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Working Paper

Is there a relationship between hospital process digitalization and quality of care? Observational study using data from hospital quality report cards and the DigitalRadar Project

Ruhr Economic Papers, No. 1085

Provided in Cooperation with:

RWI – Leibniz-Institut für Wirtschaftsforschung, Essen

Suggested Citation: Vogel, Justus; Haering, Alexander; Kuklinski, David; Geissler, Alexander (2024) : Is there a relationship between hospital process digitalization and quality of care? Observational study using data from hospital quality report cards and the DigitalRadar Project, Ruhr Economic Papers, No. 1085, ISBN 978-3-96973-260-1, RWI - Leibniz-Institut für Wirtschaftsforschung, Essen, https://doi.org/10.4419/96973260

This Version is available at: https://hdl.handle.net/10419/299234

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RUHR ECONOMIC PAPERS

Justus Vogel Alexander Haering David Kuklinski Alexander Geissler

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> > **[] [WI** #1085

Imprint

Ruhr Economic Papers

Published by

RWI – Leibniz-Institut für Wirtschaftsforschung Hohenzollernstr. 1-3, 45128 Essen, Germany Ruhr-Universität Bochum (RUB), Department of Economics Universitätsstr. 150, 44801 Bochum, Germany Technische Universität Dortmund, Department of Economic and Social Sciences Vogelpothsweg 87, 44227 Dortmund, Germany Universität Duisburg-Essen, Department of Economics Universitätsstr. 12, 45117 Essen, Germany

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Ruhr Economic Papers #1085

Responsible Editor: Ansgar Wübker

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ISSN 1864-4872 (online) - ISBN 978-3-96973-260-1

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Justus Vogel, Alexander Haering, David Kuklinski and Alexander Geissler

Is There a Relationship between Hospital Process Digitalization and Quality of Care? – Observational Study Using Data from Hospital Quality Report Cards and the DigitalRadar Project



Bibliografische Informationen der Deutschen Nationalbibliothek

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available on the Internet at http://dnb.dnb.de

RWI is funded by the Federal Government and the federal state of North Rhine-Westphalia.

http://dx.doi.org/10.4419/96973260 ISSN 1864-4872 (online) ISBN 978-3-96973-260-1 Justus Vogel, Alexander Haering, David Kuklinski and Alexander Geissler*

Is There a Relationship between Hospital Process Digitalization and Quality of Care? – Observational Study Using Data from Hospital Quality Report Cards and the DigitalRadar Project

Abstract

Hospital digitalization is to reduce costs, increase efficiency and productivity, and to improve quality of care. However, the literature lacks clarity on the meaning of "hospital digitalization," how to measure it, and what quality it might affect. We use data from the DigitalRadar project from 2021 describing amongst other dimensions - process digitalization. We combine these statistically sensitive data with two process (pre-operative waiting time for osteosynthesis and hip replacement after femur fracture) and two risk-adjusted outcome quality indicators (inpatient mortality ratio of patients hospitalized with outpatientacquired pneumonia, ratio of new cases with inpatient-acquired decubitus/ ulcers). Our sample size ranges between 664 and 1,566 hospitals, depending on the investigated indication. We use multivariate linear regression with the respective quality indicator as dependent variable and different digitalization subdimensions as independent variables. Overall, we find no significant correlation between outcome or process quality and the majority of sub-dimensions. Only digitalization of documentation and diagnosis shows a consistently positive and weakly significant correlation (p<0.1) with the ratio of new cases with a decubitus/ulcer. We araye that this lack of statistical significance is in part due to the insufficient statistical sensitivity of the available quality indicators. Moreover, available and routinely measured quality indicators seem not to be apt to reflect digitalization effects. We conclude that empiric assessment of a digitalization-quality relationship needs the development of more fitting and sensitive quality indicators. Otherwise, study designs such as small-scale pre-post intervention assessments of the introduction of specific software will remain the gold standard in digitalization-quality research.

JEL-Codes: II1, I18, M15

Keywords: Digitalization; quality of care; digitalization-quality relationship; hospital process digitalization

June 2024

^{*} Justus Vogel, David Kuklinski, Alexander Geissler, all University of St. Gallen; Alexander Haering, RWI. - We thank all our colleagues of the Konsortium DigitalRadar Krankenhaus, the German Federal Ministry of Health (BMG) as well as all hospitals participating in the DigitalRadar evaluation project. The BMG funds the DigitalRadar evaluation project, part of the Hospital Future Act funded by the NextGeneration Program of the European Union. Data from the DigitalRadar was used for this study. The BMG played no role in study design, data collection, analysis and interpretation of data, or the writing of this manuscript. Funding: The study received no funding. Competing interests: AH and AG are part of the DigitalRadar evaluation project funded by the German Federal Ministry of Health. JV and DK declare no financial or non-financial competing interests. Author Contribution Statement: All authors contributed to conceptualization. JV and AH developed the methodology. AH and DK were responsible for data curation and AH performed all analyses. All authors interpreted the results. JV wrote the original draft. All authors reviewed and edited the manuscript. AG supervised. Ethics approval and consent to participate: Not applicable. Consent for publication: Not applicable. – All correspondence to: Alexander Haering, RWI, Hohenzollernstraße 1-3, 45128 Essen, Germany, e-mail: alexander.haering@rwi-essen.de

1 Introduction

Major stakeholders of health systems expect digitalization to increase efficiency of health service delivery, reduce costs, and/ or – and most importantly – enhance quality of care. These expectations culminate in according legislation passed in various countries [1–3]. In Germany, for instance, the Digital Healthcare Act and the Hospital Future Act address both the digitalization of patient pathways and offerings as well as provider structures and processes.

