between EMR capabilities and the size of a hospital's IT budget.

Conclusions

The findings of this research project support studies from the U.S. that hospital organizational and environmental factors are associated with the adoption and use of EMR technologies. The findings generally supported half of the hypotheses forwarded in the study design. There was no support for example for the hypothesis that EMR capabilities in the Netherlands are positively associated with hospital competition and population density. This latter finding suggests the need for subsequent research studies surrounding a 'leadership and culture' hypothesis.

Keywords:
Hospital, EMR

INTRODUCTION

The EMR has emerged as a very significant component of the health information technology landscape. [1] EMRs are "systems that integrate electronically originated and maintained patient-level clinical information, derived from multiple sources, into one point of access and replaces the paper medical record as the primary source of patient information." [2] EMRs are expected to drastically change healthcare by making care more efficient while also improving quality through the automation of care and the more complete documentation and dissemination of individual medical records. [3] However, the implementation and use of EMRs in acute care hospitals has been slow. [4] The barriers to EMR adoption are varied and include cost, concerns regarding information security, and physician resistance. [5] Although there has been discussion of widespread EMR use for several years, a national interoperable EMR system in The Netherlands (NL) has yet to emerge. A national interoperable EMR system would allow patients, payers, and providers to document and widely share health information for individuals quickly using computers, but would require a standardized format, confidentiality regulations, nearly unanimous support, and a large financial investment. [6] While this type of a system does not yet exist, several NL healthcare providers have already implemented EMRs and reported their experiences. While the overall adoption of EMRs has been slow, it has not been completely stagnant.

Purpose and research question

Given that IT is assumed to be fundamental to an organization's survival and growth, they face the critical challenge of integrating, building, and reconfiguring IT resources so as to obtain competitive advantage and superior performance. Recently, a number of researchers [7–10] have applied resource based view and resource dependence theory to investigating IT business value, with mixed results. One major research stream explores the relationships between IT and environmental issues. Another major stream explores the relationships between IT and other organizational factors (i.e., organizational strategy, organizational process, organizational culture, organizational structure). A third major stream explores the relationships between IT and methods of organizing IT resources to align them with enterprises. However, at present, we know very little about these relationships in hospitals. The purpose of this study is to identify organizational and environmental factors that are associated with the adoption and use of hospital EMRs. The results of this study may guide policy and practice by identifying specific barriers to hospital EMR use.

Theoretical model

For this study we used the Resource dependence theory model. This theory begins with the premise that organizations are not in control of all of the resources they need to survive. As such, many of the organization's strategies for survival include attempts to reduce their dependence on external resources in times of uncertainty by securing necessary inputs. Moreover, Iroju O., et al [6] claim that the omnipresence of information and communications technology (ICT) makes information about quality and prices more readily available, generally lowering dependence among buyers and suppliers able to develop alternatives more readily. This may disturb the power balance. We elected to apply the Resource Dependence Theory to the adoption of hospital EMRs because this theory allows us to develop a fairly comprehensive model [11] (see Figure 1) to identify significant predictors and barriers to EMR use.

Hypotheses to test

According to the Resource Dependence theory, environmental uncertainty may motivate organizational action or strategy. [12] Organizations in areas of greater uncertainty are more likely to take action to secure resources than organizations in areas of less uncertainty. After all, organizations with certain access to necessary resources do not need to secure inputs from the environment, while organizations in uncertain environments must adapt to their surroundings in order to survive. Since EMRs may lead to better hospital performance and outcomes as well as increasing efficiency, some hospitals may use EMRs as a strategy to combat this environmental uncertainty. From this model we deducted the following hypotheses.

H1: Hospitals in a lower population density area are less likely to have advanced EMR capabilities.

As hospitals are scarcer in areas of lower population areas, (potential) patients have less choice and hospitals have less urgency to adopt advanced technologies like EMRs As hospitals are scarcer in areas of lower population areas, (potential) patients have less choice and hospitals have less urgency to adopt advanced technologies like EMRs.

H2: As environmental competition increases, the likelihood of having advanced EMR capabilities increases.

The level of competition in an external environment, according to Resource Dependency theory, is a large predictor of organizational strategy and action. In an area with a great deal of competition, hospitals must compete for the same resources, thus making inputs

potentially scarcer and placing hospitals under more pressure to distinguish themselves from competitors, thus securing their market share of patients. If patients have more choices, they may elect where to go for healthcare and will likely choose a hospital that offers new or better services such as EMRs. Hospitals may reason that EMRs will make them more appealing to the patient population in an area of high competition where patients have choices of where to receive care. In the Netherlands the bargaining of hospital services is done exclusively by the healthcare insurance companies. In some areas certain healthcare insurance companies have a prevalent position.

H3: Larger hospitals are more likely to have advanced EMR capabilities.

Perhaps the greatest barrier to hospital EMR adoption is the cost of implementation and maintenance. With adequate financial resources, hospitals are likely more able to purchase the often-expensive EMR systems and equipment. However, not all hospitals have the financial means to implement and use complete EMR systems. Those with smaller operating margins are less likely to have the funds to buy and implement EMRs. Organizational power is often associated with organizational size since larger organizations tend to have greater impact on a community than smaller organizations. More powerful organizations may also be those that control vital resources in an environment, and for this reason, these organizations may be in a better position to name the terms of exchange. The power associated with size allows hospitals to more easily achieve economies of scale for services, and larger purchases will likely lead to more negotiation power with suppliers.

H4: Academic affiliated hospitals are more likely to have advanced EMR capabilities.

University and top teaching hospitals provide a great deal of specialized care and medical research, as well as provide the training and education of many of the nation's healthcare workforce. According to Retchin and Wenzel, [13] university health centers, as top teaching hospitals, can easily adapt to the use of EMRs because they "have the expertise to resolve remaining software issues, the components necessary for the integrated delivery, a culture for innovation in clinical practice, and a generation of future providers that can be acclimated to the requisites for computerized records" (p.493). Another reason for this increased likelihood is that medical training occurs in these hospitals, and younger medical trainees tend to be more comfortable with computers as they have recently used them in school. Because of this, the staff resistance to EMR use may not be as great as in other hospitals.

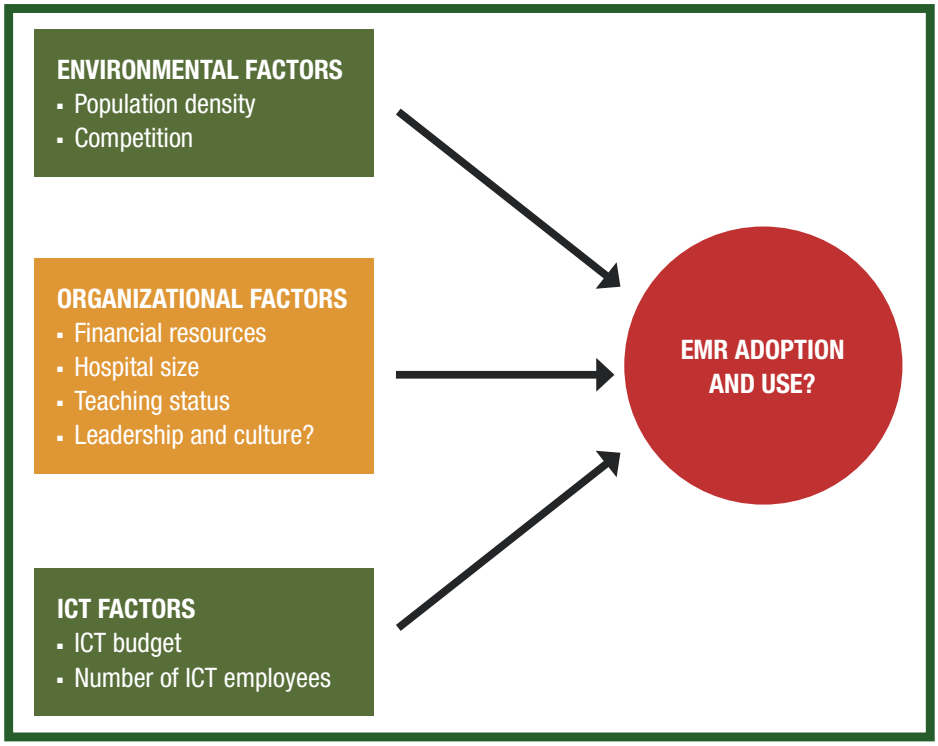

Figure 1: Comparable model (also used by Kazley, A.S.; Ozcan, Y.A., Organizational and environmental determinants of hospital EMR adoption: a national study 11)

H5: Hospitals with relatively higher ICT budgets tend to have more advanced EMR capabilities.

EMR implementation requires several tens of millions of euro's budget over the years to bring result to success. ICT budgets typically fall in the range from 2% to 10% of a hospital's total expenditure. It is to be expected that the higher the structural budget the better the EMR adoption.

H6: Hospitals with relatively more ICT employees tend to have more advanced EMR capabilities.

The successful implementation of EMR systems needs a broad range of expertise to include information architects, project managers, infrastructure specialists, and maintenance specialists. We expect that having more and better resources lead to better EMR use.

METHODS

For the measurement of the level of implementation of information systems, the concept of maturity of information systems has been developed. There is a large number of methods or models available to measure the level of implementation of IT. [14] This study will use the EMRAM scoring approach developed by HIMSS Analytics. [15] EMRAM is an eight-stage maturation model reflecting the EMR capabilities in hospitals, ranging from a completely paper-based environment (Stage 0) to a highly advanced digital patient record environment (Stage 7). The EMRAM model [16] is perhaps one of the most commonly cited EMR maturation models in the world, as its scoring approach has been applied to over 10,000 hospitals in the U.S., Canada, Europe, the Middle and Far-East, and Australia. To adjudicate a hospital's EMR maturation, the CEOs of every hospital in the Netherlands (93) were invited to participate in this study. Seventy-two hospitals (77.4%) joined the study. The scoring process was done by identifying the software used in the different functional areas of the hospital. Depending on the level of maturity, each hospital CEO was presented with approximately 150 questions (available from the authors) to focus on varied issues to include demographics, software functionalities, processes, integration standards, and usage in percentage by physicians and nurses. In order to monitor the quality of the scoring process, the authors conducted site visits on selected hospitals. Validation was done by the quality assurance department of HIMSS Analytics Europe and the scoring by a proprietary scoring algorithm (HIMSS Analytics North America). If a hospital received an EMRAM Stage 6 score, an additional 59 questions were asked by a validation team of international peer inspectors mostly from Stage 6 or 7 hospitals in the EU. Stage 6 hospitals can apply for a Stage 7 validation, consisting of a 2-day visit of peer inspectors. EMRAM scores lower than Stage 6 are not publicly shared by HIMSS Analytics. The Netherlands was awarded its first EMRAM Stage 7 hospital in February 2015. This outcome is outside the scope of this project (2012-2014).

RESULTS

Non-Response analysis

A profile of the 21 Dutch hospitals that did not participate in the study is reflected in Table 1.

Table 1: Non-Response Analysis

		N total	non response	N nresp	response	N resp
Number of beds	large (>=562)	31	16.1%	5	83.9%	26
	medium (>340; <562)	31	9.7%	4	87.1%	27
	small (<=340)	31	38.7%	12	61.3%	19
Type of hospital	university	8	25.0%	2	75.0%	6
	general	55	29.1%	16	70.9%	39
	teaching hospital	30	10.0%	3	90.0%	27
Region	east	16	31.3%	5	68.8%	11
	north	19	36.8%	7	63.2%	12
	south	21	4.8%	1	95.2%	20
	west	37	21.6%	8	78.4%	29

Small hospitals were less likely to participate. Remarkably is the high participation in the south.

Representing approximately 22% of all Dutch acute-care hospitals, perhaps the most remarkable characteristic differentiating survey participates was hospital size. Over 57% of non-participants were small hospital providers as defined by the number of beds associated with the hospital (see Table 1). Hospital size as an influencer on survey participation is not unique to this survey effort and may be the result of a multiplicity of factors (e.g., limited staff availability to complete the survey). Regional variances also seemed to play a factor in survey participation as hospital non-participation rates ranged from 4.8% in the southern part of the Netherlands, to 36.8% in northern NL. The remarkably high non-participation rate in the northern part of the country maybe due to the relatively high concentration of smaller hospitals in this region compared to other regions.

EMRAM scores of Dutch hospital

Table 2 describes the different EMRAM stages and profiles of the EMRAM distribution of NL hospitals.

TABLE 2: Frequency Distribution of EMRAM Scores (Q2 2015)

HIMSS level		Frequency	Percent	Characteristics (EU model)
Stage	7	0	0	Complete EMR; CCD transactions to share data; Data warehousing feeding outcomes reports, quality assurance, and business intelligence.
	6	11	15.3	Physician documentation interaction with full CDSS (structured templates related to clinical protocols trigger variance & compliance alerts) and Closed loop medication administration.
	5	31	43.1	Full complement of PACS displaces all filmbased images.
	4	2	2.8	CPOE in at least one clinical service area and/or for medication (i.e., e-Prescribing); may have Clinical Decision Support based on clinical protocols.
	3	0	0	Nursing/clinical documentation (flow sheets); may have Clinical Decision Support for error checking during order entry and/or PACS available outside Radiology
	2	27	37.5	Clinical Data Repository (CDR) / Electronic Patient Record; may have Controlled Medical Vocabulary, Clinical Decision Support (CDSS) for rudimentary conflict checking,
	1	1	1.4	Major ancillary clinical systems are installed (pharmacy, laboratory, radiology) or laboratory, pharmacy, radiology information system data output is delivered to the hospital for online access and processing if the ancillary service is not provided inhouse, but by external service providers
	0	0	0	All Three Ancillaries (Laboratory, Radiology and Pharmacy) not Installed OR not processing Laboratory, Radiology and Pharmacy data output online from external service providers.
	Total	72	100	

Stage 3, Stage 6, and Stage 7 requirements present as challenges for NL hospitals.

The distribution profile is significant in that it suggests some EMRAM requirements are more challenging for NL hospitals than others. EMRAM Stage 3 presents as the first notable challenge to NL hospitals, as 37.5% of the hospitals in this study have yet to satisfy the requirements of this stage. Once EMRAM Stage 3 requirements are met, the EMRAM profile then suggests NL hospitals are likely to be challenged in meeting the requirements of EMRAM Stage 6 (Closed loop medication administration [CLMA] and

decision support [CDSS]). Progressing past EMRAM Stage 5, CLMA must be live in all inpatient units (EMRAM Stage 7 requirement) or at least in one clinical unit (EMRAM Stage 6 requirement). Only 11 hospitals in the NL had surpassed EMRAM Stage 5 requirements during the time of this study. Note that in March 2015, one NL hospital successfully met all of the requirements to satisfy EMRAM Stage 7 (UMC Radboud in Nijmegen), becoming the third hospital in all of Europe to achieve this distinction (Hospital de Dénia Marina Salud in Denia, Spain, University Medical Center Hamburg-Eppendorf, Germany, and RadboudUMC in Nijmegen, The Netherlands).

RESULTS OF TESTS REGARDING THE HYPOTHESES

University hospitals in the Netherlands are a special group. They have different financial models, have special teaching and research missions, and are in general a lot larger than other hospitals in the NL. They combine ICT efforts for healthcare, education, and research, and have more advanced ICT organizations; although, some are struggling with the more advanced position. Teaching hospitals and general hospitals are more focused on patient throughput than university hospitals; this has to do with the different missions and financial model. For this reason, the university hospitals were excluded, with the exception of hypothesis H4, where those hospitals are compared with the other hospitals.

H1: Hospitals in a lower population density area are less likely to have advanced EMR capabilities.

The ‘Randstad’ area of NL (defined by the area around Amsterdam, The Hague, Rotterdam, and Utrecht, with 40% of the total population of the Netherlands) has a much higher concentration of individuals (population density =3267/km2) than the other regions of the country (average population density of the non-Randstad region = 1186/km2) (see Table 3). In comparing the EMR profiles of the densely populated Randstad region hospitals to hospitals in the other lower densely populated regions, we find no support for our first hypothesis. On the contrary, the lowest scoring hospitals (52.2% versus 30.2%) are in areas of higher population density.

TABLE 3: Population Density by EMRAM Stage

	Stage 0-2			Stage 3-5			Stage 6 and 7			Total		
	Populationdensitykm2			populationdensitykm2			populationdensitykm2			populationdensitykm2		
	Mean	Count	Row N %	Mean	Count	Row N %	Mean	Count	Row N %	Mean	Count	Row N %
non-Randstad	951	13	30.2%	1215	25	58.1%	1649	5	11.6%	1186	43	100%
Randstad	3534	12	52.2%	3021	8	34.8%	2859	3	13.0%	3287	23	100%

The Randstad region has the highest population density, but the lowest EMRAM score.