Studies measure "digitalization" in very different ways. One approach is to investigate the effect of specific digitalization measures, e.g., the implementation of a clinical decision support system [4–6]. In another research strand, researchers use categorical variables transformed into ordinal or dummy variables for electronic medical record (EMR) or electronic health record (EHR) adoption [7–9], or they use discrete or continuous digital maturity scores [10–12]. A widely-used discrete digital maturity score is the Electronic Medical Record Adoption Model (EMRAM) expressing digital maturity with stages from 0 (lowest digital maturity) to 7 (highest digital maturity) [13]. An example for a continuous digital maturity score, ranked on a scale from 0 (not digitized) to 100 (fully digitized), and developed for the evaluation of the Hospital Future Act's investment program in Germany [14].

Similarly, studies use different "quality of care" measures when analyzing a digitalization-quality relationship. Austin et al., for instance, conduct an intervention study investigating the effects of an electronic medication management system on outcome quality measured both in clinical terms (e.g., rate of heparin-induced thrombocytopenia) and as adverse events (e.g., hospital-acquired bleeding complications) [9]. Martin et al., on the other hand, conduct an observational study evaluating the impact of digitalization on outcome quality measured by risk-adjusted hospital-level 30-day mortality, 28-day readmission rates, complication rates, harm-free care rates, and risk-adjusted risk of long length of stay [15]. Similarly, Van Poelgesst et al. assess the correlation between EMRAM stages and different composite measures for overall quality, medical care, patient orientation, and effective treatment [16]. Another Dutch observational study examines the relationship between EMRAM stages and the length of stay of colorectal cancer patients [17].

While early reviews pointed towards a positive digitalization-quality relationship [18], more recent large-scale retrospective observational studies do not find a significant relationship (e.g., [15, 19]) and reviews report (partially) inconclusive results (e.g., [20, 21]), or are debated in the literature [22–24]. We hypothesize that this might be due to the different ways of measuring both digitalization and quality of care. Moreover, we argue that the used digital maturity level measure needs to "fit" to the investigated quality indicator. Thus, when investigating a digitalization-quality relationship, we aim to meet four conditions:

- (1) The hypotheses for a positive relationship between the digitalization measure and quality indicator need to be well founded. In other words, it is not at all obvious how general digital maturity measures such as a higher EMRAM stage or a stronger EHR adoption rate should affect outcome quality measures such as mortality or readmission.
- (2) The digitalization measure needs to be statistically sensitive enough to detect differences in digitalization. Binary or ordinally scaled EHR adoption rates and discrete EMRAM stages might not be apt to reflect digitalization differences between hospitals, especially at process level.
- (3) The quality measure needs to be statistically sensitive enough to detect quality differences. In other words, if the quality measure cannot reflect the (potential) quality variation between hospitals, the possibility to show a significant relationship to digitalization might be impaired.
- (4) In accordance with condition (1), the digital maturity measure needs to be specific enough to meet condition (1). Following the structure-process-outcome quality logic of Donabedian [25], it should measure process digitalization increasing process quality, potentially leading to better outcomes. Based on the considerations above, we investigate the following two research questions:
 - I Is a higher level of process digitalization associated with better process quality?
 - II Is a higher level of process digitalization associated with better outcome quality?

Process and risk-adjusted quality indicators are reported routinely as part of the German external inpatient quality assurance program (esQS). We combine these data with the data from the first measurement period of the DR-evaluation project. With these data, we run four different series of multivariate regressions with two process and two risk-adjusted outcome quality indicators as dependent variables, DR-score sub-dimensions as independent variables, and up to 6 hospital characteristics as controls. To meet condition (1), we perform a logical match of DR-score levels (dimensions, sub-dimensions, and questions) with fitting quality indicators from the esQS dataset.

The DR-score is a continuous variable based on a total of 198 questions structured in seven dimensions with up to eight sub-dimensions each [14]. Each sub-dimension is a continuous variable scaled between 0 (no points achieved) to 1 (all possible points achieved) and they can be analyzed separately. Five of the seven dimensions and their sub-dimensions consider process digitalization, namely (1) Organizational control & data management (21 questions); (2) clinical processes (56 questions), (3) information exchange (25 questions), (4) telehealth (12 questions), and (5) patient participation (8 questions). Due to this process digitalization focus and their continuous nature, DR-score sub-dimensions should fulfill conditions (2) and (4).

Medical process quality is usually measured in time intervals, e.g., door-to-ballon time for acute myocardic infarction [26] or decision-to-delivery time for emergency caesarian sections [27]. We hypothesize that one of digitalization's main contributions in a hospital setting is the optimization and (semi-) automation of care processes and supporting processes. Thus, process quality indicators should be receptible to process digitalization. Furthermore, higher process quality should also lead to better outcomes ([25] and, e.g., [26] for acute myocardial infarction). Using esQS process and outcome quality indicators, we might also be able to meet condition (3).

2 Methods

Data

We use data from the DR-evaluation project from 2021 and esQS data from 2020 and 2021 (see Table 1).

-				
Category	Source	Variable(s)	Year(s)	Description/ measurement
Process		Pre-operative waiting time before primary hip replacement surgery after fracture of the femur (dependent variable I)	2020; 2021	Continuous variable between 0 and 100. Indicates a hospital's share of cases that received hip re- placement surgery later than 24 hours after a frac- ture of the femur.
quality	esQ5	Pre-operative waiting time before osteosynthesis surgery after fracture of the femur (dependent variable II)	2020; 2021	Continuous variable between 0 and 100. Indicates a hospital's share of cases that received an osteo- synthesis surgery later than 24 hours after a frac- ture of the femur.
Outcomo		Risk-adjusted inpatient mortality ratio of pa- tients hospitalized for outpatient-acquired pneu- monia (dependent variable III)	2020; 2021	Continuous variable describing a hospital's ob- served to expected ratio of inpatient deaths of pa- tients hospitalized for pneumonia.
quality	esQS	Risk-adjusted ratio of inpatient cases with a new bedsore/ decubitus, excluding decubitus/ ulcers of level/ category 1 (dependent variable IV)	2020; 2021	Continuous variable describing a hospital's ob- served to expected ratio of cases developing a bedsore/ decubitus of level/ category 2 or higher during their hospital stay.
Digital maturity	Digital- Radar	Five to seven DR-score sub-dimensions, depend- ing on quality indicator: Documentation and di- agnosis, decision support, access to information, telehealth emergency department, data manage- ment, order management, order and medication management, flexible working	2021	Continuous variables between 0 and 1 represent- ing the hospital's attained share of total points. For instance, a score of 0.52 for a sub-dimension means that a hospital attained 52% of the total score for this sub-dimension.
Hospital charac-		Hospital size measured in number of beds Ownership Federal state Emergency level Teaching hospital		Four dummy variables categorizing hospitals by their number of beds (less than 250, 250 to 500, 501 to 700, more than 700).
teristics				Three dummy variables indicating ownership (public, private for profit, private not-for-profit).
	Digital-			Sixteen dummy variables indicating a hospital's state.
	Radar			Four dummy variables indicating the level of emergency services and of the emergency depart- ment.
				Dummy variable indicating whether a hospital is a teaching hospital training residents or not.
		University hospital	2021	Dummy variable indicating whether a hospital is a university medical center or not.

Table 1: Overview and description of model variables

Annotations: A detailed description of the DR-dataset can be found in [14]. Methodological explanations regarding the esQS indicators can be found in [28]. The esQS datset can be obtained from the German Joint Federal Commission upon request (see [29]). The esQS indicators are developed and assessed by the German Institute for Quality Assurance and Transparency in Health Care (IQTIG).

We matched the two data sources using a unique hospital identifier and, where necessary, hospital

address data. We averaged quality indicator values to receive more robust quality values. Hospital char-

acteristics are control variables potentially influencing both quality and digitalization.

We investigate the association of selected DR sub-dimensions and each quality indicator in four separate

models. To meet condition (1) outlined in the introduction, we perform a logical matching of single

questions, sub-dimensions, and dimensions of the DR questionnaire [30] with care and care supporting processes forming the basis of the treatment of the sickness targeted by an indicator (see Table 4 in the supplements). When doing this logical matching, we rely on similar considerations regarding the mechanisms behind how digitalization might change quality of care as summarized by Atasoy et al. [21]. The authors name clinical decision support, improved clinial communication, improved information management, and information exchange between providers and across sectors as main levers for improving quality of care. Lastly, regarding conditions (2) and (3), we opted for DR sub-dimensions with sufficient variability and and quality indicators with both variability and large sample sizes (see descriptive results below).

The two selected process quality indicators assess the pre-operative waiting time for patients suffering from a femur fracture. Minimizing pre-operative waiting time for these patients is essential both for optimal pain management as well as outcomes such as mortality, perioperative complications, and revisions [31–33]. Thus, in the esQS program, a goal of less than 24 hours pre-operative waiting time is set for hospitals. Both process indicators are continuous variables from 0 to 100. A value of 10, for instance, would mean that the requirement of a pre-operative surgery time of less than 24 hours was not met in 10% of the cases [34, 35].

The first outcome quality indicator assesses the mortality of patients that were hospitalized for pneumonia, excluding patients hospitalized with a palliative therapy goal [36]. 13 risk factors significantly associated with inpatient mortality are used for risk-adjustment (e.g., age, gender, chronic bed confinement, mean arterial blood pressure at admission, etc.). In the esQS program, there are also five process quality indicators measured for this indication, underscoring the relationship between process and outcome quality for this indication. The second outcome quality indicator assesses the quality of nursing processes measuring the ratio of observed to expected newly developed bedsores [37]. Ten risk factors significantly associated with the development of bedsores are considered for risk-adjustment (e.g., age, number of ventilation hours, adipositas, diabetes, infections, etc.). All data is at hospital site level. The main inclusion criterion was that a hospital site needed to be part of the DR dataset. If the investigated quality indicator was not available for a hospital site for at least one year, the hospital site was excluded from analysis. Moreover, we excluded hospitals for which the calculation of quality indicators was based on less than 20 cases (cf. [28]). Lastly, hospital sites were excluded if the value of their quality indicator was an outlier, i.e., if it was outside of the 95%-confidence interval of the sample median as approximated by Chambers et al. [38]. To check the robustness of our results, we provide an analysis including these outliers as a supplement.

Our initial sample for all four models was 1,624 hospital sites included in the DR dataset (Figure 1). After applying all exclusion criteria, final samples were 665 for hip replacement after femur fracture, 674 for osteosynthesis after femur fracture, 1,126 for hospitalized pneumonia, and 1,566 for development of decubitus/ ulcers.



Figure 1: Inclusion, exclusion and data cleaning steps to derive final samples

Annotations: For some hospitals, only one site was listed in the DR-dataset yet there was more than one site in the esQS dataset. In these cases, the same hospital's DR-score was assigned to all sites (22 hospital sites for hip replacement after femur fracture, 20 for osteosynthesis after femur fracture, 71 for hospitalized pneumonia, and 102 for development of decubitus/ ulcers,).

Empirical Approach and Statistical Model

For each quality indicator, we run a separate set of seven multivariate linear regressions. With each new specification, we add control variables. By starting out with no control variables as the first regression, we test whether process digitalization described by the DR-score sub-dimensions influences the investigated quality indicators. By cumulatively adding federal state fixed-effects (regression 2), hospital bed categories (regression 3), ownership type (regression 4), emergency level (regression 5), teaching

hospital status (regression 6), and a university hospital dummy (regression 7), we assess whether a digitalization-quality relationship potentially found in the first regression holds.