H2: As environmental competition increases, the likelihood of having advanced EMR capabilities increases.

The 'Randstad' area of NL (defined by the area around Amsterdam, The Hague, Rotterdam and Utrecht with 40% of total population of the Netherlands) has the highest concentration of hospitals in all of NL. With the density of hospitals per 10km in the Randstad area equaling 4.5, compared to a hospital density of 1.3 in the non-Randstad area, [17] the findings of this study provide no support for the hypothesis that EMR adoption increases based on environmental competition (Table 4). On the contrary, the non-Randstad area generally presents as having a more advanced EMR profile as the largest grouping of hospitals in the non-Randstad area (58.1%) are in Stage 3-5, while in the Randstad area 52.2% are in Stages 1 and 2.

TABLE 4: Competition Density by EMRAM Stage

competion density	Average numbers of hospitals within a 10km area	Stage 0-2		Stage 3-5		Stage 6 and 7	
		Count	Row N%	Count	Row N%	Count	Row N%
non-Randstad	1.3	13	30.2%	25	58.1%	5	11.6%
Randstad	4.5	12	52.2%	8	34.8%	3	8.3%

Non-Randstad region has more digital potential

H3: Larger hospitals are more likely to have advanced EMR capabilities.

Although not statistically significant, the general pattern emerging from this study (Table 5) supports the hypothesis that larger hospitals tended to have more advanced EMR capabilities than smaller hospitals. This pattern is reflected in the number of staffed beds.

TABLE 5: Hospital Size by EMRAM Stage

		Stage 0-2			Stage 3-5			Stage 6 and 7		
		Mean	Row N%	Count	Mean	Row N%	Count	Mean	Row N%	Count
number of beds		422	37.9%		501	50.0%		582	12.1%	
number of beds 0<340<562	large		28.6%	6		57.1%	12		14.3%	3
	medium		30.8%	8		57.7%	15		11.5%	2
	small		57.9%	11		31.6%	6		10.5%	2

Larger hospitals tended to have more advanced EMR capabilities than smaller hospitals

H4: Academic affiliated hospitals are more likely to have advanced EMR capabilities.

Academic affiliated hospitals not only have a higher percentage of Stage 6 and Stage 7 hospitals (21.2%) than general hospitals (10.3%) but have a much lower percentage of hospitals in the entry EMRAM stages (27,3% versus 48,7% respectively) (see Table 6). These findings support the hypothesis that hospital type tends to influence a hospital's EMR capabilities.

TABLE 6: Hospital type by EMRAM Stage

		Stage 0-2		Stage 3-5		Stage 6 and 7	
		Count	Row N%	Count	Row N%	Count	Row N%
academic affiliated	Yes	9	27.3%	17	51.5%	7	21.2%
	No	19	48.7%	16	41.0%	4	10.3%

Academic affiliated hospitals have more advanced EMR capabilities.

H5: Hospitals with a relatively higher ICT budget tend to have more advanced EMR capabilities.

Findings of this study (reflected in Table 7) support the hypothesis that hospitals with advanced EMR capabilities tend to have higher ICT budgets than those hospitals with lower EMR capabilities. The budgetary demands appear to grow in a fairly linear manner, raising notable concerns worthy of future exploration.

TABLE 7: Average Hospital ICT Budgets by EMRAM Stage

	Stage 0-2	Stage 3-5	Stage 6 and 7
	Mean	Mean	Mean
ICT budget in € millions	5.1914	6.7400	8.3000
ICT budget as percentage of hospital budget	3.06%	3.63%	4.17%

Hospitals with higher IT budgets score better.

H6: Hospitals with more ICT employees have more advanced EMR capabilities.
The findings of this study support the hypothesis that hospitals with more ICT employees tend to have more advanced EMR capabilities. As reflected in Table 8, the number of ICT workers per hospital bed increases with advancing EMR capabilities. These findings unfortunately do not detail the type of ICT workers. Future research efforts might want to consider if there is a shifting demand in the type of ICT worker as hospitals progress in their EMR capabilities.

TABLE 8: Average Number of ICT Employees by EMRAM Stage

	Stage 0-2	Stage 3-5	Stage 6 and 7
	Mean	Mean	Mean
numbers of ICT employees per hospital bed	0.0782	0.0831	0.1015

Hospitals with more ICT employees tend to have more advanced EMR capabilities

DISCUSSION

Leveraging the HIMSS Analytics EMRAM to define the basic EMR as one that exceeds the infrastructure of an EMRAM Stage 5 hospital, we found that only 15.3% of NL hospitals during our study period had a basic EMR system in at least one clinical area (EMRAM Stage 6). With so few NL hospitals operating a basic EMR system, we are left to question those factors that might be at work influencing a hospital's EMR progression. This study considered two major classes of variables: the EMRAM requirements themselves and intervening organizational and environmental forces. With respect to EMRAM requirements, the findings of this analysis suggest NL hospitals may be particularly challenged in addressing one distinct requirement of the HIMSS Analytics EMRAM. With 37.5% of hospitals having successfully met the requirements of Stage 2 but not Stage 3, the requirements of Stage 3 appear to be a challenge for a sizeable percentage of NL hospitals. And indeed, when looking further into the data, we find that electronic nursing/clinical documentation presents as a particular challenge. We are uncertain as

to why so many hospitals in the Netherlands have been apparently slow to implement a nursing documentation system but do question if it has something to do with the value placed on nurses in Dutch hospitals. While nurses play a significant role in patient care in a hospital, their role (and by extension perceived value) are often times secondary to the role of the attending physician. If true, then it is possible IT leaders are placing a greater emphasis on EMRAM applications targeted towards physicians than nurses. A notable observation: physician related applications (Computerized Physician Order Entry; Physician Documentation) are higher order applications in EMRAM. This hypothesis certainly warrants further exploration as there is a strong argument to be made in prioritizing the automation of nursing documentation, especially as a means of reducing the transmission of erroneous patient information.

Once EMRAM Stage 3 requirements are met, the EMRAM profile then suggests NL hospitals are likely to be challenged in meeting the requirements of EMRAM Stage 6 (Closed loop medication administration [CLMA] and advanced decision support [CDSS]), with 43.1% of the hospitals in EMRAM Stage 5. The CLMA process includes ePrescribing, medication dispensing and tracking, and administration and documentation in the electronic Medication Administration Record (eMAR). A CDSS function (i.e., alerts) must be available at the point of care immediately prior to administration to ensure the five rights of administration check (right patient, right medication, right dose, right route, and right time). Especially the guarantee of the right medication and the right dose is a challenge in the NL, as bar coded unit doses are not always readily available from the pharmaceutical industries by lack of European bar code standards for drugs. The other class of variables influencing EMR adoption in NL hospitals involves organizational and environmental forces. By considering a wide array of relevant variables, the results of this study support the general assertion that EMR adoption is influenced by organizational and environmental forces. More specifically, variances in EMR adoption rates varied notably by hospital size and hospital type. The same holds for smaller hospitals. Smaller hospitals are unlikely to have the financial or human resource means to implement and use an EMR system. This is consistent with previous research that has identified cost as the greatest barrier to EMR adoption and use. [2,18] When hospitals make an investment in an EMR system and when the implementation is successful, the payers and purchasers also benefit. This misalignment of incentives represents perhaps the single most important barrier to moving ahead. Additionally, it is possible that a smaller hospital may not have the human resources available to run such a system. If this is the case, these smaller hospitals may need to form a coalition to investigate the feasibility of a

group purchase and implementation of EMRs. Because EMRs are expensive, and larger hospitals have begun using EMRs more than smaller hospitals, it is possible that without greater economies of scale for implementation, EMRs are too costly for the smaller hospitals. If EMRs do in fact improve hospital quality or efficiency, policymakers should take steps to encourage hospital EMR use. These steps could include programs that aid hospitals in implementing and using EMRs with EMR hardware and software, as well as training and personnel to help with implementation. These programs will be especially important to smaller hospitals. Policymakers may also, at some point, offer greater financial reimbursement for hospitals that use EMRs as a way to encourage hospital use. Additionally, more regulations from payer groups and policymakers can ensure that hospital EMR use is practiced. These regulations may be in the form of requirements for certification, endorsements, or accreditation. Previous research has concluded similar incentives are necessary for more widespread EMR adoption. [19] Three of the six university hospitals represented in this study (total of eight university hospitals in the Netherlands) have full EMR systems in use in at least one clinical unit. University hospitals have far more resources than non-university hospitals and have a different financial model with more government funding. They have more IT budget and more ICT employees. Teaching hospitals are well represented in the group that is implementing additional functionalities, which also reflects other findings. They have higher and better resources. Hospitals with higher ICT budgets were expected to do better, which is the case.

CONCLUSION

Although small hospitals and hospitals located in the northern part of the Netherlands were underrepresented in the study, the 72 hospitals that did participate provided a fairly good representation of the total population of the Netherland's 93 hospitals. Although the group is relatively small, and no robust statistically significant conclusions could be drawn, three of the six hypotheses were supported. Adoption and use of the EMR tends to be positively associated with larger hospitals and teaching hospitals. Not found was a relationship between hospital density and population density, as a measure for the competition level, and the EMRAM score. According to the Resource Dependence theory, resources in areas with low density populations are scarcer in areas of lower population, (potential) patients have less choice, and hospitals feel less urgency to adopt advanced technologies like EMRs. No proof was found for this statement in the Netherlands in this study. Competition in the Netherlands is a new and developing phenomenon. The healthcare insurance companies and the Government play a dominant role. So

competition in the classic sense may not be an important factor in the way hospitals act. In general, the findings of this study support the conclusions found in other studies in the U.S. A 'leadership and culture' hypothesis was not a part of this research project. It is our feeling that this might be an important factor for the level of digitalization in hospitals in the Netherlands. This may be a subject for subsequent research.

LIMITATIONS OF THE STUDY AND SUGGESTIONS FOR FURTHER RESEARCH

There are limitations to our study. First, although we achieved a 77% response rate, the hospitals that did not respond to our survey were somewhat different from those that did respond. Given those non-responding hospitals were more likely to have characteristics associated with lower levels of adoption of EHRs, residual bias may have led us to overestimate adoption levels. Little is known about governance characteristics and organizational performance for EMR adopters. [20,21] As pressures about healthcare quality and related costs increases dramatically in the Netherlands, it may be of value to examine hospitals with a sophisticated EMR and compare those hospitals to similar hospitals (with a less sophisticated EMR) to understand the association between EMR capabilities and IT governance characteristics. Presence and length of stay of key ICT players like CMIO and CIO in the hospital organization may be a good indicator to investigate and test a related hypothesis. We did not measure presence and length of stay of key ICT players in this project. So, testing of this hypothesis was not part of this study.

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CHAPTER 3

The Association between eHealth Capabilities and the Quality and Safety of Health Care in The Netherlands: Comparison of HIMSS Analytics EMRAM data with Elsevier's 'The Best Hospitals' data.

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ABSTRACT

Objective

To test the hypothesis that advanced electronic medical record (EMR) capabilities are associated with better quality and safety of hospital care.

Methods and Findings

We used data from the HIMSS Analytics EMR Adoption Model (EMRAMSM) to measure the adoption and use of information technology in Dutch hospitals. To measure the quality and safety of healthcare in Dutch Hospitals we used select data from the publicly available basic set and the safety set of the Health Care Inspectorate (IGZ) and the Dutch Health Care Transparency Program 'Zichtbare Zorg' (ZIZO) program. The quality and safety measures selected reflect the measures used to score Dutch hospitals as presented in Elsevier's annual 'The Best Hospitals' publication. The scores of this publication are based upon 542 of the 1516 available indicators from this basic set and safety set. Almost all indicators from the hospital-wide indicator sets are included in the selection, as are a large portion of indicators for acute care delivered by all hospitals. Of the 84 non-academic hospitals in the Netherlands, 67 (80 %) were included in this study.

Results

There is no statistically significant association found between a hospital's EMRAM score and their overall quality/ safety performance in the Elsevier hospital scoring model.

Conclusion

There is no evidence found to support the research hypothesis at this point in time. This outcome maybe the result of a multiplicity of factors to include the (limited) use of the methodologies used in this study, the fact that no fully digitalized hospital (EMRAM stage 7) is yet present in the NL, and/or the organizational competency of the NL hospitals in fully leveraging the EMR to facilitate patient care. Further research is needed to explore these findings.

Keywords

Hospital, Safety, Care, Quality, EMR

INTRODUCTION

Implementations of potentially transformative information technologies are currently underway internationally, often with significant impact on national expenditure.[1,2] Such large-scale efforts and expenditures have been justified on the grounds that EMR, picture archiving and communication systems (PACS), electronic prescribing (ePrescribing) and associated computerized provider (or physician) order entry systems (CPOE), and computerized decision support systems (CDSS) are supposed to help to address the problems of variable quality and safety in modern health care .[3] However, the scientific basis of such claims, which are repeatedly made and seemingly uncritically accepted, remains to be firmly established. [4–10] This paper has the objective to contribute to the scientific discourse on the relationship between the digitalization of hospital care and quality and safety of such care by exploring the experience in one European country with fairly advanced EMR capabilities: The Netherlands. The hypothesis to be tested is: advanced electronic medical record (EMR) capabilities are positively associated with quality and safety of hospital care.

METHODS

For the measurement of the level of implementation of information systems the concept of maturity of information systems has been developed. There are a large number of methods or models available to measure the level of implementation of information technology.[11] This study will use the so-called Electronic Medical Record Adoption Model (EMRAM) scoring approach developed by Healthcare Information and Management Systems Society (HIMSS) Analytics.[12] EMRAM is an eight-stage maturation model reflecting the EMR capabilities in hospitals, ranging from a completely paper-based environment (Stage 0) to a highly advanced digital patient record environment (Stage 7). The EMRAM model is perhaps one of the most commonly cited EMR maturation models in the world as its scoring approach has been applied to over 10.000 hospitals in the U.S., Canada, Europe, the Middle and Far-East and Australia. For a more detailed description of the HIMSS Analytics EMR Adoption Model, see.[13]

To adjudicate a hospital's EMR maturation, the CEOs of every non-academic hospital in the Netherlands (84) were invited to participate in the EMRAM study. In the beginning of 2014, 67 hospitals (80 %) joined the program. The scoring process was done by identifying the software used in the different functional areas of the hospital. At least 150 questions

per hospital were asked about demographics, software functionalities, processes, integration standards, usage in percentage by physician and nurses, depending on the available software in the hospital. In order to monitor the quality of the scoring process closely and distances in the Netherlands are never more than 200 km it was decided to do onsite visits. Depending on the complexity of the software environment, visits took between 1.5 and 4 h. For instance, in the case of software from multiple vendors instead of one vendor identification of how the software is interconnected and integrated took more time. Validation was done by the quality assurance department of HIMSS Analytics Europe, and the scoring was done by a proprietary scoring algorithm by HIMSS Analytics North America (Table 1). If a hospital received an EMRAM stage 6 score, an additional 59 questions were asked by a validation team of international peer inspectors mostly from stage 6 or7 hospitals in the EU. Stage6 hospitals can apply for a stage 7 validation, consisting of a 2-day visit of peer inspectors. One day will be used for presentations of predefined issues and one day for hospital visits to check life processes and the paperless status of the hospital. Until stage 5 the achieved score is secret to make participation to this study easy to decide. Two consecutive measurements with an interval of 18 months were taken. No stage 7 hospital was measured in the NL until to date (Dec 2014). One of the senior researchers of HIMSS Analytics is co-author of this study.

Table 1 Frequency distribution of EMRAM scores

EMRAM Score	Frequency	Percent	Cumulative Percent
7	0	0	0
6	7	10	10
5	32	48	58
4	2	3	61
2	25	37	99
1	1	1	100
0	0	0	100
Total	67	100	

To measure the quality and safety of healthcare in Dutch Hospitals we used select data from the publicly available basic set and the safety set of the Health Care Inspectorate (IGZ) and the Dutch Health Care Transparency Program 'Zichtbare Zorg' (ZIZO) program (both sets survey year 2013). The quality and safety measures selected reflect the measures used to score Dutch hospitals as presented in Elsevier's annual 'The Best Hospitals' publication. As the discussions about the transparency of the healthcare

delivered in Dutch hospitals lasts, these are the best available data at this moment. Comparable reports are published, discussed and disputed in other countries.[14–16] The scores of Elsevier are, as opposed to other reports in the Netherlands, based upon publicly available indicators and based upon a scientific method to construct composite indicators.[17] This method has been prepared jointly by the OECD and the Applied Statistics and Econometrics Unit of the Joint Research Centre of the European Commission in Ispra, Italy. The scores of the Elsevier publication (Fig. 1) are based upon 542 of the 1516 publicly available indicators from the above-mentioned datasets (IGZ and ZIZO).