All regressions can be formulated based on Ordinary Least Squares:

$$y_i = \beta_0 + \beta_{e,i} D'_i + \beta_{x,i} X'_i + \varepsilon_i$$

where *y* is the value of the respective quality indicator of hospital site *i*. D'_i is a vector of the DR-score sub-dimensions of hospital site *i*. X'_i is a vector of hospital control variables. The composition of this vector differs between regressions (cf. above). ε_i are heteroskedasticity-robust standard errors.

3 Results

Descriptive Results

Table 2 shows the descriptive results for all four samples.

The descriptives of the quality indicators indicate that the variation of most variables should be sufficient to detect quality differences as standard deviations are roughly 50% or more of sample means. Variations of values for the DR-sub-dimensions we include in our model are quite diverse. One group of sub-dimensions has relatively low sample means below 0.33 with standard deviations of roughly 50% or more of sample means (decision support, order & medication management, telehealth emergency department, and data management). The other group has relatively high sample means of 0.59 and higher with relatively low standard deviations (access to information, order management, flexible working). The sub-dimension documentation/ diagnosis is in between these two groups with sample means between 0.45 and 0.48 and standard deviations between 0.15 and 0.17.

Regarding hospital characteristics, the two samples of hospitals treating femur fracture contain more larger, less private not-for-profit, and more teaching hospitals as well as university medical centers. Besides, all hospitals in these two samples have an emergency department of at least level 1. The two samples for hospitalized pneumonia and development of ulcers/ bedsores are larger and, in the case of the latter indication, contain almost all German hospital sites.

Table 2: Descriptive results

	Hip replace femur fract	ement after aure (n=665)	Osteosynt femur fract	hesis after ure (n=674)	Hospitalize nia (n:	ed pneumo- =1,126)	Development of decu- bitus/ ulcers (n=1,566)	
	Mean (SD)		Mean (SD)		Mean (SD)		Mean (SD)	
	or n (%)	Min, Max	or n (%)	Min, Max	or n (%)	Min, Max	or n (%)	Min, Max
Respective quality indicator								
Pre-operative waiting time ¹	10.60 (5.02)	0.00, 24.51	10.51 (5.15)	0.00, 23.33	-	-	-	-
Pneumonia: Mortality ratio ²	-	-	-	-	0.86 (0.46)	0.00, 2.09	-	-
Decubitus: Ratio of new cases ³	-	-	-	-	-	-	0.84 (0.64)	0.00, 2.72
Digitalradar sub-dimensions								
Clinical processes								
Documentation/Diagnosis	0.48 (0.15)	0.04, 0.90	0.48 (0.15)	0.04, 0.90	0.46 (0.16)	0.00, 0.90	0.45 (0.17)	0.00, 0.90
Decision support	0.23 (0.18)	0.01, 0.84	0.22 (0.18)	0.01, 0.81	-	-	0.20 (0.18)	0.00, 0.84
Access to information	0.70 (0.15)	0.10, 1.00	0.70 (0.15)	0.10, 1.00	0.68 (0.18)	0.00, 1.00	-	-
Order management	-	-	-	-	0.64 (0.19)	0.01, 1.00	0.59 (0.23)	0.01, 1.00
Order & med. mgt.	-	-	-	-	0.21 (0.18)	0.01, 0.69	0.20 (0.17)	0.01, 0.69
Flexible working	-	-	-	-	0.78 (0.24)	0.01, 1.00	-	-
Telehealth								
Emergency Department	0.13 (0.16)	0.00, 0.85	0.13 (0.16)	0.01, 0.85	-	-	-	-
Organizational control & data management								
Data management	0.33 (0.14)	0.01, 0.73	0.33 (0.14)	0.01, 0.73	0.32 (0.14)	0.01, 0.73	0.31 (0.15)	0.01, 0.73
Hospital characteristics								
Bed category								
less than 250	203 (31%)	-	209 (31%)	-	471 (42%)	-	800 (51%)	-
250 to 500	250 (38%)	-	251 (37%)	-	358 (32%)	-	416 (27%)	-
501 to 700	93 (14%)	-	96 (14%)	-	132 (12%)	-	164 (10%)	-
more than 700	119 (18%)	-	118 (18%)	-	165 (15%)	-	186 (12%)	-
Ownership								
public	256 (38%)	-	263 (39%)	-	469 (42%)	-	582 (37%)	-
private for profit	294 (44%)	-	299 (44%)	-	430 (38%)	-	555 (35%)	-
private not-for-profit	115 (17%)	-	112 (17%)	-	227 (20%)	-	429 (27%)	-
Emergency level ⁴								
no emergency level	-	-	-	-	131 (12%)		478 (31%)	
Level 1	321 (48%)	-	328 (49%)	-	527 (47%)	-	582 (37%)	-
Level 2	206 (31%)	-	207 (31%)	-	301 (27%)	-	314 (20%)	-
Level 3	138 (21%)	-	139 (21%)	-	167 (15%)	-	192 (12%)	-
Teaching hospital	522 (78%)	-	519 (77%)	-	779 (69%)	-	930 (59%)	-
University medical center	30 (4.5%)	-	30 (4.5%)	-	43 (3.8%)	-	51 (3.3%)	-

Annotations: (1) Continuous variable between 0 and 100. Indicates a hospital's share of cases that received hip replacement or osetosynthesis surgery later than 24 hours after a fracture of the femur; (2) Continuous variable describing a hospital's observed to expected ratio of inpatient deaths of patients hospitalized for pneumonia; (3) Continuous variable describing a hospital's observed to expected ratio of cases developing a bedsore/ decubitus of level/ category 2 or higher during their hospital stay; (4) Level 1 describes "Basic emergency care", Level 2 "Extended emergency care", and Level 3 "Comprehensive emergency care" [39]

A simple correlation analysis of the quality indicators and the DR-score (see Figure 2) provides four insights relevant for the discussion of our main model results: (1) for all four quality indicators, there are many hospitals with values equal to 0, (2) while variation of quality indicators seems to be high at first sight, the y-axis scales are rather small, (3) also the variation of DR-score values seems to be high

at first, yet the vast majority of hospitals score between 15 and 60 (or even between 20 and 55 for the two process quality indicators), (4) there is no correlation between the DR-score and the quality indicators, except for development of decubitus/ ulcers. Adding to (4), this correlation is positive, however, thus counter-intuitive to our reasoning and hypotheses.