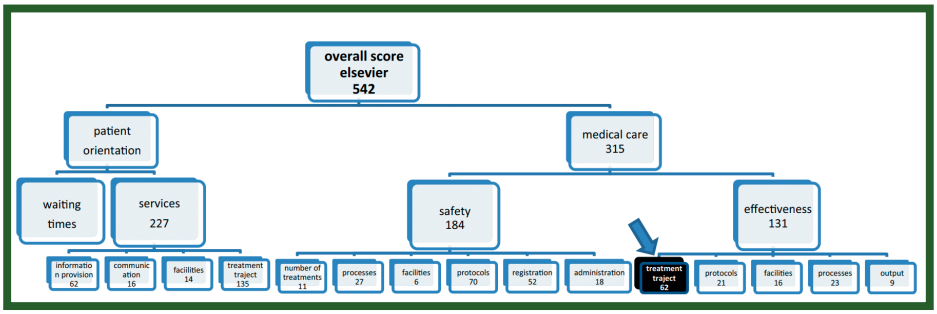

Fig. 1 Structure of Elsevier scores based upon 542 indicators of publicity available hospital wide indicator sets

Almost all indicators from the hospital-wide indicator sets are included in the above-mentioned selection and a large portion of indicators for acute care. Some acute care is only delivered by specialized hospitals and cannot be used to compare all hospitals. Only those indicators for acute care are included that are delivered by all hospitals like infectious diseases, cardiovascular diseases and the surgical process. No indicators were selected for which a case mix correction is still necessary. In this study, the different indicators are combined into compound indicators. The annual reports have been collected and analyzed by 'SiRM - Strategies in Regulated Markets', a consultancy firm in The Hague. The indicators are first scaled to a uniform scale (z-score) and are then added together weighted. Hospitals that have not submitted data are given the scored lowest value. Hospitals could correct possible erroneous values: 68 hospitals have sent SIRM updates of their values. Care-related indicators are divided into the domains of 'effectiveness', 'patient orientation' and 'safety' (Fig. 1).

The scores in these three domains, together with waiting lists, determine the position of the hospital in the Elsevier study on 'The Best Hospitals'. The scores on the domains of 'safety' and 'effectiveness' are bundled in a score for 'medical care'. The scores on

'waiting times' and the domain 'services' in a score for 'patient orientation'. The scores for 'medical care' and 'patient orientation' determine together the 'total score'.

The score of a hospital is expressed in one to four balls (Table 2).

Table 2 Cross table of Elsevier scores and some underlying indicator sets

Elsevier score	overall		medical care		patient orientation		effective treatment	
	frequency	percent	frequency	percent	frequency	percent	frequent	percent
4	12	17.91	11	16.42	9	13.43	11	16.42
3	34	50.75	23	34.33	35	52.24	22	32.84
2	13	19.40	22	32.84	16	23.88	24	35.82
1	8	11.94	11	16.42	7	10.45	10	14.93
total hospitals	67	100.0	67	100.0	67	100.0	67	100

The balls do not contain any value judgment of Elsevier but indicate how the hospital scores on the selected indicators compared with the average in the Netherlands. The participating hospitals do not qualify as "bad" or "good' in an absolute sense. The 'effective treatment' indicator (red box in Fig. 1) is part of the Elsevier effectiveness domain (Fig. 1) and is based upon 62 (only ZiZo) so called 'structure' indicators [18] per hospital. Elsevier and SiRM have made available the scores and all underlying data for the purpose of this study. One of the senior researchers of SiRM is co-author of this paper. Per hospital the 106 underlying EMRAM eHealth indicators and the 26 Elsevier indicators per hospital were included in a SPSS database. In a later stage also the mentioned 542 underlying basic indicators of the 26 Elsevier indicators were included to test the hypothesis of this paper.

RESULTS

No significant correlation is found between the EMRAM scores and the Elsevier performance indicators (Tables 3 and 4).

Table 3 Cross table of overall Elsevier scores and EMRAM scores

Overall Score Elsevier	EMRAM score								Total
	0	1	2	3	4	5	6	7	
4	0	0	3	0	1	6	2	0	12
3	0	1	14	0	1	14	4	0	34
2	0	0	3	0	0	9	1	0	13
1	0	0	5	0	0	3	0	0	8
Total	0	1	25	0	2	32	7	0	67

Table 4 correlation of EMRAM scores and Elsevier scores

Correlations		Overal score Elsevier	Patient Orientation	Medical Care	Effectiveness	Effectivenes Treatment Traject
EMRAMscore	Pearson Correlation	.124	.081	.105	.075	.233*
	Sig. (1-tailed)	.158	.258	.199	.272	.035
	N	67	67	67	67	67

* Correlation is significant at the 0.05 level (1-tailed)

Looking at underlying indicators, a one tailed significant (0.35 %) negative correlation (−0,223) (Fig. 2) is found between the EMRAM score and the Elsevier 2013 'effective treatment' indicator (see red box in Fig. 1). This 'effective treatment' indicator is defined by Elsevier as 'a measure for how the hospital organizes the treatment process for patients. The boxplot of Fig. 2 also illustrates a negative correlation.

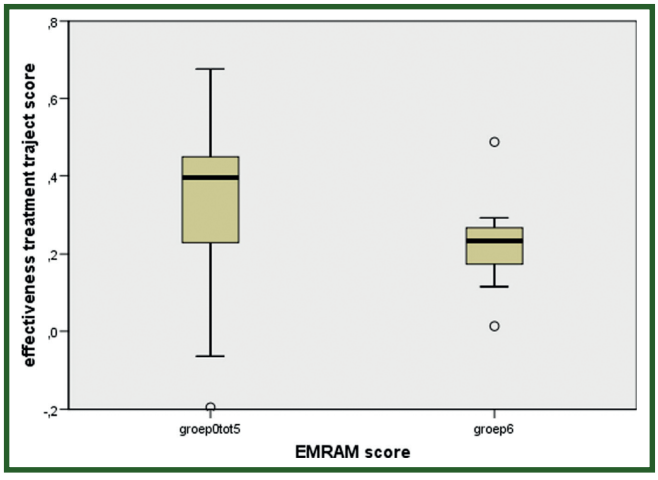

Fig. 2 Comparison of median effective treatment score of EMRAM group 0–5 and group 6

DISCUSSION

The hypothesis of this study, that there is a positive association between advanced electronic medical record (EMR) capabilities and quality and safety of hospital care in The Netherlands was not supported at this point in time by the findings of this study.

There are several reasons as to why these findings did not support the study hypothesis. For one, the models used to evaluate both the hospital's EMR capabilities (the EMRAM model) and the quality and safety of hospital care in NL (the Elsevier model) may not be as sensitive as needed to capture the variances in performance outcomes. The EMRAM scoring approach for example, may over-inflate a hospital's true EMR capabilities. While the EMRAM framework was designed to give guidance for the sequence of implementing EMR functionalities in hospitals by scoring hospitals on the "presence" of EMR tools, the "pervasiveness" of EMR tool use is not addressed until higher stages of the model. As such, hospitals could qualify as a stage 4 hospital if the required functionalities and facilities are implemented in only one patient care service area in the hospital even though other parts of the hospital reflect the capabilities of lower EMRAM stages. As such, it is possible that hospitals are not fully realizing the quality and safety benefits of their EMR because the tool's use is not universally employed throughout the hospital, even though they are recognized as having fairly advanced EMR capabilities.

Secondly the Elsevier model. The scoring of the Elsevier model is mainly based (87 %) upon so called 'structure' indicators. The 'effective treatment' indicator is based upon 62 (100 %) 'structure' indicators. 'Outcome' or 'process' indicators are generally considered as better indicators for quality of care.[18] Transparency of hospitals is a big issue in the NL (as is abroad) because even if outcome indicators are measured, they are most of the time not available for publication. To illustrate the dispute in the Netherlands, the ministry of Health made 2015 the year of the transparency. However, it could be

that not only methodological limitations in this paper explain the absence of a positive relation between digitalization and quality of care. Recent literature [19,20] has indicated and discussed comparable findings.

In the study of Jarvis [16] of 2988 hospitals with EMRAM scores in the USA, 248 were classified as 'advanced EMR use' (EMRAM stage 6 or 7). The remaining hospitals were classified as 'non-advanced EMR use'. Estimated clinical process of care and patient

experience of care scores were calculated by the American Hospital Association (AHA) by using data from Hospital Compare. Before adjusting for hospital characteristics (#beds, system status, teaching hospital, profit, and geographic region) EMRAM stage 7 users had significant higher clinical process scores and significant lower experience of care scores. After controlling for hospital characteristics, EMRAM stage 7 advanced EMR use was associated with significantly higher process of care scored than both EMRAM stage 6 advanced users and non-advanced users. There was no difference in process of care scores between EMRAM stage 6 advanced use and non-advanced use. After adjusting for hospital characteristics, there was no difference in experience of care scores by level of advanced use. These findings may support our conclusion that EMRAM stage 6 may not be a good enough indicator for advanced EMR use, because hospitals could qualify as a stage 6 hospital if the required functionalities and facilities are implemented in only one patient care service area in the hospital even though other parts of the hospital reflect the capabilities of lower EMRAM stages. Only at stage 7 the required functionalities and facilities are implemented in every patient care service area in the hospital. The number of hospitals in the NL (67) may not be enough to adjust for hospital characteristics in our study. No significant difference between hospital characteristics and EMRAM score was found in our study (Data available at the first author).

CONCLUSION

The hypothesis of this study, that there is a positive association between advanced electronic medical record (EMR) capabilities and quality and safety of hospital care in the Netherlands, was not supported by the findings of this study at this point in time. This outcome may be caused by a multiplicity of factors (such as the characteristics of the models being used, the varied EMR implementation strategies employed by hospital leaders in the Netherlands, and/or the mastery of the staff in using these technologies) leading one to conclude that future research efforts should give careful consideration to these variables.

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CHAPTER 4

Patient safety outcomes and their association with the level of digitization in Dutch hospitals

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ABSTRACT

Background

Experts consider health information technology key to improving efficiency and quality of health care. The purpose of this study is to explore the association between the use of Electronic Medical Record (EMR) technologies in Dutch hospitals and patient safety outcomes. The outcomes studied were the number of adverse events (AE), preventable AEs, medication related AEs, preventable medication-related AEs, unplanned readmissions and the length of hospital stay.

Methods

Two data sets were leveraged for this study: the HIMSS (Health Information Management Systems Society) Analytics Electronic Medical Record Adoption Model (EMRAMSM) and the Netherlands Institute for Health Services Research (NIVEL) database. A total of 17 hospitals with a valid EMRAM score and associated NIVEL patients (n=3,436) during the study period were included in the comparative set. A multilevel binomial regression method (adverse events and unplanned readmissions) and linear regression analyses (length of stay) were used to investigate the association, while adjusting for over-representation of deceased patients, differences in hospital departments and hospital types.

Results and conclusions

An association between the use of EMRs and patient safety outcomes could not be confirmed. This might be caused by the small number of participating hospitals. Another reason could be the status of implementing EMR capabilities in the Netherlands. As many hospitals in the Netherlands are investing in information technology on a large scale by replacing their EMR systems it is expected this may change in the nearby future. Further research in the future may provide clarity.

Keywords:

Electronic Medical Records, Adverse Events, patient safety, length of stay, EMRAM.

INTRODUCTION

Implementations of potentially transformative eHealth technologies throughout the world frequently have a significant impact on national health expenditures. Such large-scale efforts and investments have been justified on the grounds that the electronic medical record (EMR), picture archiving and communication systems (PACS), electronic prescribing (ePrescribing) and associated computerized provider (or physician) order entry systems (CPOE), and computerized decision support systems (CDSS) are supposed to help to address the problems of variable quality and safety in modern health care.[1–5] However, the scientific basis of such claims, which are repeatedly made and seemingly uncritically accepted, remains to be firmly established.

For the measurement of the level of implementation of information systems a concept of maturity of these systems has been developed. There is a number of methods or models available to measure the level of implementation of information technology.[6] One of these methods is the so-called Electronic Medical Record Adoption Model (EMRAM) scoring approach developed by Healthcare Information and Management Systems Society (HIMSS) Analytics. [7] This model is distinguished from other models that it also surveys the actual use of the available software and not only the available functionality. EMRAM is an eight-stage maturation model reflecting the EMR capabilities in hospitals, ranging from a completely paper-based environment (Stage 0) to a highly advanced near paperless and digital patient record environment (Stage 7). Previous studies on this model in the Netherlands show that EMRAM stage 3, the first stage in which clinical functionalities (nursing) become available, presents as the first notable challenge to Dutch hospitals; 37.5% of the hospitals in this study (Q2-2015) have yet to satisfy the requirements of this stage. The basic and more advanced clinical capabilities are expected to help to increase the quality, safety and efficiency of the treatment of patients in the hospital.[8]

Table 1 - Frequency distribution of EMRAM scores (Q2 2015) in the Netherlands

HIMSS level		Frequency	Percent	Characteristics
Stage	7	0	0	Complete EMR; data analytics to improve care
	6	11	15.3	Physician documentation (templates); full CDSS; Closed loop medication administration
	5	31	43.1	Full R-PACS
	4	2	2.8	CPOE; Clinical Decision Support (clinical protocols)
	3	0	0	Clinical documentation; Clinical Decision Support (error checking)
	2	27	37.5	Clinical Data Repository (CDR); Controlled Medical Vocabulary; CDS; HIE (internal)
	1	1	1.4	All three ancillaries installed – Lab, Rad, Pharmacy
	0	0	0	All three ancillaries not Installed
	Total	72	100	

Patient safety has been high on the international agenda for several decades since the 1999 Institute of Medicine report 'To Err Is Human'.[9] Many retrospective patient record review studies in various countries have followed this Harvard Medical Practice Study HMPS in an attempt to evaluate patient safety. [10–14] To keep track of changes in patient safety at a national level, three patient safety measurements with patient records from 2004, 2008 and 2011/2012 have been carried out by the Netherlands by Netherlands Institute for Health Services Research (NIVEL).[11,15–17] These studies demonstrated significant overall improvement of the years, but also showed that differences in patient safety outcomes exist between hospitals. Since EMRs may lead to better hospital performance and outcomes, hospitals may use EMRs to improve the quality of care. The key assumption to be explored in this study is that when basic clinical functionalities are available in a hospital (EMRAM>=3), patients will have a more effective and safe hospitalization compared to hospitals with lesser capabilities. Effective communication through EMRs could prevent medical or organizational mistakes. From this concept, we deducted the following expected associations for our study.

- In hospitals with more advanced EMR capabilities the expected number of patients with AEs is smaller;
- In hospitals with more advanced EMR capabilities the expected number of patients with preventable AEs is smaller;
- In hospitals with more advanced EMR capabilities the expected number of patients with AEs caused by medication is smaller;
- In hospitals with more advanced EMR capabilities the expected number of readmissions is smaller.
- In hospitals with more advanced EMR capabilities the expected average Lengths of Stay (LOS) is shorter.

Given the nature of this retrospective database study, associations that are demonstrated are considered exploratory, and will need further confirmation in subsequent research.

METHODS

EMRAM

The scoring process is done (2012-2014) by identifying the software used in the different functional areas of the hospital. At least 150 questions per hospital are included about demographics, software functionalities, processes, integration standards, usage in percentage by physician and nurses, depending on the available software in the hospital.[7] The surveys are filled in by the author of this manuscript in presence of the hospital officials in charge (mainly ICT, pharmacist, medical specialist). As clinical EMR capabilities (nursing/clinical documentation, flow sheets and basic decision support etc.), are implemented from EMRAM stage 3 and higher and the number of hospitals per EMRAM score is small, it was decided to split the hospitals into two groups: the lower EMRAM group with EMRAM-scores 0 to 2 (EMRAM012) and the higher EMRAM group (EMRAM-scores 3 to 6 - EMRAM3456), with more advanced clinical functionalities.

Dutch Adverse Event Study

The details of the design of the Dutch Adverse Event study has been published elsewhere.[13] To keep track of changes in patient safety at a national level, three patient safety measurements with patient records from 2004, 2008 and 2011/2012 have been carried out in the Netherlands in this study. As the EMRAM study took place in 2012-2014 only patients measured during the last study in 2011/2012 of this large retrospective patient record review study were used. A retrospective patient record review study was

performed using patient admissions from 1 April 2011 until 31 March 2012, in 20 hospitals, out of the total of 93 Dutch hospitals. The sample was stratified for university, tertiary teaching and general hospitals. Within the strata the hospitals were selected randomly and a proper representation of both urban and rural settings in the sample was verified. Hospitals had to have at least 200 beds, an intensive care unit and an emergency room to be eligible. Therefore, four hospitals were excluded, leaving 89 hospitals from which the sample was drawn. In each hospital, 200 patient admissions were selected. In total 4,048 patient admissions were included. Patients admitted to the psychiatry department, obstetrics and children under 1 year were excluded to be comparable with other studies using the same review methods. Fifty percent of the records were of patients who were discharged from the hospital after a stay of at least 24 hours. The other 50% were of patients who died in hospital during admission. This made it possible to estimate the number of preventable deaths as this is a relatively small patient group. These patients were sampled from all inpatient deaths, regardless of their length of stay (LOS).

The method of determining AEs was comparable to those of other international studies. First, a nurse screened the records by using triggers indicating potential AEs. Admissions that were positive for at least one trigger were reviewed further by a physician. The presence and preventability of an AE was determined based on a standardized procedure and preceded by several underlying questions to secure a systematic assessment.

An AE was defined by three criteria:

- an unintended injury;
- the injury resulting in a longer hospital stay, temporary or permanent disability, or death;
- the injury was caused by healthcare management rather than the patient's disease.

An AE was found to be preventable when the care given fell below the current level of expected performance for practitioners or systems. The causation by healthcare of an AE as well as its preventability was scored on a six-point 'Likert Scale' after consideration through a set of supportive questions to standardize the procedure. This score is counted as caused by healthcare or preventable if the score was 4–6. A score of 4–6 indicated that the reviewer regarded the event as having a >50% chance of being caused by healthcare or being preventable. The physicians assessed the clinical process that was related to

the AE: surgery, drug/fluid, medical procedure, diagnostic, other clinical management, discharge or other.

AEs that occurred during the patient's index hospital admission[1]*, and were detected during either the index admission or subsequent admissions over the following 12-month period, were counted. Also counted were AEs related to patient admissions in the same hospital within the 12 months preceding the index admission but that were not detected until the index admission. Consequently, patient records of the index hospital admission were reviewed, as were the patient records of patient admissions before and after the index admission. The way the AEs were counted was the same for all periods of measurement.

We selected patient outcomes in the NIVEL database that might be influenced by a higher EMRAM score: the number of AEs, medication related AEs, the number of unplanned readmissions and the length of stay (LOS) in the hospital.

For the LOS, our thesis behind this study is that when basic clinical functionalities (EMRAM>=3) are available in a hospital, the patients will have a more efficient hospitalization. Efficient communication could prevent medical or organizational mistakes and make it possible to transfer patients from an intensive care unit (ICU) to a general ward and transfer patients from the ward to home without undue delay.

STATISTICAL ANALYSIS

We used descriptive statistical techniques to describe the effect of more advanced EMR facilities in hospitals on the number of adverse events (AE), the preventable AEs and the medication related AEs (MRAE).

Further analyses on patient level were performed. After weighing for the sample frame, the total study sample was representative of the total Dutch population of hospitalized patients.[10] Multilevel binomial regression (adverse events and unplanned readmissions) and linear regression analyses (length of stay) were performed to analyze the relation between the EMRAM groups (independent variable) and respectively, the number of AEs,

1 * As the EMRAM study took place in 2012-2014 only patients measured in 2011/2012 of this large retrospective patient record review study were used.

the preventable AEs, the MRAEs, the preventable MRAEs the number of readmissions (RA) and the length of stay in the hospital (the dependent variables in the model). Multilevel analyses were used because the data had a hierarchical structure: patients (level 1) were clustered within hospital departments (level 2), and hospital departments were clustered within hospitals (level 3).[18] Adjustments were made for the stratified sample to correct for over-representation of deceased patients and for hospital types.[10]

RESULTS

From the 20 hospitals selected by NIVEL, 17 are measured in the EMRAM study, leaving 3436 patients (Table 2). Seven hospitals had an EMRAM-score 2, nine hospitals an EMRAM-score 5 and one hospital with EMRAM-score 6. As the EMRAM study took place in 2012-2014 only patients (3436) measured in 2011/2012 of the retrospective patient record review study were used.

Table 2 - Number of patients per EMRAM score and per hospital type

Type of Hospital	Number of Hospitals	EMRAM-score			Total number of patients
		EMRAM 2	EMRAM 5	EMRAM 6	
University	2	1	1	0	406
Tertiary teaching	7	3	3	1	1423
General	8	3	5	0	1607
Total number of hospitals	17	7	9	1	3436
Total number of patients	3436	1405	1829	202	

It concerned 311 patients with at least one adverse event. That is 9% of 3.436 patients. On hospital level, no indication was found that a higher EMRAM score might lead to better patient outcomes (Table 3). The median values of the number of patients with at least one adverse event ranged from 4.4% in EMRAM group 2 to 7.2% in EMRAM group 5. For the three hospitals of which no EMRAM score is known, the median was 10.8%. In EMRAM group 6 only one hospital is present, which may be too small to draw conclusions from.

Table 3 - Median of number of patients with at least one AE per hospital

		Number of hospitals Median	Patients with at least one adverse event (%)	Patients with at least one preventable adverse event (%)	Patients with at least one medication-related adverse event (%)
			Median	Median	
EMRAM score	missing	3	10,8 % *	0,9 % *	2,9 %*
	2	7	4,4 % *	1,1 % *	1,1 % *
	5	9	7,1 % *	1.1 % *	1,1 % *
	6	1	6,3 % *	2,2 % *	1,2 % *

* corrected for over presentation of deceased patients and hospital type according to NIVEL method (ref: [11])

In the dataset of NIVEL (with 17 hospitals) in total 333 events with care-related damage were found in 311 patients. It concerned 292 patients with one event documented, 17 patients with two events, one patient with three events and one patient with four events. In the analyses on patient level the number of patients with one or more events with care-related harm was counted and not the number of events (n = 311 vs. n = 333). For patients with multiple events the patient is characterized by the event that led to the highest degree of preventability. The weighted percentages of patients with at least one event are presented in Table 4. In any case the total number of patients with AEs divided by total number of patients in % per EMRAM score is increasing from EMRAM-score 2 to EMRAM-score 5 on this descriptive scale. This increase is not consolidated for EMRAM-score 6 (one hospital).

Table 4 - Patients that experience at least one (preventable) AE or (preventable) MRAE per EMRAM-score

	EMRAM-score 2	EMRAM-score 5	EMRAM-score 6	Total N (%)
	N %	N %	N %	
Patients with at least one AE	5.6 % *	7.2 % *	6.4 % *	6.5 % *
Patients with at least one preventable AE	1.3 % *	1.7 % *	2.2 % *	1.6 % *
Patients with at least one MRAE	1.4 % *	1.7 %*	1.2 % *	1.5 % *

AE= adverse event; MRAE= medication-related adverse event
* corrected for over presentation of deceased patients and hospital type according to NIVEL method (ref: (11))

The result of the multilevel analysis is presented in table 5. From these results, it is clear that none of the four postulated associations was (strongly) supported by the data, although for AEs, preventable AEs, and Medication related AEs the estimated odds ratios were smaller than 1. This is in line with the expected smaller risks.

Table 5 - Odds ratios for higher EMRAM score calculated with a multilevel model

Patients with:	Odds ratio (EMRAM>=3/EMRAM<3)	95% confidence-interval (CI)	
		Lower	Upper
Adverse events (AE)*	0,84	0,87	1,63
Preventable AE*	0,86	0,74	1,80
Medication related AE*	0,41	0,65	1,86
Unplanned readmissions*	1,10	0,87	1,41

Dichotomized: EMRAM012 = 0 and EMRAM3456 =1

* adjusted for: over-representation of deceased patients, type of hospital department and hospital types

For length of stay, the estimated association is also not significant. The estimated difference in mean length of stay is numerically in the expected direction, amounting to 0,24 days (95% confidence interval -1,4 to 0,9 days) shorter for hospitals with higher EMRAM scores.

Table 6 - Influence of EMRAM score on length of Stay (LOS) in the hospital (days).

Length of Stay (LOS) in the hospital (days) *		95% confidence-interval (CI)	
		Lower	Upper
Mean LOS in hospitals with EMRAM <3	6,0	5,0	7,0
Mean difference with hospitals with EMRAM >=3	-0,24	-1,4	0,9

EMRAM012 = 0 and EMRAM3456 =1

* adjusted for: over-representation of deceased patients, type of hospital department and hospital types

DISCUSSION

We did not find a significant relation between the EMRAM-score and the number of patients with adverse events (AE), preventable AEs, AE caused by medication, the number of readmissions (RA) and the length of stay (LOS**)**. Those are remarkable findings, and this is not what we expected. This may be caused by the low level of digitalization of Dutch hospitals. No EMRAM stage 7 hospitals are present yet in the Netherlands. Hospitals struggle with the introduction of advanced functionalities like closed loop medication administration, evidence-based decision support and the introduction of clinical pathways in a broad sense. These characteristics are a prerequisite for stage 7. As many hospitals in the Netherlands are investing in information technology on a large scale by replacing their EMR systems it is expected this may change in the nearby future. Another factor is the quality of the collected EMRAM data. The actual use of EMR software can only be measured reliably by measuring the actual quality of stored data and that is not done. In primary care such tools are available.[19] It cannot be excluded that unknown or non-measured factors affect both the dependent and the independent variables. Through stratification and the use of multivariate techniques, these effects are addressed for the known distorting factors. Further research in the future may provide clarity. Remarkable is the high median number of AE in the hospitals that did not join the EMRAM program (Table 4). Because earlier studies indicated that smaller hospitals did not join the EMRAM study [20] and at the same time these studies indicated that smaller hospitals in the Netherlands have a lower EMRAM score. This may lead to the conclusion that smaller hospitals can win by implementing more sophisticated EMR capabilities.

Limitations of the study and suggestions for further research

There are limitations to our study. First, although we achieved a 77% response rate, the hospitals that did not respond to the HIMSS survey were somewhat different from those that did respond. Small hospitals and hospitals located in the northern part of the Netherlands were underrepresented in the study. Given that non-responding hospitals were more likely to have characteristics associated with lower levels of adoption of electronic health records (especially size), residual bias may be present in estimating the associations. Another remark has to be made about the time frame in which measurement were taken in both studies. The Nivel database measurements were taken in the period 2011/2012, while the EMRAM measurements were done in the period 2012/2014 (with only 2 out of 17 in 2014). We assume that the effect of implementing

more advanced EMR capabilities did not influence the AE scores in such a short period, although also here a small bias cannot be excluded.

CONCLUSIONS

Although for four of the five pre-defined potential associations the observed effects were numerically in the direction as expected, statistically there was no clear support for any of the associations. Besides sample size, other reasons for the fact that associations could not be confirmed could be those hospitals in the Netherlands struggle with the introduction of advanced functionalities like closed loop medication administration, evidence-based decision support and the introduction of clinical pathways in a broad sense.

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CHAPTER 5

Level of digitization in Dutch hospitals and the lengths of stay of patients with colorectal cancer.

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ABSTRACT

Background

A substantial amount of research has been published on the association between the use of electronic medical records (EMRs) and quality outcomes in U.S. hospitals, while limited research has focused on the Western European experience. The purpose of this study is to explore the association between the use of EMR technologies in Dutch hospitals and length of stay after colorectal cancer surgery.

Methods

Two data sets were leveraged for this study: the HIMSS Analytics Electronic Medical Record Adoption Model (EMRAMSM) and the Dutch surgical colorectal audit (DSCA). The HIMSS Analytics EMRAM score was used to define a Dutch hospital's electronic medical records (EMR) capabilities while the DSCA was used to profile colorectal surgery quality outcomes (specifically total length of stay (LOS) in the hospital and the LOS in ICU). A total of 72 hospitals with a valid EMRAM score and associated DSCA patients (n=30.358) during the study period (2012 – 2014) were included in the comparative set. A multivariate regression method was used to test differences adjusted for case mix, year of surgery, surgical technique and for complications, as well as stratifying for academic affiliated hospitals and general hospitals.

Results

A significant negative association was observed to exist between the total LOS (relative median LOS 0,974, CI 95% 0.959 - 0,989) of patients treated in advanced EMR hospitals (high EMRAM score cohort) versus patients treated at less advanced EMR care settings, once the data was adjusted for the case mix, year of surgery and type of surgery (laparoscopy or laparotomy). Adjusting for complications in a subgroup of general hospitals (n=39) yielded essentially the same results (relative median LOS 0,934, CI 95% 0,915 - 0,954). No consistent significant associations were found with respect to LOS on the ICU.

Conclusions.

The findings of this study suggest advanced EMR capabilities support a healthcare provider's efforts to achieve desired quality outcomes and efficiency in Western European hospitals.

Keywords:

Hospital, Colorectal Surgery, Quality Assurance, Health Care, EM, Maturity Model

INTRODUCTION

Implementations of potentially transformative eHealth technologies throughout the world frequently have a significant impact on national health expenditures. Such large-scale efforts and investments have been justified on the grounds that the EMR, picture archiving and communication systems (PACS), electronic prescribing (ePrescribing) and associated computerized provider (or physician) order entry systems (CPOE), and computerized decision support systems (CDSS) are supposed to help to address the problems of variable quality and safety in modern health care[1–6]. However, the scientific basis of such claims, which are repeatedly made and seemingly uncritically accepted, remains to be firmly established.

For the measurement of the level of implementation of information systems a concept of maturity of these systems has been developed. There is a large number of methods or models available to measure the level of implementation of information technology[7]. One of these methods is the so-called Electronic Medical Record Adoption Model (EMRAM) scoring approach developed by Healthcare Information and Management Systems Society (HIMSS) Analytics[8]. EMRAM is an eight-stage maturation model reflecting the EMR capabilities in hospitals, ranging from a completely paper-based environment (Stage 0) to a highly advanced paperless and digital patient record environment (Stage 7). The scoring process is done by identifying the software used in the different functional areas of the hospital. At least 150 questions per hospital are included about demographics, software functionalities, processes, integration standards, usage in percentage by physician and nurses, depending on the available software in the hospital. Previous studies on this model in the Netherlands show that EMRAM stage 3, the first stage in which clinical functionalities (nursing) become available, presents as the first notable challenge to Dutch hospitals; 37.5% of the hospitals in this study have yet to satisfy the requirements of this stage. The basic and more advanced clinical capabilities should help to increase the quality, safety and efficiency of the treatment of patients in the hospital[9].

The Dutch surgical colorectal audit (DSCA), started in 2009, is a nationwide audit used to monitor, evaluate, and improve quality of care of primary colorectal cancer surgery. It provides feedback to all hospitals in the Netherlands on a set of quality measures and indicators. While EMRs may lead to better hospital performance and outcomes, hospitals may use EMRs to improve the quality of care. This paper has the objective to contribute to the scientific discourse on the relationship between the digitalization of hospital data and the effect on quality of care, with colorectal cancer as a guiding example [10,11].

Our thesis behind this study is that when basic clinical functionalities (EMRAM>=3) are available in a hospital, the patients will have a more efficient hospitalization. Efficient communication could prevent medical or organizational mistakes and make it possible to transfer patients from an intensive care unit (ICU) to a general ward and transfer patients from the ward to home without undue delay. We used the post-operative length of stay (LOS) in this study because that is where the presumed effect is expected. Preoperative patients are usually admitted to the hospital the same day or the day before the surgery.

University and top teaching hospitals provide a great deal of specialized care and medical research, as well as the training and education of many of the nation's health care providers. Former studies [12,13] indicate that academic affiliated hospitals may more easily adapt to changes than general hospitals. According to Retchin and Wenzel[13], university health centers, as well as top teaching hospitals, can easily adapt to the use of EMRs because they, "have the expertise to resolve remaining software issues, the components necessary for the integrated delivery, a culture for innovation in clinical practice, and a generation of future providers that can be acclimated to the requisites for computerized records"(p.493 of Retchin and Wenzel[13]). Another reason for this increased likelihood is that medical training occurs in these hospitals, and younger medical trainees tend to be more comfortable with computers as they have recently used them in school[14]. Because of this, the staff resistance to EMR use may not be as great as in other hospitals[13]. Based upon these properties we expect that in academic affiliated hospitals the above-mentioned effect is even stronger. From this model (Figure 1) we deducted the following hypotheses.