Figure 2: Scatter plots quality indicators and DR-score

Annotations: The lines in the figures display a linear fit between the x and y variables. The shaded area represents the 95% confidence interval. Each data point corresponds to a unique combination of x and y values. The variable "n" indicates the number of observations.

Statistical Model

We present model results in Table 3. Our analysis shows that the influence of the majority of the selected sub-dimensions on the quality indicators is insignificant for all four treatments/ indications.

Regarding the two process quality indicators, a higher score for the sub-dimensions documentation/ diagnosis (clinical processes), emergency department (telehealth), and for osteosynthesis after femur fracture also access to information (clinical processes), is consistently associated with a lower share of cases not treated within 24 hours, yet this relationship is statistically insignificant. The remaining subdimensions' coefficients are consistently positive, yet results for these sub-dimensions are also insignificant. Besides, the magnitude of all sub-dimensions' effect on pre-operative waiting time for both types of surgery is very low: Even if significant, a one point increase of a sub-dimension's score (which is scaled between 0 and 1) would increase or decrease the share of cases treated within 24 hours by less than one to 2.5 percentage points. In line with this, our seven model specifications can only explain small parts of the observations' variation, as indicated by the relatively small adjusted R².

Regarding risk-adjusted inpatient mortality for patients hospitalized for pneumonia, device and location independent flexible working (clinical processes) is consistently associated with a lower mortality ratio (p<0.05 for all specifications except specification (2) with p<0.1). Both the magnitude and statistical significance are comparable across specifications. Contrarily, access to information (clinical processes) is positively associated with a higher mortality ratio in the first two specifications (p<0.01 and p<0.05). This relationship becomes insignificant and weakens in magnitude once controlling for hospital size (specification 3). The other sub-dimensions are consistently associated with a lower mortality ratio yet all effects are statistically insignificant and small in magnitude (exception: data management in specification three, -0.204 and p<0.1).

With respect to the risk-adjusted ratio of new cases developing decubitus/ ulcers, the digital maturity of the sub-dimension documentation/ diagnosis (clinical processes) has a consistently positive, weakly significant association with the ratio of new cases (p<0.05 for first two and p<0.1 for the remaining specifications): A one point increase of the sub-dimension's score is associated with a .241 to .279 points increase in the ratio of new decubitus/ ulcers cases. This means that a higher digital maturity is associated with worse quality in this case, as a higher risk-adjusted ratio indicates additional observed cases with an equal number of expected cases. Similarly, order management (clinical processes) is positively and significantly associated with the ratio of new cases at first (p<0.01 for first two specifications), then weakens in significance and magnitude once controlling for size- (p<0.05) and ownership (p<0.1), and finally becomes insignificant once controlling for hospitals' emergency level. Decision support (clinical processes) is positively and weakly statistically associated with the ratio of new cases for specifications. (2) and (3) (p<0.1) but insignificant for all other specifications. The remaining two sub-dimensions order and medication management (clinical processes) and data management (organization control & data management) both had a very small, insignificant positive or negative influence, depending on the specification.

Robustness check

We present the results of our robustness check including hospital sites with quality indicator values considered as outliers in the supplements (see Table 5). Overall, our results are robust as the robustness check also shows insignificant associations between the vast majority of DR-score sub-dimensions and quality indicators. One minor difference is that for the development of decubitus/ ulcers, decision support is consistently statistically significant (p<0.05 for specifications (1) to (3), p<0.1 afterwards) instead of documentation/ diagnosis. Moreover, flexible working is insignificant for all specifications for hospitalized pneumonia. Lastly, for the robustness check, the specifications of our regressions achieve a worse fit as for our main model as indicated by regressions' lower adjusted-R².