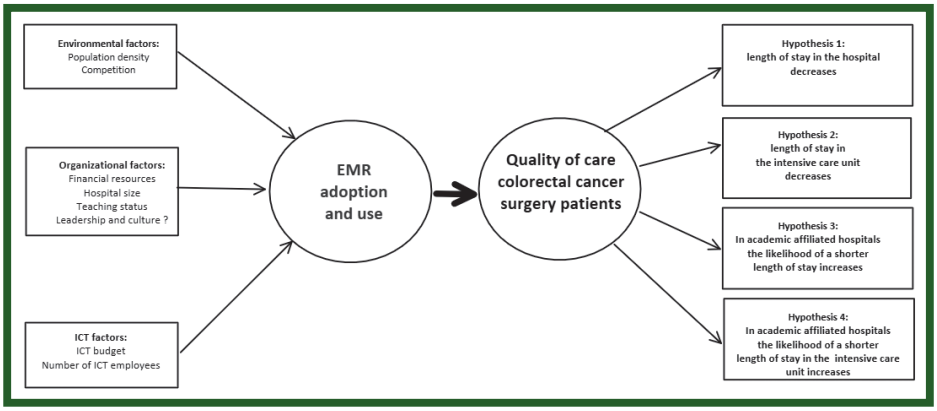

Figure 1 - the theoretical model

Hypothesis 1:
In hospitals with more advanced EMR capabilities the likelihood of a shorter LOS on average of colorectal cancer surgery patients in the hospital increases.

Hypothesis 2:
In hospitals with more advanced EMR capabilities the likelihood of a shorter LOS on average in the ICU of colorectal cancer surgery patients increases.

Hypothesis 3:
The likelihood of a shorter LOS on average of colorectal cancer surgery patients increases in academic affiliated hospitals with more advanced EMR capabilities.

Hypothesis 4:
The likelihood of a shorter LOS on average in the ICU of colorectal cancer surgery patients increases in academic affiliated hospitals with more advanced EMR capabilities.

METHODS

Data were collected from the DSCA. This disease specific registry contains information on patient, tumor, treatment, and short-term outcome characteristics. All hospitals in the Netherlands register their primary colorectal cancer patients that undergo a resection in this database. Details of this dataset regarding collection and methodology have been published previously. [15 16]

Patients

All patients undergoing surgical resection for primary colorectal cancer between January 1, 2012, and December 31, 2014, and registered in the DSCA before March 30, 2015, were evaluated in this study. For this study no ethical approval or informed consent was required under Dutch law. Minimal data requirements to consider a patient eligible for analyses were information on tumor location, date of surgery, and mortality. Patients with local excisions were excluded (n=393) Patients with LOS of 0 or less, or LOS that was missing were excluded (n=358), because the origin of this outcome is possibly grounded on registration mistakes.

Hospitals

Every hospital in the NL (N=93) was invited to participate in the EMRAM study. In 2014, 72 hospitals (80%) joined the EMRAM program. Of this group of hospitals (N=34) are

considered academic affiliated (university and top teaching hospitals) for the purpose of this study. These hospitals provide high-complex care, lead the way in innovation and research and train (surgical) residents. For the primary objective of this study, the EMRAM scores of the hospitals present in both databases (EMRAM and DCSA) were dichotomized into hospitals with clinical functionalities (EMRAM >=3) and hospitals without clinical functionalities (EMRAM<3).

Outcomes

Length of stay is shown in days, calculated by subtracting the date of surgery from the date of dismissal from the hospital. Length of stay on the ICU is registered directly into the registry.

Statistical analysis

The primary analysis is a multivariate regression analysis on the logarithmically transformed LOS, adjusted for patient and tumor characteristics, year of surgery, hospital type and type of surgery (laparoscopy of laparotomy). Patient and tumor characteristics adjusted for are gender, BMI-index, age, ASA classification, primary location of the tumor, pathological T stage, metastasis, perioperative tumor complications, urgency, additional resections for tumor growth and metastasis. Details concerning the use of relevant case-mix factors have been described elsewhere[16 17]. We repeated the multivariate regression, by additionally adjusting for surgical complications in three stages: a single complication, a complication combined with reoperation and a complication leading to death. The analyses are repeated for the total group of hospitals (N=73), the group of academic affiliated hospitals (N=34) and the group of general hospitals (N=39). Significance was considered for the primary research question, with a p-value<0.05.

RESULTS

Patients and hospitals

In total 73 hospitals, including 30.358 patients were included in this study. In table 1 the distribution of patients' characteristics among the EMRAM low group and the EMRAM high group are shown. A significant effect (relative median LOS=0,974, CI 95% 0.959 - 0,989) is found between patients in the EMRAM low group and the LOS in the EMRAM high hospital group when corrected for the case mix, year of operation and type of surgery (laparoscopy or laparotomy). Additional adjustment for patients with complications confirms the association (relative median LOS 0,969, CI 95% 0,956 – 0,981). For LOS in the

ICU the multivariate regression does not show a significant association of higher EMRAM score with smaller LOS (relative median LOS 0,995, CI 95% 0,942 – 1,050). After adjustment for patients with complications there is also no significant association (relative median LOS 1,010 CI 95% 0,962 – 1,060).

Table 1 - patient and hospital characteristic per EMRAM Group.

Patient and hospital characteristics		EMRAM-score			
		EMRAM <3		EMRAM>=3	
		Count	Column N %	Count	Column N %
sex	Male	4462	55,8%	9341	55,1%
	Female	3540	44,2%	7627	44,9%
BMI categories with missing	Unknown	199	2,50%	451	2,7%
	<18.5	170	2,1%	276	1,6%
	18.5-25	3195	39,9%	6758	39,8%
	25-30	3110	38,8%	6732	39,7%
	30+	1334	16,7%	2759	16,3%
Age	<=60	1528	19,1%	2972	17,5%
	61 – 70	2538	31,7%	5341	31,5%
	71 – 80	2674	33,4%	5903	34,8%
	>=81	1268	15,8%	2747	16,2%
Charlson score in 3 groups	Charlson score 0	3967	49,5%	8586	50,6%
	Charlson score 1	1813	22,6%	3877	22,8%
	Charlson score 2+	2228	27,8%	4513	26,6%
ASA score in 3 groups	I – II	6157	77,0%	13099	77,2%
	III	1732	21,6%	3620	21,3%
	IV – V	112	1,4%	254	1,5%

Table 1 - Continued.

Patient and hospital characteristics		EMRAM-score			
		EMRAM <3		EMRAM>=3	
		Count	Column N %	Count	Column N %
Location of tumor	Caecum	1126	14,1%	2321	13,7%
	Appendix	40	0,5%	89	0,5%
	Ascending colon	1043	13,0%	2221	13,1%
	Hepatic flexure	315	3,9%	751	4,4%
	Transverse colon	413	5,2%	1013	6,0%
	Splenic flexure	195	2,4%	403	2,4%
	Descending colon	368	4,6%	773	4,6%
	Sigmoideal colon	2307	28,8%	4617	27,2%
	Rectum	2201	27,5%	4788	28,2%
Pathological T stage	Tx/T0	23	0,3%	35	0,2%
	T1	812	10,2%	1693	10,1%
	T2	1564	19,7%	3390	20,2%
	T3	4544	57,1%	9442	56,2%
	T4	1012	12,7%	2255	13,4%
Distant metastasis	No/missing	7092	88,6%	15190	89,5%
	Yes	916	11,4%	1786	10,5%
Pre-operative tumor complications	No/missing	5330	66,6%	9619	56,7%
	Yes	2678	33,4%	7357	43,3%
Urgent/not urgent	Elective (incl. after stent)	6864	85,8%	14741	86,9%
	Urgent/ Emergency	1140	14,2%	2227	13,1%
Additional resection because of metastasis	No	7643	95,4%	16470	97,0%
	Yes	365	4,6%	506	3,0%
Additional resection because of extensive tumor growth	No	7209	90,0%	15489	91,2%
	Extensive	353	4,4%	682	4,0%
	Limited	446	5,6%	805	4,7%
Surgical technique	Laparotomy	3424	43,0%	6864	40,6%
	Laparoscopy	4546	57,0%	10039	59,4%

Table 1 - Continued.

Patient and hospital characteristics		EMRAM-score			
		EMRAM <3		EMRAM>=3	
		Count	Column N %	Count	Column N %
Complications	No complications	5570	69,8%	11362	67,1%
	Complication	1431	17,9%	3400	20,1%
	Complications and reintervention	770	9,6%	1777	10,5%
	Complications and death	214	2,7%	403	2,4%
Size of hospital admitted	Small	1489	18,6%	2006	11,8%
	Medium	3711	46,3%	5789	34,1%
	Large	2808	35,1%	9181	54,1%
Type of hospital admitted	General hospitals	4446	55,5%	5965	35,1%
	Academic affiliated	3562	44,5%	11011	64,9%
Region of hospital admitted	East	1271	15,9%	3438	20,3%
	North	1517	18,9%	1728	10,2%
	South	1727	21,6%	5547	32,7%
	West	3493	43,6%	6263	36,9%

Looking at the subgroup of academic affiliated hospitals (N=34) (Table 3) the significance of the change of the LOS in the hospital when corrected for the case mix, year of operation and type of surgery (laparoscopy or laparotomy) disappears. Still, when corrected for complications there is a significant decreasing effect.

Looking at the subgroup of general hospitals (n=39) (Table 4) a significant negative association (relative median LOS 0,934, CI 95% 0,915 - 0,954) is found when corrected for the case mix. This means an estimated decrease of the median LOS of 6,6% and 6,1% when also corrected for complications (e^{B1}=0,939). For LOS in de ICU the multivariate regression shows a significant (relative median LOS 1,104, CI 95% 1,036 – 1,177) increase for hospitals with higher EMRAM scores. When additionally adjusted for complications, there are no significant associations

Table 2 – Length of stay of patient in total hospital group

	Univariate regression			Multivariate regression***			Multivariate regression****		
	Exp(B)	95% C.I.for B		Exp(B)	95% C.I.for B		Exp(B)	95% C.I.for B	
		Lower	Upper		Lower	Upper		Lower	Upper
	Logarithm of LOS in the hospital								
EMRAM <3	B0=2,055			B0=1,606			B0=1,471		
EMRAM >=3	B1=-0,002	-0,019	0,016	B1=-0,026	-0,042	-0,011	B1=-0,032	-0,045	-0,019
median LOS >=3/median LOS <3	e^{B1}=0,998	0,981	1,016	e^{B1}=0,974	0,959	0,989	e^{B1}=0,969	0,956	0,981
	Logarithm of LOS in the ICU								
EMRAM <3	B0=0,744			B0=0,437			B0=0,043		
EMRAM >=3	B1=0,101	0,046	0,156	B1=-0,005	-0,060	0,049	B1=0,010	-0,038	0,058
median LOS >=3/median LOS <3	e^{B1}=1,106	1,047	1,169	e^{B1}=0,995	0,942	1,050	e^{B1}=1,010	0,962	1,060

*** adjusted for: case-mix, year of registration, hospital type and technique of treatment (laparoscopic/laparotomy)
**** adjusted for: as before plus complications

Table 3 – Length of stay (LOS) for patients in academic affiliated hospitals

	Univariate regression			Multivariate regression***			Multivariate regression****		
	B	95% C.I.for B		Exp(B)	95% C.I.for B		B	95% C.I.for B	
		Lower	Upper		Lower	Upper		Lower	Upper
	Logarithm of LOS in the hospital								
EMRAM <3	B0=2,100			B0=1,586			B0=1,445		
EMRAM >=3	B1=-0,013	-0,038	0,011	B1=-0,009	-0,029	0,011	B1=-0,034	-0,051	-0,018
median LOS >=3/median LOS <3	e^{B1}=0,987	0,963	1,011	e^{B1}=0,991	0,971	1,011	e^{B1}=0,967	0,950	0,982

Table 3 - Continued.

	Univariate regression			Multivariate regression***			Multivariate regression****		
	B	95% C.I.for B		Exp(B)	95% C.I.for B		B	95% C.I.for B	
		Lower	Upper		Lower	Upper		Lower	Upper
	Logarithm of LOS in the ICU								
EMRAM <3	B0=0,785			B0=0,652			B0=0.231		
EMRAM >=3	B1= 0,089	0,002	0,176	B1=0,011	-0,063	0,085	B1=0,017	-0,049	0,083
median LOS >=3/median LOS <3	e^{B1}=1,093	1,002	1,192	e^{B1}=1,011	0,939	1,089	e^{B1}=1,017	0,952	1,086

*** adjusted for: case-mix, year of registration, hospital type and technique of treatment (laparoscopic/laparotomy)
**** adjusted for: as before plus complications

Table 4 – Length of stay (LOS) for patients in general hospitals.

	Univariate regression			Multivariate regression***			Multivariate regression****		
	B	95% C.I.for B		Exp(B)	95% C.I.for B		B	95% C.I.for B	
		Lower	Upper		Lower	Upper		Lower	Upper
	Logarithm of LOS in the hospital								
EMRAM <3	B0=2,019			B0=1,529			B0=1,411		
EMRAM >=3	B1=-0,027	-0,053	-0,002	B1=-0,068	-0,089	-0,047	B1=-0,063	-0,081	-0,045
median LOS >=3/median LOS <3	e^{B1}=0,973	0,948	0,998	e^{B1}=0,934	0,915	0,954	e^{B1}=0,939	0,922	0,956
	Logarithm of LOS in the ICU								
EMRAM <3	B0=0,721			B0=0,454			B0=0.073		
EMRAM >=3	B1= 0,075	0,000	0,150	B1=0,099	0,035	0,163	B1=0,054	-0,002	0,109
median LOS >=3/median LOS <3	e^{B1}=1,077	1,000	1,161	e^{B1}=1,104	1,036	1,177	e^{B1}=1,056	0,998	1,115

*** adjusted for: case-mix, year of registration, hospital type and technique of treatment (laparoscopic/laparotomy)
**** adjusted for: as before plus complications

Results of tests regarding the hypotheses.
Hypothesis 1 (in hospitals with more advanced EMR capabilities the likelihood of a shorter LOS on average of colorectal cancer surgery patients in the hospital increases) is supported by our findings. Hypothesis 2 (in hospitals with more advanced EMR capabilities the likelihood of a shorter LOS on average in the ICU of colorectal cancer surgery patients increases) is not supported by our findings. On the contrary a not significant increase of the LOS in the ICU is found. Hypothesis 3 (the likelihood of a shorter LOS on average of colorectal cancer surgery patients increases in academic affiliated hospitals with more advanced EMR capabilities) is not supported by our findings. On the contrary a stronger effect is measured by general hospitals instead by academic affiliated hospitals. Hypothesis 4 (the likelihood of a shorter LOS on average in the ICU of colorectal cancer surgery patients increases in academic affiliated hospitals with more advanced EMR capabilities) is also not supported by our findings.

DISCUSSION

For this study we tested the relation between the availability of clinical software in the hospital (EMRAM stage 3 and higher) and the LOS. For the total group of hospitals, we found a significant association as expected; LOS is shorter in hospitals with more advanced clinical software. Looking in more detail at the group of hospitals we found that the correlation is stronger in general hospitals than in academic affiliated hospitals, even when corrected for their different case mix[11]. A possible reason behind this difference might be that the academic affiliated hospitals have had EMRs longer, thus they have already made some macro adjustments that affect LOS and general hospitals are not yet as mature in EMR use and thus are still deriving the initial benefits. In addition, it is shown [18] that resident involvement may increase LOS in advanced laparoscopic surgery. This could mask the effect of the EMR.

Not clear is the slightly larger LOS in the ICU of EMRAM stage 3 or higher hospitals, especially in general hospitals (significant after case-mix correction). The difference could lie in the different levels of ICU; the least advanced ICU level is in the Netherlands frequently used for extended recovery. After repeating the analyses of general hospitals with exclusion of the lowest ICU level we see the correlation changes to a decreasing ratio, but after correction for complications also this is not significant anymore (data not shown). During our EMRAM investigation of the hospitals we found out that the software used in the ICU and the operating room, the so-called Patient Data Management System

(PDMS), is most of the time not integrated with the EMR system of the entire hospital. So the management of the LOS in the ICU may differ from the management of the LOS in the hospital. Only at EMRAM stage 6 and 7 the integration of the EMR system with the PDMS system is mandatory. It may also be a side effect of the diversity of hospitals in the EMRAM high group. In this group, hospitals with basic clinical facilities are present, but also hospitals with more advanced digital processes and evidence-based intelligence. If in future more hospitals will reach the highest, full digital, stage 7 level a third group (EMRAM>=6) can be added to look for the association with more advanced (outcome) indicators in the DSCA database. Further research is suggested to look for this relationship.

Limitations of the study and suggestions for further research

There are limitations to our study. First, although we achieved a 77% response rate, the hospitals that did not respond to our survey were somewhat different from those that did respond. Small hospitals and hospitals located in the northern part of the Netherlands were underrepresented in the study. The 72 hospitals that did participate provided a fairly good representation of the total population of the Netherlands 93 hospitals. Given that nonresponding hospitals were more likely to have characteristics associated with lower levels of adoption of electronic health records, residual bias may have led us to overestimate adoption levels. Furthermore, although we adjusted for an extensive number of patient and tumor factors, unknown confounding factors could still be present.