Table 3: Model results

	Dependent variable: Value for respective quality indicator								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)		
Hip replacement aft	er femur fractu	re (N=665)							
Clinical Processes									
Document./ Diagn.	-2.449 (1.683)	-2.261 (1.708)	-2.220 (1.713)	-2.007 (1.696)	-1.890 (1.705)	-1.749 (1.701)	-1.657 (1.699)		
Decision support	1.333 (1.369)	1.660 (1.364)	1.779 (1.367)	1.671 (1.362)	1.656 (1.366)	1.694 (1.365)	1.685 (1.373)		
Access to inform.	0.852 (1.607)	0.202 (1.602)	0.401 (1.630)	0.409 (1.617)	0.314 (1.638)	0.393 (1.630)	0.422 (1.634)		
Telehealth									
Emergency dept.	-0.662 (1.177)	-0.896 (1.271)	-0.957 (1.284)	-1.017 (1.294)	-1.023 (1.297)	-1.072 (1.305)	-0.960 (1.277)		
Organizational Contr	ol & Data Manag	ement							
Data management	0.624 (1.559)	0.365 (1.553)	0.356 (1.535)	0.913 (1.557)	0.906 (1.560)	0.815 (1.554)	0.438 (1.574)		
R ² (adj.)	-0.003	0.060	0.061	0.067	0.064	0.065	0.070		
Osteosynthesis after	r femur fracture	(N=674)							
Clinical Processes									
Document./ Diagn.	-1.563 (1.675)	-2.018 (1.699)	-2.343 (1.685)	-2.278 (1.687)	-2.226 (1.677)	-2.066 (1.664)	-1.980 (1.659)		
Decision support	0.355 (1.337)	0.649 (1.365)	0.812 (1.364)	0.733 (1.388)	0.747 (1.391)	0.805 (1.394)	0.776 (1.380)		
Access to inform.	-0.718 (1.447)	-0.371 (1.504)	-0.960 (1.502)	-0.980 (1.508)	-0.698 (1.528)	-0.672 (1.524)	-0.609 (1.515)		
Telehealth		. ,	. ,	. ,	. ,				
Emergency dept.	-0.977 (1.297)	-1.256 (1.404)	-1.650 (1.442)	-1.690 (1.442)	-1.665 (1.449)	-1.708 (1.451)	-1.571 (1.439)		
Organizational Contr	ol & Data Manag	ement							
Data management	0.985 (1.717)	1.298 (1.735)	0.933 (1.734)	0.936 (1.755)	0.906 (1.749)	0.879 (1.748)	0.464 (1.755)		
R ² (adj.)	-0.004	0.022	0.030	0.028	0.027	0.029	0.034		
Hospitalized pneum	nonia (N = 1,127)							
Clinical Processes									
Document./ Diagn.	-0.121 (0.132)	-0.066 (0.132)	-0.065 (0.131)	-0.054 (0.131)	-0.091 (0.129)	-0.077 (0.128)	-0.078 (0.128)		
Decision support	-0.034 (0.100)	-0.047 (0.100)	-0.029 (0.099)	-0.052 (0.100)	-0.069 (0.096)	-0.071 (0.096)	-0.071 (0.096)		
Access to inform.	0.269*** (0.102)	0.247** (0.103)	0.146 (0.104)	0.142 (0.104)	0.156 (0.101)	0.159 (0.101)	0.159 (0.101)		
Order mgt.	0.023 (0.094)	0.023 (0.093)	0.027 (0.092)	0.026 (0.093)	-0.033 (0.092)	-0.036 (0.091)	-0.036 (0.091)		
Order & med. mgt.	0.091 (0.102)	0.120 (0.102)	0.028 (0.102)	-0.001 (0.103)	0.068 (0.101)	0.071 (0.101)	0.071 (0.101)		
Flexible working	-0.134** (0.065)	-0.112* (0.064)	-0.151** (0.063)	-0.143** (0.064)	-0.147** (0.062)	-0.150** (0.061)	-0.150** (0.061)		
Organizational Contr	ol & Data Manag	ement		· · · · ·		,	~ /		
Data management	-0.143 (0.121)	-0.187 (0.120)	-0.204* (0.117)	-0.180 (0.119)	-0.175 (0.115)	-0.175 (0.115)	-0.174 (0.115)		
R ² (adj.)	0.008	0.053	0.085	0.087	0.130	0.130	0.129		
Development of dec	ubitus/ ulcers (N=1,566)							
Clinical Processes									
Document./ Diagn.	0.279** (0.14)	0.282** (0.138)	0.245* (0.135)	0.254* (0.134)	0.255* (0.133)	0.241* (0.133)	0.252* (0.133)		
Decision support	0.177 (0.120)	0.197* (0.119)	0.201* (0.115)	0.161 (0.116)	0.121 (0.116)	0.126 (0.116)	0.124 (0.116)		
Order mgt.	0.341*** (0.087)	0.295*** (0.087)	0.200** (0.085)	0.160* (0.086)	0.082 (0.087)	0.080 (0.087)	0.081 (0.087)		
Order & med. mgt.	0.062 (0.123)	0.103 (0.122)	-0.046 (0.121)	-0.082 (0.120)	0.005 (0.121)	0.005 (0.121)	-0.003 (0.121)		
Organizational Contr	ol & Data Manag	ement	. ,	. ,	. ,				
Data management	0.026 (0.134)	-0.066 (0.131)	-0.112 (0.127)	-0.041 (0.129)	-0.044 (0.128)	-0.046 (0.128)	-0.057 (0.128)		
R ² (adj.)	0.045	0.082	0.123	0.128	0.139	0.139	0.139		
Federal states	No	Yes	Yes	Yes	Yes	Yes	Yes		
Bed category	No	No	Yes	Yes	Yes	Yes	Yes		
Ownership	No	No	No	Yes	Yes	Yes	Yes		
Emergency level	No	No	No	No	Yes	Yes	Yes		
Teaching hospital	No	No	No	No	No	Yes	Yes		
University hospital	No	No	No	No	No	No	Yes		

Annotations: Document./ Diagn. = Documentation and Diagnosis; Access to inform. = Access to information; Order & med. Mgt. = Order & medication management. Asterisks indicate the significance level: *** p < 0.01, ** p < 0.05, * p < 0.10.

4 Discussion

Overall, we cannot show a consistent digitalization-quality relationship for the overwhelming majority of the four investigated quality indicators and the five to seven DR-score sub-dimensions. Thus, we might have to answer both our research questions negatively: A higher level of process digitalization seems not to be associated with better process or outcome quality for the four treatments and indications we investigated. We discuss this finding along the conditions that we specified in the introduction.

Condition (1) implies that digital processes and their underlying questions and scores in the DR-questionnaire and -dataset should be logically-linked to medical process quality and ultimately also outcome quality (see Table 4 in the supplements). We performed the logical match of DR-questions and esQS quality indicators accordingly, following Atasoy et al.'s hypotheses [21].

We provide one example of our selection and matching logic to make this process more transparent. For instance, we argue that pre-operative waiting time of hip replacement and osteosynthesis surgery patients is logically-linked to the DR-question "In the emergency room, patient admission, triage, medical orders and documentation tasks are carried out digitally. This is done via the [hospital information system] or special systems with interfaces to the [hospital information system]" [30]. We hypothesize that a higher digital maturity of these emergency room processes (admission, triage, etc.) might lead to faster decision-making decreasing pre-operative waiting time of emergency and urgent surgeries, including hip replacement and osteosynthesis surgery after femur fracture. Thus, we included the question's sub-dimension (i.e., documentation/diagnosis) as independent variable in our model.

While the assumptions regarding the digitalization-quality mechanism might be valid, we believe a problem might arise from how process quality is measured in the esQS pogram. While process digitalization might decrease pre-operative time measured in minutes or hours, the esQS quality indicators measure how many times a hospital surpassed the pre-defined threshold of 24 hours – which is much harder to affect with process digitalization.

Regarding condition (3), namely the statistical sensitivity of the used quality indicators, our descriptive results show that there are many observations of "perfect" quality (i.e., values of 0). Moreover,

observations of "bad" quality (values grater than 15 for hip replacement and osteosynthesis surgery after femur fracture; values greater than 1.0 and especially 2.0 for risk-adjusted ratios) are scarce. When including quality indicator outliers (i.e., "very bad" quality hospitals) in our robustness check, our main findings did not change. Therefore, we suspect that while the range of values and standard deviations are considerably high, the quality indicators cannot detect quality differences between hospital sufficiently well - at least not in the context of our research questions. The esQS program is a quality monitoring program that was developed and is conducted to detect the worst hospitals in order to engange them in structured quality dialogues [28]. Moreover, all quality indicators are self-reported. These two facts might also explain partially, why we do not observe bad and very bad quality frequently affecting our ability to find statistically significant associations between process digitalization and quality of care. Lastly, future research might want to focus on other effectiveness measures such as time saved in a process, reduced waiting time, or changes in utilization (e.g., of the emergency department or operating room area) to show the benefits of (process) digitalization in a first step. These are measures often considered by intervention studies, e.g., investigating the effects of a digital tumor board [40]. Once such a relationship has been established, fitting quality measures can be found that are positively related to these effectiveness measures. For instance, higher operating room utilization might lead to more patients receiving surgery on time positively affecting perceived hospital service quality.

Findings from the literature

Martin et al. analyze the association of the NHS Clinical Digital Maturity Index (CDMI) score with five different quality measures [15]. In univariate and multivariate linear regressions, they investigate how the CDMI score as a whole as well as its three dimensions, readiness, capability (most closely related to process digitalization), and infrastructure, influence different types of quality (n = 136 NHS hospitals). The CDMI score was from 2016, quality indicators and control variables were measured between January 2015 and January 2016. For three risk-adjusted indicators (30-day hospital level mortality index, perecentage of episodes of care with complications, and the number of emergency readmissions with 28-days of discharge), they find no significant association. Regarding the last two quality indicators,

risk-adjusted long length of stay was positively associated with the CDMI score while a higher CDMI score was associated with more harm free episodes of care. Thus, the study's findings are rather inconclusive. Our findings are mostly in line with the study's findings. Also the methodology is similar to ours: The authors test associations of single digital maturity dimensions, they use sets of linear regressions, and they are interested in the relationship of digital maturity on different quality measures. Our study differs from Martin et al. insofar that we put greater emphasis on process digitalization and how it might be linked to process and outcome quality and we use even more detailed digital maturity sub-dimensions. Lastly, the study's descriptives show that its hospital sample seems to be digitally more mature than ours. For instance, the study sample's mean CDMI is at 797 out of 1400 while our sample's DR-score means are in between 33.82 and 36.46 out of 100 points.

Van Poelgeest et al. examine the relationship of EMRAM stages and the Elsevier 'best hospitals' score, a composite measure based on 542 different quality indicators, as well as the the overall Elsevier score's three domains medical care, patient orientation, and effective treatment, for 67 Dutch non-academic hospitals. The authors only find insignificant relationships. While these findings are in line with ours, the authors seem to disregard all of the conditions that we defined for showing a digitalization-quality relationship. The EMRAM stages are ordinally scaled from 0 to 7 and a hospital can only advance to the next stage if it complies with all requirements from the former stage [13]. Thus, these stages can only detect major differences in digital maturity milestones and levels rather than processes' digital maturity. In addition, the authors use "bundled" values for the quality scores, i.e., an ordinal scale from 1 to 4. Expressing quality with such variables and scales might be detrimental when aiming to show a digitalization-quality relationship as outlined in our discussion. Lastly, the authors do not provide specific hypotheses for a logical match of their digital maturity measure and quality indicators.

Limitations

The quality indicators from the esQS program are self-reported. This might create both reporting bias and the reported quality indicator values might thus be better than hospitals' actual quality. The COVID-19 pandemic might have influenced hospitals' performance in terms of quality. The organization responsible for the evaluation of the esQS quality indicators, the Institute for Quality Assurance and Transparency in Health Care (IQTIG), continued quality indicator measurement and assessment throughout the pandemic. According to the IQTIG, the main limitation during the COVID-19 pandemic is that quality indicators are not comparable to earlier years and that for elective indications, case volume was significantly lower leading to smaller hospital and patient samples [41]. In fact, the IQTIG reports an even slightly higher case volume for femur fracture, a non-elective indication, in 2021 than in 2019 (58,951 and 58,406).