CONCLUSION

We found a significant association between the level of digitalization of hospitals and the length of stay after colorectal cancer surgery, consistent with shorter length of stay in hospitals with higher levels of digitization.

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CHAPTER 6

Medical Specialists' Perspectives on the Influence of Electronic Medical Record Use on the Quality of Hospital Care: Semi structured Interview Study.

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ABSTRACT

Background

Numerous publications show that electronic medical records (EMR) may provide an important contribution to increasing the quality of care. There are indications that particularly the medical specialist plays an important role in the use of EMRs in hospitals.

Objective

The aim of this study was to examine how, and by which aspects, the relationship between EMR use and quality of care in hospitals is influenced according to medical specialists.

Methods

To answer this question, a qualitative study was conducted in the period August- October 2018. Semi-structured interviews of around 90 minutes were held with eleven medical specialists of eleven different Dutch hospitals. For the analysis of the answers, we used a previously published taxonomy of factors that can influence the use of EMRs.

Results

The professional experience of the participating medical specialists varied between 5 and 27 years. Using a previously published taxonomy, these medical specialists considered technical barriers the most significant for EMR use. The suboptimal change processes surrounding implementation were also perceived as a major barrier. A final major problem is related to the categories 'social', the relation with the patient and fellow care providers, and 'psychological', based on their personal issues, knowledge, perceptions, and 'time', the time required to select, implement, and learn how to use EMR systems, and subsequently enter data into the system. On the positive side, they also identified potential technical facilitators, particularly in the assured availability of information to all health care professionals involved in the care of a patient. They see promise in using EMRs for medical decision support to improve quality of care but consider these possibilities currently lacking.

Conclusions

The eleven medical specialists shared positive experiences of EMR use when comparing it to the formerly used paper records. The fact that involved healthcare professionals can access the patient data at any time they need itis considered important. However, in

practice, potential quality improvement lags behind as long as decision support cannot be applied due to the lack of a fully coded patient record.

Keywords:
Electronic medical record (EMR), Hospitals, Quality, Healthcare, Medical specialist

INTRODUCTION

In modern-day hospitals, information technology is present in many forms. Among these are information systems, networks, databases, and websites. An electronic medical record (EMR) comprehensively includes all information to support medical diagnosis and treatment within the same institution or health system. Various authors agree that EMRs can offer an important contribution to increasing the quality of care. [1,2]. However, how are electronic medical record use and quality of medical care related in a hospital context?

In previous studies, the two authors of this paper have attempted to establish links between the extent of EMR use and the quality of medical care[3–5]. In those previous quantitative studies, they used a specially developed tool to measure the degree of EMR use in Dutch hospitals. These eight stages (0 - 7) measurement tool, the so-called EMR Adoption Model (EMRAM) from HIMSS analytics, aims to encourage hospitals to use EMR in a higher stage. [6] The HIMSS definition of an environment with a complete EMR (stage 7) is "an environment that is composed of the clinical data repository, clinical decision support, controlled medical vocabulary, order entry, computerized practitioner order entry, and clinical and physician documentation applications".[7] Ultimately, the model should lead to the use of EMR systems so that the hospital no longer uses paper charts. The findings of the quantitative analysis in the previous studies [3–5] show Dutch hospitals in 2014 particularly struggled with the electronic nursing documentation. In 2012/2014, 37.5 percent of Dutch hospitals were unable to upload this information in the EMR. Once this challenge is met, the next challenge for Dutch hospitals will be to equip the EMR with a Closed Loop Medication Administration (CLMA) and advanced Clinical Decision Support System (CDSS).

A 2015 study [4] tried to find a correlation between the EMRAM score and the Elsevier performance indicators. This yearly Elsevier publication is a Dutch nationwide publication of quality indicators for hospitals. No statistically significant correlations were found.

In the 2017 study [5], a positive association between the use of EMRs and patient quality outcomes was found for the 'length of stay' (LOS) for patients with colorectal cancer in Dutch hospitals as measured by DSCA audits.

In a third study (2018, not yet published, available from the first author), we did not find a significant relation between the EMRAM score and the number of patients with adverse

events (AE), preventable AEs, AE caused by medication, the number of readmissions (RA) and the length of stay (LOS**)** as measured in the NIVEL study [8]. Our research team did not understand why a better EMRAM score does not lead to a better quality of care. We had the impression that two intervening aspects play a role: The implementation process itself and the role of medical specialists. We got this impression because of several publications about both aspects.

The first of these is a paper written by Adler-Milstein and colleagues [9], which emphasizes the importance of the implementation process of more mature IT systems for reaching higher quality. Recent studies suggest that unsuccessful implementation of EMR systems could be due to poorly designed EMR systems, poor use of EMRs by clinicians, or social organisational aspects such as goal conflicts, lack of time, or lack of support from colleagues [10]. The second factor is the role of the medical specialist [11,12]. Previous studies show it is an important factor in the 'adoption and use' [6] of EMR systems in hospitals. Medical specialists are a main frontline user-group of EMR systems. In addition, whether or not they support and effectively use EMR systems will greatly influence other user-groups in a medical institution, such as nurses, pharmacists, and administrative staff. To optimise EMR use, it is therefore essential to understand what physicians perceive to be key aspects that either support or hinder the use of EMR systems which can positively impact medical treatment and care. To substantiate our ideas about not finding a relation between the EMRAM score and quality of care, we started this study with the following open research question:

'Which positive or negative aspects influence, the relation between EMR use and the quality of medical care, according to medical specialists?'

METHODS

To answer the research question, a qualitative research study was performed. A qualitative design was considered appropriate for this question, as the primary objective was to explore more in-depth perceptions of factors and processes related to a more complex system, including social and technical components [13].

In the period 2012-2015, the development of EMR use in 72 Dutch hospitals was measured using the so-called EMRAM score [14]. The hospitals that were measured twice in the research period and did not work with nursing documentation in the EMR nor with

CLMA and advanced CDSS were asked to participate in this follow-up study (table 1). Two hospitals achieved a higher stage on the EMRAM score, eight hospitals stayed on the same level, and one did not respond (table 1).

Table 1 – Summary of participating hospitals based on EMRAM-score.

Participant number	Name	Nursing documentation and CLMA/advanced CDSS in EMR in 2012/2014	Nursing Documentation and CLMA/advanced CDSS in EMR in 2018
1	UMC	No	No
2	UMC	No	Yes
3	teaching hospital	No	No
4	teaching hospital	No	No
5	teaching hospital	No	Information not available
6	teaching hospital	No	No
7	local hospital	No	No
8	local hospital	No	No
9	local hospital	No	No
10	local hospital	No	No
11	local hospital	No	Yes

Hospitals were approached through the chairs of their medical staff and were asked to nominate a medical specialist to participate in this study. In order to be eligible specialists were required to have worked for more than five years in the hospital in question. Overall, the selection of participants was geared towards a balanced mix of different specialisms (surgical, non-surgical, small specialisms).

In the period August- October 2018, a semi-structured interview of about 90 minutes was held with the relevant medical specialist of the participating hospital. The abovementioned research question was at the core of this interview. An item list (available from the first author) was used by the interviewer to help the participants focus on relevant experiences in case the conversation halted. We only asked questions about aspects they were personally dealing with; we were not interested in second-hand accounts.

For the analysis of the answers, we used the classification of aspects that can influence the implementation of EMR systems based on the taxonomy of Boonstra et al [15]. This systematic literature review was carried out to identify all the barriers that result in physicians showing resistance towards EMR systems. Table 2 shows the headlines of this taxonomy model.

Table 2 - Summary of categories

quote category	description
'technical'	the technical aspects of the systems, the technical capabilities of the physicians and the suppliers
'psychological'	concerns regarding the use of EMRs that are based on their personal issues, knowledge, and perceptions.
'social'	The relation with the patient and fellow care providers, but also with suppliers, insurers, and politicians.
'time'	time required to select, implement, and learn how to use EMR systems, and subsequently enter data into the system
'finance'	financial issues including those related to the monetary issues involved in implementing EMR systems
'legal'	Privacy or security concerns regarding patients' medical information
'organization'	Organisational characteristics, such assize and type of the individual practices.
'change process'	The influence of the organisational culture, incentives, community level participation and leadership

We used this taxonomy for the same aspects in a neutral connotation, as the same taxonomy can be followed when categorizing aspects as facilitators. All authors participated in the allocation of aspects from the interviews to a factor of the described taxonomy, with initial allocation by the first author and validation by the second and third. The results were recorded in an Excel-file that is available on request from the first author. Based on this classification and the primary interview recordings, the authors reached consensus about the best way to allocate quotes to the categories of the taxonomy. All authors agreed with the final allocation of quotes.

Ethics approval and consent to participate

As this study did not involve research on patients or human subjects, no 'Medical Ethical Committee' approval was required under Dutch law. Neither the Dutch Medical Research Involving human subjects Act (WMO), Wet Medisch-Wetenschappelijk Onderzoek met

Mensen, nor the University required ethics approval for the type of work conducted in this research. All participants orally and voluntarily agreed to participate in this study. They allowed us to use the data they provided, including quotes, under the condition of confidentiality.

RESULTS

Eleven hospitals (table 3) agreed to participate in this qualitative study. Three hospitals (one regional and two teaching hospitals) were unwilling or unable to participate. Each participating hospital nominated one medical specialist to be interviewed, representing 10 different specialties and between 5 to 27 years of experience in their current hospital. Six of them were (former) chair of medical staff.

Table 3 – Summary participating hospitals and medical specialists

Type hospital	Number	Number of specialists	Participants (nr)	Age	Gender	Number of years of experience in hospital
UMC	2	732 - 1050	internist (1) anaesthetist (2)	43 -57	1 female 1 male	10 - 13
teaching hospital	4	240 - 377	rheumatologist (3) radiologist (4) internist (5) surgeon (6)	49 – 62	2 male 2 female	11 - 23
local hospital	5	70 - 187	paediatric neurologist (7) vascular surgeon (8) gynaecologist (9) cardiologist (10) pharmacist (11)	42 – 59	5 male	5 - 27

In total, participants made160 observations regarding aspects that influence the relation between the extent of EMR use and the quality of care, 122 observations were characterised as ‘barrier’ and 38 as ‘facilitator’. First, we will discuss the ‘technical aspects’ that are mentioned most often. Next, we will discuss the other aspects of EMRs that influence the quality of care. Not every aspect of the taxonomy was used because some aspects were not mentioned during the interviews. The aspect ‘Legal’, related to information safety, was not mentioned in any of the interviews with medical specialists. The aspect ‘organizational’ (type and size of the hospital) could not be addressed in the analysis because it was not part of the design of the study and out of scope of individual

participants. As explained in the methods paragraph, the 'change process' aspect is of particular interest from a systems perspective, and it will be treated last to reflect on possible future developments.

Participating hospitals included two academic hospitals, four teaching hospitals and five local hospitals (see also table 1, 3). However, based on hospital type, no difference was found between participants' observations. The availability of nursing documentation and of the CLMA and advanced CDSS in the hospital concerned did not lead to differences (see also table 1, 3) in the experiences of the medical specialists.

The technical aspects

During the interviews, this was the category all medical specialists chose to talk about first. It therefore seems like medical specialists consider it the most important factor influencing EMR use in the hospital. To provide more insight, the related tables include a subdivision of the technical aspects, followed by quotes from participants to illustrate what is meant with the more abstract terms of the model. A complete list of all quotes is available from the first author.

Customisability

Within the category 'technical', 'customisability' [table 4] is mentioned most often, more often as 'barrier' than as 'facilitator'. The medical specialist compares the EMR systems in the hospital with the intelligent systems that can be used at home to buy a book or book a trip. It seems as though an administrative system has simply been converted into a medical system point-blank.

Table 4 - Customisability - Illustrative quotes from participants

Technical aspects of EMRs	Quote category	Quote
Customisability refers to the ability of the technology system to adapt to specific needs of the user.	barrier	*"Not intuitive. Terrible user interface. Unpleasant system, it clearly hasn't been primarily designed for doctors and paramedics. An originally administrative system that has been reshaped into a medical system"*. (participant 2)
		"*It is digital, but that about says it all. Leaves much to be desired*" (participant 9)
		"*We can see the added value, but these systems are shoddy. Not intuitive*" (participant 8)
		"*Preoperative clinic: Supplementary lab research takes 1-2 days. If you want to change policy based on the results, the EMR system shows that this is impossible because the patient has not been hospitalised but is not present at the outpatient clinic either*" (participant 2)
	facilitator	"*Innumerable positive points; accessible everywhere, even at home. No more illegible notes*" (participant 10)
		"Back in the day, the paper records often got lost. Lab results are available more quickly now and the medical specialist can quickly see the daily reports of the nurses" (participant 7)

Interconnectivity/standardisation'

The exchange of dossiers is often not possible due to lack of standardization, and files are often split up between different specialties, because that is how the medical practice is organized in the hospital [table 5], Getting an integral view of a patient's situation is therefore difficult but especially important with multimorbid patients (an ever-growing group]. General data such as blood pressure, smoking and alcohol use are often contradictory and recorded more than once. Sometimes, multiple systems have to be used simultaneously during treatment because files are not linked; a situation that medical specialists consider potentially dangerous.

Table 5 - Interconnectivity - Illustrative quotes from participants

Technical aspects of EMRs	Quote category	Quote
Interconnectivity/ standardisation EMR hardware and software can be used straight "out of the box", it has to interconnect with other devices that "complement" the EMR system	barrier	*"Many separate systems are high risk because they are not linked, for example when transferring files"* (participant 11)
		"Gynaecologists work with 4 systems (safety risk), because systems are not interlinked" (participant 9)
		"SPD now strongly split into specialties." (participant 4)
	facilitator	*"Good quality photos can be easily obtained."* (participant 7)
		"Back in the day, there was no background information available if the GP's notification read 'diarrhoea', now there is" (participant 5)

Limitation of the system

According to the participants, the IT-systems promise a great deal but offer little more than the old paper situation. Participants particularly point to the promised additional intelligence which is either absent from the systems or present in a very limited sense [table 6]. The system could offer, for example, so-called 'evidence-based' advice based on the individual and combined patient data available in the system [16]. An oft-heard theme is also the lack of analytic tools to analyse the available data and to anticipate developments in the health of patients in the hospital.

Table 6 - Limitation of the IT-system - Illustrative quotes from participants

Technical aspects of EMRs	Quote category	Quote
Limitation of the IT- system the IT systems can reach their limit, become obsolete and will no longer be useful	barrier	*"Actually, no added value, no decision support"* (participant 5)
		"*The hospital world can still learn a lot from, for example, the travel industry. It is madness that you can book a holiday in Thailand within an hour, but that scheduling an operation for a patient with a serious condition causes so many problems*" (participant 2).
		About the use of analytic tools: "*Executing the analysis was very time consuming. Analytics have to be carried out by an IT-specialist. This makes it a hopeless affair. These tools should be included in the EMR*" (participant 9).
	facilitator	"*There is a little bit of decision support for medication (prescriptions)"* (participant 5)
Complexity EMR results in physicians having to allocate time and effort if they are to master complexity	barrier	*"Reporting of transactions very complicated"* (participant 1)
	facilitator	none
Reliability the dependability of the IT-system	barrier	"*In case of failure of systems at polyclinic, nothing is available anymore*" (participant 7)
	facilitator	"*Simple but works well. Very few malfunctions. Much better than paper*" (participant 9)

Other aspects of EMRs influencing the quality of care

In table 7, other aspects of EMRs are summarized. These aspects are mentioned less often by the medical specialists but will also be important influencing factors. These observations are generally consistent with the findings published elsewhere [17,18]. One thing that stands out is that medical specialists are sometimes missing the informal contacts of meetings with colleagues that were previously necessary due to the lack of a common digital file. Equally striking is that the aspect 'financial' is hardly mentioned. The latter contrasts with findings in other publications [16].

Table 7 - Other aspects of EMRs - Illustrative quotes from participants

Other aspects of EMRs	Quote category	Quote
Computer skills of the physician and/or staff technical knowledge and skills to deal with EMR	barrier	*"Doctors are not IT-savvy. Example: radiologist who wants to look at photos at home but uses a home PC that has not been updated and therefore does not work properly"* (participant 8)
	facilitator	none
Training and support training and support associated with the EMR systems	barrier	*"The system may not be used properly by medical specialist* *• Too little knowledge of the system* *• Possibilities not known* *• Defensive Medicine: hedge behaviour"* (participant 4)
	facilitator	none
Psychological personal issues, knowledge, and perceptions	barrier	*"Check lists: system steers behaviour. Against check lists: action is carried out anyway because I have prescribed it. Medication verification is standard procedure, so why check? "* (participant 5)
		"There is a contrast between old and young specialists: I think the older ones accept a limited system more easily, their demands are less high" (participant 7)
	facilitator	*"Enforces a certain treatment and that is positive"* (participant 10)
Social **The relation with the patient and fellow care providers, but also with suppliers, insurers, and politicians.**	barrier	*"Medical specialists clearly have ideas about each other. A lot of contradictions. Hard to get on the same page"* (participant 2)
		"Back in the day, photos sometimes disappeared (dangerous), but medical specialists came to radiology because there was only one photo, this meant people knew each other, radiology was the centre, people walked in, it used to run more smoothly, now there is multidisciplinary consultation, but people don't know each other anymore". (participant 4)
	facilitator	*"Member of medical staff (gynecologist) mans a so-called "wailing wall."* (participant 8)

The aspect 'Change Process'

In table 8, illustrative quotes for the factor 'Change Process' are summarized. According to the medical specialists, several preconditions for success must be met before the successful introduction of EMRs in their hospital. There is some doubt, for example as to whether the supplier of EMRs is willing to create links to other parts of the IT-systems. However, this runs counter to market forces. Moreover, participants mention that governmental institutions often also still require medical specialists to use paper. A central theme for almost all interviewed medical specialists is the coded or non-coded recording of obtained information. They generally realize that encoding the medical record is a prerequisite for getting help from the EMR-system based on so-called evidence-based material. Several hospitals have initially started out with the recording of this information by medical specialists but have later abolished this system because the medical specialist refused to work with it.

Table 8 - The Change Process - Illustrative quotes from participants.

The Change Process	Quote
Support from organisational culture	*"There is too little attention for resistance in medical specialists due to, for example, time pressure."* (participant 8)
	"Before, medical specialists were individual, had their own working methods. By now, a technological revolution has taken place (paper records are now electronic records). But people do not want to change (95%). They have to get out of their comfort zone. You have to invest in that. Now: medical specialists' approach EMR as if it were paper." (participant 10)
	"The problem is that hospitals are not IT-minded. Hospitals are not flexible." (participant 10)
Leadership	*"On its own, the market will not provide properly functioning IT systems for hospitals* (participant 2)
	"Cytostatic control by pharmacies should be done via inspection on paper." (participant 8)
	"Participant sees movement from specialism-based (departments) towards disease -related. For example, department of bowel cancer with internist, MDL, oncologist, and radiologist. This has an impact on the way digitization is organized." (participant 4)
	"(EMR supplier mentioned) is monopolist. Does not listen to customer." (participant 4)
Incentives	*"On its own, the market will not provide properly functioning IT systems for hospitals For example, the market does not benefit from the exchangeability of data. Market forces therefore do not lead to the solution."* (participant 2)
	"No 'reward' for 'good' use." (participant 8)
Participation	*"Conclusion: Letting medical specialists do coding work is undesirable, but it is necessary to enable systems to 'offer help' on a more advanced level. This process should be structured differently by giving supporting staff a role in it"* (participant 8)

DISCUSSION

To answer the research question 'which positive or negative aspects influence the relation between the EMR use and the quality of medical care, according to medical specialists', a qualitative research study was performed.

The overall picture of the relation between the extent of EMR use and the quality of medical care according to the medical specialist shows that participants prefer digital records over the old paper ones. However, at the same time, participants consider the technical systems old-fashioned compared to the systems they can access at home to book a trip or buy a book. The inability of all those involved (professional groups, boards, suppliers, politicians) to improve this situation is described openly by some participants. By and large, participants do see the potential, but a better way to record coded information still needs to be found. The lack of interconnection between the different EMRs, for example per hospital department (such as Internal Medicine and Cardiology) is also seen as an important limitation. Noteworthy is also those financial aspects are not mentioned often. This contrasts with other studies, in which 'technical issues' and 'financial issues' are mentioned in equal measure. [12] The obvious question is then whether "money plays an important role" according to the medical specialist. Finally, these systems should be able to offer support in decision making for diagnosis and treatment. [19].

Participants indicated that it is necessary to fulfil some of the preconditions for success before the EMR can make a positive contribution to the hospital's daily practice. And that is essentially the source of the medical specialist's resistance It takes a lot of effort and time to keep the patient file up to date. The only result is a non-paper file, which they appreciate, but is ultimately not enough to motivate them. It is tempting to make encoding medical data mandatory. But without interventions in the organization this is doomed to fail, because many medical specialists are unwilling or unable to comply. In the end, inefficiently organized processes will then be automated at great cost and effort while remaining inefficient at their core. [20]

So, prior to the question of how to improve the available processes comes the basic question: what can be improved? Are the available business processes principally accepted, or can the search be directed towards a change of the existing processes?[21]

As stated, it is essential to understand what medical specialists perceive to be key aspects that either support or hinder the use of EMRs to positively impact diagnosis and treatment, now and in the future. These findings may help decide how medical processes can be improved with modern IT. Important in this approach is that the possibilities of modern IT, especially for advanced decision support, are taken as a starting point [22].

Limitations of the study

Our study has several limitations. We have only interviewed specialists from hospitals that lacked nursing documentation in 2012-2014. These hospitals found themselves in the lowest stage of EMR use according to the EMRAM model, but also had great potential to improve effectively and were able to learn from other hospitals. However, this qualitative study might still have been too early in the hospital's implementation of EMRs to identify aspects that are relevant for mature use of EMRs.

The age of the interviewed medical specialists varies between 42 and 62 years. These are medical specialists with a great deal of experience in the field. A question is whether the perspectives of younger medical specialists correspond with the perspectives of their older colleagues. Follow-up research might answer this question.

CONCLUSIONS

The eleven medical specialists shared positive experiences of EMR use, when comparing it to the formerly used paper records. The fact that the health professionals involved can access the patient data at any time they need it, is considered important. However, in practice, potential quality improvement lags behind as long as decision support cannot be applied due to the lack of a fully coded patient record.

Availability of data and materials

The datasets generated and/or analysed during the current study are available, after anonymisation, from the corresponding author on reasonable request.

DECLARATIONS

Consent for publication

All interviewees participated on a voluntary basis and were granted confidentiality. All participants have agreed with the final report of their interviews. All participating

hospitals, medical specialists and used quotes in the manuscript were anonymized. No written permission was needed in this case.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

RvP planned and conceptualised the study, developed the interview guide, acquired data, analysed, and interpreted data, and drafted the manuscript. GS assisted in developing the interview guide and was involved in the interpretation of data and in preparing an early version of the manuscript and revised the manuscript. AB assessed the adapted use of the taxonomy as published in [15]. KR supervised the study. All authors read and approved the final manuscript.

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ABBREVIATIONS

EMR use: EMR use generally alludes to the transition of information to a digital form, that is, in a form that can be used by electronic devices such as computers. In this article the term can concern the data itself, or the accompanying procedures, or a fundamental change of method (so-called digital transformation)

HIMSS: The Healthcare Information and Management Systems Society (HIMSS) is an American not-for-profit organization dedicated to improving health care in quality, safety, cost-effectiveness, and access through the best use of information technology and management systems. It was founded in 1961 as the Hospital Management Systems Society. It is now headquartered in Chicago, Illinois. The society has more than 80,000 individuals, 480 provider organizations, 470 non-profit partners and 650 health services organizations (as of December 2019).

EMRAM: The HIMSS Analytics Electronic Medical Record Adoption *Model* (*EMRAM*) incorporates methodology and algorithms to score hospitals relative to their electronic medical records (EMR) capabilities. This eight-stage (0-7) model measures the adoption and utilization of electronic medical record (EMR) functions.

CLMA: Closed Loop Medication Administration (CLMA) is a fully electronic medication management process, in which all relevant information is documented seamlessly. All the steps of the medication cycle are supported electronically – ordering, verifying, preparing, and administering – with decision support where relevant.

LOS: Length of stay (LOS) is the duration of a single episode of hospitalization.

CDSS: A clinical decision support system (CDSS) is an application that analyses data to help healthcare providers make decisions and improve patient care. A CDSS focuses on using knowledge management to get clinical advice based on multiple factors of patient-related data. Clinical decision support systems enable integrated workflows, provide assistance at the time of care, and offer care plan recommendations.

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CHAPTER 7

General discussion

This chapter encompasses the conclusions and implications of the findings in the previous chapters. It discusses the main findings, it summarizes the answer to the central research question, the scientific and policy relevance of the thesis and the strengths and weaknesses of the research. The perspective of the results for the digitization of hospitals in the Netherlands and beyond are also discussed and in addition recommendations for practice. Finally, directions for further research are explored.

INTRODUCTION

This thesis had the objective to contribute to the scientific discourse on 'the relationship between the digitization of hospital information and processes and the effect on the quality of care'. This aim was translated into the central research question:

What is the relationship between the maturity of hospital information systems and the quality of care?

This question can be divided into three sub-questions:

- How mature are the information systems of the Dutch hospitals and what are the influencing factors (determinants) for this degree of maturity?
- What is the association between the degree of maturity of information systems of hospitals and the quality of care?
- Which positive or negative aspects influence the relationship between EMR use and the quality of medical care according to medical specialists?

MAIN FINDINGS

Subquestion 1. How mature are the information systems of the Dutch hospitals and what are the influencing factors (determinants) for this degree of maturity – main findings chapter 2.

Of the 93 hospitals (2012-2014) in the Netherlands, 72 hospitals were measured, of which some hospitals repeatedly (three times) for the several underlying studies. Of the eight University Medical Centers, six participated. For the top clinical hospitals, 27 of the 30 participated. It was noticeable that the smaller general hospitals, in particular, did participate less (19 of 31). We found that for about 40% (28) of the 73 hospitals, clinical documentation, especially nursing documentation was a challenge. Nine hospitals

reached stage 6 and have implemented 'close loop medication' so the 'five rights of medication administration' [1] are guaranteed, in addition to 'intelligent' care pathways.

In most cases, discussions in the investigated 72 hospitals focused on two themes. The first relates to how the hospital in question has arranged 'closed-loop medication'. [2] The second theme is how intelligent care pathways are applied. This last concept means that the system supports the treating clinician by using decision support or artificial intelligence functionality of the EMR combined with evidence-based practices (what (and why) might be the next step in the treatment).

The second objective of this subquestion was to identify organizational, environmental factors, and IT factors associated with maturity. This identifying process was based on the 'Resource dependence theory'.[3] This theory builds on the premise that organizations are not in control of all of the resources they need to survive and therefore attempt to reduce their dependence on external resources in times of uncertainty. Since the maturity of EMR systems may lead to better hospital performance and outcomes and increased efficiency [4], hospitals may use it as a strategy to combat this environmental uncertainty. By considering a wide array of relevant variables [5], determinants investigated during this study were population density, hospital density, financial stability, hospital size, hospital type, and IT capabilities (number of ICT employees and ICT budget). The results of this study [6] do not strongly support the general assertion that maturity is influenced by organizational and environmental factors, nor IT capabilities. However, comparison of the variables on a descriptive scale suggests a consistently positive effect for hospital size, hospital type, and IT capabilities. The multivariate analysis did not find any independent association between the EMRAM-score and the selected factors. These results are somewhat unexpected and give rise to the idea that other (confounding) factors may exist in the Netherlands.

CONCLUSIONS OF THE SUBQUESTION 1

Of the 72 hospitals measured of a total of 93 hospitals in the Netherlands, 27 (37.5%) did not reach stage 3 because of lacking a digital nursing record. Hospitals that took this challenge, the full implementation of 'closed-loop medication and intelligent pathways proved to be a significant next obstacle. No significant relation was found between the selected influencing factors and the degree of maturity.

Subquestion 2. What is the association between this degree of maturity of EMR systems of hospitals and the quality of care?

Comparison of HIMSS Analytics EMRAM data with Elsevier's 'The Best Hospitals' data – main findings chapter 3.

This part of the thesis correlates the measured maturity level of EMR systems with the quality and safety used to score Dutch hospitals as presented in Elsevier's annual 'The Best Hospitals' publication. The scores of the Elsevier publication are based upon 542 of the 1516 indicators from the publicly available basic set and the safety set of the Health Care Inspectorate (IGJ) and the Dutch Health Care Transparency Program 'Zichtbare Zorg' (ZIZO) program (both sets survey year 2013). Almost all hospital-wide indicator sets are included in the selection and a large portion of indicators are for acute care. Only those indicators for acute care are included that are delivered by all hospitals like infectious diseases, cardiovascular diseases and the surgical process. The scoring of the Elsevier model is mainly based (87%) upon so called 'structure' indicators whereas 'Outcome' or 'process' indicators are generally considered as better indicators for quality of care. [7] There was no significant correlation between the EMRAM scores and the Elsevier performance indicators.

The occurrence of adverse events as measured by NIVEL and the level of digitization in Dutch hospitals – main findings chapter 4.

The next step in this thesis was to compare the adverse events and unplanned readmissions in hospitals as measured by the Netherlands Institute for Health Services Research (NIVEL). To keep track of changes in patient safety at a national level, three patient safety measurements with patient records from 2004, 2008 and 2011/2012 have been carried out by the Netherlands Institute for Health Services Research (NIVEL) in a sample of 20 hospitals, out of the total of 93 Dutch hospitals. The sample was stratified for university, tertiary teaching and general hospitals. These studies demonstrated significant overall improvement over the years and showed that differences in patient safety outcomes exist between hospitals. Since digital maturity may lead to better hospital performance and outcomes, hospitals may use it to improve the quality of care. The key assumption to be explored in this study is that when basic digital clinical functionalities are available in a hospital (EMRAM>=3), patients will have a more effective and safe hospitalization compared to hospitals with lesser EMR-maturity. From the 20 hospitals selected by NIVEL, 17 are also measured in the EMRAM study, leaving 17 hospitals for this part of the thesis.

None of the four postulated associations was (strongly) supported by the data. We did not find a significant relation between the EMRAM-score and the number of patients with adverse events (AE), preventable AEs, AE caused by medication, the number of readmissions (RA) and the length of stay (LOS**)**.

The lengths of stay of patients with colorectal cancer as measured by DSCA and the level of digitization in Dutch hospitals– main findings chapter 5.

This study correlates the level of digitization as measured by EMRAM with postoperative length of stay (LOS) as measured by the Dutch surgical colorectal audit (DSCA). DSCA, started in 2009, is a nationwide audit used to monitor, evaluate and improve quality of care of primary colorectal cancer surgery. It provides feedback to all hospitals in the Netherlands on a set of quality measures and indicators. While digital maturity may lead to better hospital performance and outcomes, hospitals may use it to improve the quality of care. Our hypothesis behind this part of the thesis is that when basic digital clinical functionalities (EMRAM>=3) are available in a hospital, the patients will have a more efficient hospitalization. Efficient communication could prevent medical or organizational mistakes and make it possible to transfer patients from an intensive care unit (ICU) to a general ward and transfer patients from the ward to home without undue delay. We used the post-operative length of stay (LOS) in this study because that is where the presumed effect is expected. Based on these studies the following hypotheses were tested:

- Hypothesis 1: In hospitals with more EMR maturity the likelihood of a shorter LOS on average of colorectal cancer surgery patients in the hospital increases.
- Hypothesis 2: In hospitals with more EMR maturity the likelihood of a shorter LOS on average in the ICU (Intensive Care Unit) of colorectal cancer surgery patients increases.
- Hypothesis 3: The likelihood of a shorter LOS on average of colorectal cancer surgery patients increases in academic affiliated hospitals with more mature IT systems.
- Hypothesis 4: The likelihood of a shorter LOS on average in the ICU of colorectal cancer surgery patients increases in academic affiliated hospitals with more mature EMR systems.

In total 72 hospitals, including 30.358 patients were included in this study. A multivariate regression method was used to test differences adjusted for case mix, year of surgery,

surgical technique and for complications, as well as stratifying for academic affiliated hospitals and general hospitals.

This multivariate analysis demonstrated that hypothesis 1, EMR maturity is associated with a shorter LOS on average of colorectal cancer surgery patients, is supported by our findings. All other hypotheses were not confirmed.

CONCLUSIONS OF SUBQUESTION 2 (CHAPTERS 3, 4 AND 5):

The three quantitative sub-studies showed little (LOS) or no association between maturity and quality of care. This led us to the third subquestion to inquire about the reflections of the medical specialists, as a key player, of the participating hospitals on the results found.

Subquestion 3. The relationship between EMR use and the influencing factors according to the medical specialist - Main findings chapter 6.

To answer this research subquestion, a qualitative research study was performed. A qualitative design was considered appropriate for this question, as the primary objective was to explore more in-depth perceptions of factors and processes related to a more complex system, including social and technical components [8].

The medical specialists predominantly identified barriers. When the answers received, were categorized using a previously published taxonomy [9] , the medical specialist considered technical factors the most significant barriers for EMR use to have a positive effect on quality of care, followed by the suboptimal change processes surrounding implementation. On the positive side, they also identified potential technical facilitators, particularly in the assured availability of information to all health professionals involved in patient care.

The overall picture shows that respondents prefer digital over the old paper records. The fact that involved health professionals can access the patient data at any time they need it, is considered important. However, at the same time, respondents consider the technical systems old-fashioned compared to the systems they can access at home to book a trip or buy a book. The inability of all those involved (professional groups, boards, suppliers, politicians) to improve this situation is described openly by some participants. By and large, respondents do see the potential, but a way to record coded information

still needs to be found. The lack of interconnection of systems (in the hospital) is also seen as an important limitation.

CONCLUSION OF THE SUBQUESTION 3.

The eleven medical specialists interviewed shared positive experiences of EMR use in comparison with the former recordings on paper. But it takes a lot of effort and time to keep the patient file up to date. The only result is a non-paper file, which they appreciate, but is ultimately not enough to motivate them. It is tempting to make encoding medical data mandatory.

STRENGTHS, WEAKNESSES, AND LIMITATIONS OF THE STUDY

A strength of this study is the broad scope. Quality of care information from multiple sources (IGJ, ZIZO, Elsevier, NIVEL, DSCA) is used. The maturity of EMR-systems was repeatedly (for some hospitals three times) measured. Hospitals have been visited during about a four-hour visit and not interviewed by phone as usual at HIMSS. The factors (determinants) affecting this maturity are analyzed. And in addition, medical specialists are asked for their experiences about the influence of maturity on the quality of care. And finally, the 72 hospitals that did participate provided a fairly good representation of the total population of the 93 hospitals in the Netherlands.

But there are also weaknesses of this study. The Netherlands is small, so numbers are small, and difficult to find significant confounding factors. Small hospitals and hospitals located in the northern part of the Netherlands were underrepresented in the study. Although a 77% response rate was achieved, the hospitals that did not respond to the survey differed from those that did respond. Given those nonresponding hospitals were more likely to have characteristics associated with lower maturity levels, a residual bias may have led us to overestimate adoption levels. Furthermore, although we adjusted for many factors, unknown confounding factors could still be present such as the lack of active involvement of professionals and management.

The main disadvantage of the qualitative analysis among medical specialists is that their findings cannot be extended to broader populations with the same degree of certainty as quantitative analyses. The main objective of this qualitative study was to detect possible factors why the previous quantitative studies did not show a relation. Assessing the

conclusions of this qualitative study requires quantitative confirmation. In the qualitative study, only medical specialists were interviewed from hospitals with an EMRAM score 2 in 2012. These hospitals found themselves in low maturity according to the EMRAM model but with significant potential to improve effectiveness and in a position to have learned from other hospitals before the interviews. However, this qualitative study might still have been too early in the hospital's implementation of EMR to identify relevant factors for the mature use of EMRs. And finally, the age of the interviewed medical specialists varies between 42 and 62 years. These are medical specialists with a great deal of experience in the field. A question is whether the perception of younger medical specialists corresponds with those of their older colleagues. The younger medical specialist usually does an essential part of the work.

ANSWERING THE CENTRAL RESEARCH QUESTION WITH A MAIN CONCLUSION.

The central question of this thesis is: What is the relation between the maturity of hospital EMR systems and the quality of care. The three quantitative sub-studies showed little or no association between maturity and quality of care. We found that implementing clinical documentation, especially nursing documentation, 'Closed Loop Medication Administration', and intelligent pathways including CDSS, present as a challenge to create an impulse for quality improvement. The interviewed medical specialists prefer digital over the old paper records. The fact that the involved health professionals can access the patient data at any time they need it, is considered important.

DISCUSSION OF THE MAIN CONCLUSION

Two discussion points arise from this main conclusion:

1. The five studies give rise to the hypothesis "Potential quality improvement lags behind as long as decision support cannot be applied by lack of a fully coded patient record". However, we could not test this this hypothesis. For this it is necessary to have comparable hospitals: One group with a fully coded patient record with decision support and one group without it. The first group meets the EMRAM stage 7 score: They should achieve an effect with regard to the quality of the care provided. In the Netherlands only two hospitals acquired the EMRAM stage 7 status in 2020. The follow-up time was too short to do a not-randomized comparable case study.

This hypothesis finds also some support in the experiences in American level 7 hospitals which show a higher quality of care in single case studies. [10] [11] . However, these case studies are not conducted with comparable hospitals without decision support.

2. The five studies give also rise to the hypothesis: “Expanding digitization of a hospital improves only quality of care when professionals are able to change easily clinical pathways within the hospital” [10,11] . Clinical pathways are professional, multidisciplinary agreements for treating and caring a patient group with the same diagnosis. [12] Expanded digitization could offer quality data which give rise to evaluation which inspires to change a clinical pathway. In Figure 3 we show this missing link. If this is only possible in the organization and in the IT system of the hospital with a delay of a couple of years and with high costs-of-change, the relation between expansion of digitization and quality improvement will stay weak, because in that case many medical specialists are unwilling or unable to comply. Implementing new systems requires technological rethinking and organizational and even social rethinking. [13] [14] The significance of technological transition-related problems is clear. [15] In our study we were not able to investigate the relation between the EMRAM score, the quality of care and changes in the clinical pathways.

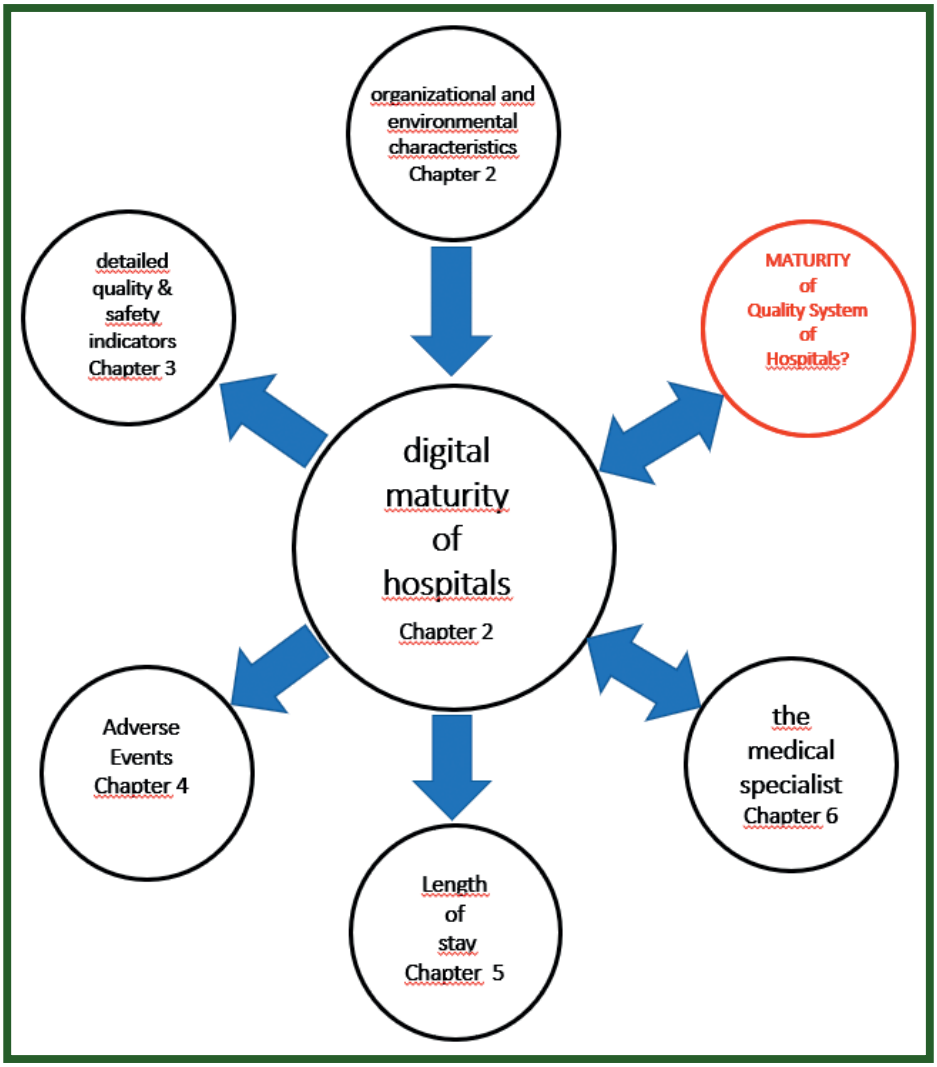

Figure 3 – Suggestions for further research.

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SUMMARY

Implementations of potentially transformative eHealth technologies are currently underway internationally, often with significant impact on national expenditure. Such large-scale efforts and expenditures have been justified on the grounds that picture archiving and communication systems (PACS), electronic prescribing (ePrescribing) and associated computerized provider (or physician) order entry systems (CPOE), and computerized decision support systems (CDSS) are supposed to help to address the problems of variable quality and safety in modern health care. However, the scientific basis of such claims, which are repeatedly made, remains to be firmly established. This paper has the objective to contribute to the scientific discourse on the relationship between the digitalization of hospital care and quality and safety of such care by exploring the experience in the Netherlands. The central question of this thesis is: What is the relation between the maturity of hospital EMR systems and the quality of care. The three sub-studies showed little or no association between maturity and quality of care. We found that implementing clinical documentation, especially nursing documentation, 'Closed Loop Medication Administration', and intelligent pathways including CDSS, present as a challenge. The interviewed medical specialists prefer digital over the old paper records. The fact that involved health professionals can access the patient data at any time they need it, is considered important. However, in practice, potential quality improvement lags behind as long as decision support cannot be applied by lack of a fully coded patient record.

We believe that Dutch hospitals are only at the beginning of a digital transformation. Moreover, a number of preconditions must also be met, such as the active involvement of professionals and management. It is not just a technical transformation but mainly an organizational one.

SAMENVATTING

Implementaties van potentieel transformerende e-gezondheidstechnologieën zijn momenteel internationaal grootschalig aan de gang, vaak met aanzienlijke gevolgen voor de nationale uitgaven. Dergelijke grootschalige inspanningen en uitgaven zijn gerechtvaardigd op grond van het feit dat beeldarchiverings- en communicatiesystemen (PACS), elektronisch voorschrijven (ePrescribing) en bijbehorende geautomatiseerde order entry systems (CPOE) en geautomatiseerde beslissingsondersteunende systemen (CDSS) geacht worden te helpen de problemen van variabele kwaliteit en veiligheid in de moderne gezondheidszorg aan te pakken. De wetenschappelijke basis van dergelijke beweringen, die herhaaldelijk worden gedaan, moet echter nog stevig worden vastgesteld. Dit proefschrift heeft als doel een bijdrage te leveren aan het wetenschappelijke discours over de relatie tussen de digitalisering van ziekenhuiszorg en kwaliteit en veiligheid van dergelijke zorg door de ervaring in Nederland te verkennen. De centrale vraag van dit proefschrift is: Wat is de relatie tussen de volwassenheid van ziekenhuis-EPD-systemen en de kwaliteit van zorg. De drie deelstudies toonden weinig of geen verband tussen volwassenheid en kwaliteit van zorg. We ontdekten dat het implementeren van klinische documentatie, met name verpleegkundige documentatie, 'Closed Loop Medication Administration', en intelligente zorgpaden, waaronder CDSS, een uitdaging vormen. De geïnterviewde medisch specialisten verkiezen digitaal boven de oude papieren dossiers. Het feit dat betrokken gezondheidswerkers op elk moment toegang hebben tot de patiëntgegevens die ze nodig hebben, wordt als belangrijk beschouwd. In de praktijk blijft potentiële kwaliteitsverbetering echter achter zolang beslissingsondersteuning niet kan worden toegepast door het ontbreken van een volledig gecodeerd patiëntendossier. Wij geloven dat Nederlandse ziekenhuizen nog maar aan het begin staan van een digitale transformatie. Bovendien moet ook aan een aantal randvoorwaarden worden voldaan, zoals de actieve betrokkenheid van professionals en management. Het is niet alleen een technische transformatie, maar vooral een organisatorische.

ACKNOWLEDGEMENTS

In 2011 I wrote an article about 'Telehealth': in the CIO Magazine in the series 'CIO in healthcare'. The article was a reflection of an interview with Guus Schrijvers. Even then, he had a strong opinion about the obstacles that stand in the way of good health care. He was clearly already thinking about his book 'Care innovation according to the cappuccino model' (2014). We talked about my research commissioned by HIMSS to investigate the degree of digitization in Dutch hospitals. He surprised me then by saying that he did not know whether this digitization would improve the quality of care. Guus thanks for the start and the guidance afterwards. And hopefully we will 'experience' something together in healthcare in the coming years. After Guus' retirement in 2012, we realized that the extra 5 years to supervise PhD candidates would not be sufficient given the complexity of the matter. We found my former colleague at Organon, Kit Roes, willing to take over part of the guidance and eventually become the main promoter of the research project. The accuracy of this mathematician was the next challenge to take. It had to be 'exact'. Kit, thanks for this experience. The theme 'about you, without you' led us to find the medical specialist Leonard Witkamp willing to participate in the research. He was of the opinion that we should also involve his fellow medical specialists in the research and so it happened. It became the most beautiful part of the research project. Unfortunately, Leonard was unable to complete the joint ride because of the termination of his assignment as professor of 'Telemedicine' at the AMC. Leonard thanks for this valuable contribution and tip. The result was a series of interviews with eleven experienced medical specialists who took the time to reflect on the research question from their perspective, without hesitation. A shocking outcome is my conclusion: The medical specialist suffered a lot from the digitization wave and the 'real' positive effect on the quality of care was still doubtful in their eyes. Thank you, medical specialists, for their insight into your daily practice.

Finally, and last but not least the role of my wife Vera. She repeatedly pointed out to me that there are other things to experience in this life than the digitization of healthcare. For example, two cats came to live with us and we bought a Volkswagen Van to explore the world up close. One of the cats regularly sat on my keyboard when I wanted to start writing an important analysis again. And Vera did not fail to regularly ask 'shall we tour for a week .....'. But I understood that this is very normal, because Guus also regularly hung his trailer tent behind his car to explore the world with his wife Els.

ABOUT THE AUTHOR

After completing his studies at the Technical University of Delft and the Medical Faculty of the Erasmus University of Rotterdam, Rube van Poelgeest began his career as a member of the scientific staff of the professor of cardiology in the University Hospital of Utrecht (UMCU). He has been intensively involved in the introduction of research computers in the hospital, particularly cardiology, but also in other disciplines in the UMCU (neurology, dermatology, biochemistry and cardiac surgery). Intrigued by the possibilities of information technology, he moved to the business applications of ICT in the banking industry, where at that time, the 'big' work took place. He focused on the application of information technology to enhance competition. Internet technology has played an important role. He has been CIO in various financial companies such as Univé, AXA, UWV, Fortis, PGGM, Achmea Pensions, where information technology played an important role in situations where mergers or integration platforms took place for more customer focus. He was also CIO in the pharmaceutical industry (Organon), responsible for global integration (70 countries) of the existing ICT systems. His last assignments relate to the health care sector, where ICT plays an increasingly important role as a vehicle to streamline the care chain. He investigated 80 of the 90+ hospitals in the Netherlands with the EMRAM model of HIMSS Analytics. He was part of a research project in the Netherlands investigating the relation between EMR maturity and quality of care more specifically patient safety. He published a series (30+) about the 'CIO in healthcare' in the CIO magazine of the Netherlands. From 2015 he developed the 'ICT-ladder' for general practitioners together with two general practitioners (SpinDok) and in cooperation with the LHV-MN. The ICT Ladder is a maturity model for the development of information technology in the general practice. The model helps GPs grow into a paperless environment in five steps, with a fully integrated digital file. In 2016 he implemented a regional cooperation organization together with a former general practitioner. He has broad experience in ICT management at companies in situations where the good use of ICT matters. The professionalization of the work within companies is the common thread that runs through all his assignments. In his assignments, he always strives for a robust (strategic) framework within which work is carried out. His strength is to achieve results after a well-prepared path has been taken. The active involvement of stakeholders, specialists in the various relevant fields and the target organization is emphatically his specialty and that way of working is where he gets his motivation.

Some colleagues consider Rube van Poelgeest a ‘reflexive practitioner’, someone who is able to systematically examine, reflect on and report on their own work environment and that of one’s peers.

In that role he is an esteemed columnist and published about 75 articles and columns mainly about the role of ICT management in healthcare.