Regarding patients hospitalized for outpatient-acquired pneumonia, the IQTIG calculated one inpatient mortality ratio trying to exclude COVID-19 positive patients and one ratio independent of COVID-19 infection. We use the ratio independent of COVID-19 infections as the data quality for the ratio excluding COVID-19 patients seemed inadequate due to two reasons. Firstly, the IQTIG states that they cannot guarantee that in fact all COVID-19 patients were excluded and secondly, the variation of indicator values is considerably higher for the ratio excluding COVID-19 patients than for the ratio including all patients hospitalized for pneumonia.

The DR-score is based on a questionnaire, i.e., our digitalization measure is also self-reported. While this might also lead to reporting bias, it should be minimal as the algorithm for calculating the DR-score is not transparent [14]. Moreover, there has only been one measurement so far. Thus, hospitals lacked the information and experience to perform "gaming", i.e., to select answers in a way to maximize their score. Lastly, hospitals had an incentive to answer questions truthfully as partaking in the evaluation includes a detailed benchmarking. Hospitals received an account for a web-based benchmarking tool allowing them to compare their own digital maturity with their peers. If they answered questions incorrectly on purpose, this benchmarking would become worthless for them.

In addition to the aforementioned limitations, another reason for the observed discrepancies may be the absence of exogenous variation in our treatment variable. Consequently, the influence of various factors, that are associated with digital infrastructure, may confound our results. This makes it challenging to identify the underlying causes of our findings, such as omitted variable bias and reverse causality. Hence, we can only investigate associations and no causal effects as such. Once additional DR-data become available in 2024/25, a fixed-effect model should be developed to confirm or rebut our hypotheses and findings.

5 Conclusion

We could not show a positive digitalization-quality relationship for inpatient hospital care. While this is in line with other recent observational studies, this result seems unsatisfactory considering the (supposed) intuitive logic of a digitalization-quality relationship, findings from intervention studies investigating effects of specific digitalization measures, and last but not least the policy-driven overarching goal of digitalization of healthcare.

From our discussion structured along the four conditions regarding a digitalization-quality relationship, we conclude that process quality indicators need to be developed and first and foremost measured in a way apt to reflect digital optimization and to detect quality variation.

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Supplements

Table 4: Logical matching of DR-sub-dimensions and quality indicators

Indica- tion/ treat- ment	Quality in- dicator	DR- dimen- sion	DR- sub-di- men- sion	Examples of relevant DR question(s) and answers
			Documen-ta- tion/ Diagnosis	In the emergency room, patient admission, triage, medical orders and documentation tasks are carried out digitally. This is done via the KIS/KAS or special systems with interfaces to the KIS/KAS (1) No emergency room available, (2) Not implemented to (6) Fully imple- mented, (7) Don't know
Hip replacement surgery after fracture of the femur AND Osteosynthesis surgery after fracture of the femur	Pre-opera-	tesses	E	The data exchange in the emergency room enables the uninterrupted transmission of relevant data (including NFDM, according to the interoperability directory), control of processes of emergency care (ambulance service, emergency room, emergency room) and bed management (1) No emergency room available, (2) Not implemented to (6) Fully implemented, (7) Don't know Please indicate to what extent (percentage) the following information can be accessed digitally and in a structured manner by clinical staff via the HIS in the patient context: Laboratory test results - (1) 0%; (2) 1-25%; (3) 26-49%; (4) 50-75%; (5) 76-94%; (5) 95-100%; (6) Not relevant / no access required Please indicate to what extent (percentage) the following information can be accessed digitally and in a structured manner by clinical staff
	tive waiting time before primary hip replacement surgery af- ter fracture of the femur AND Pre-opera- tive waiting time before osteo-syn- thesis sur-	Clinical pro	Access to information	via the HIS in the patient context: Radiology imaging results - (1) 0%; (2) 1-25%; (3) 26-49%; (4) 50-75%; (5) 76-94%; (5) 95-100%; (6) Not relevant / no access required Please indicate to what extent (percentage) the following information can be accessed digitally and in a structured manner by clinical staff via the HIS in the patient context: Cardiology imaging results - (1) 0%; (2) 1-25%; (3) 26-49%; (4) 50-75%; (5) 76-94%; (5) 95-100%; (6) Not relevant / no access required Please indicate to what extent (percentage) the following information can be accessed digitally and in a structured manner by clinical staff via the HIS in the patient context: DICOM-based images (especially from radiology and cardiology) - (1) 0%; (2) 1-25%; (3) 26-49%; (4) 50-75%; (5) 76-94%; (5) 95-100%; (6) Not relevant / no access required For emergencies/emergency situations, there is a defined documenta-
	gery after fracture of the femur			tion process to ensure the integrity of patient data and to be able to prove and check services or care measures provided (1) No emer- gency room available; (2) Not implemented to (6) Fully implemented; (7) Don't know
		Telehealth	Emergency department	In the hospital emergency room, digital applications are used in real time to exchange structured information or documents with emer- gency services, control centers and any upstream service providers. For example, information can be exchanged before the patient arrives in the emergency care unit to enable a faster admission, triage, and treatment process. - Please choose all options relevant for your hospital: (1) not applica- ble; (2) Not implemented; (3) With emergency services; (4) with part- ner outpatient doctors; (5) with hospitals; (6) with control centers; (7) Don't know Physicians in the hospital have access to medical information (e.g. ini- tial findings, vital signs, ECGs) even before the patient arrives. This way, medical staff can, for instance, prepare themselves for a patient and organize needed resources before the patient arrives. - (1) not applicable; (2) Yes - using the AKTIN protocol; (3) Yes - using alternative technologies/ protocols; (4) No; (5) Don't know

Indica- tion/ treat- ment	Quality in- dicator	DR- dimen- sion	DR- sub-di- men- sion	Examples of relevant DR question(s) and answers		
ment		Organiza- tional control & data man-	Data mgt.	The hospital integrates externally generated data, e.g. from other service providers, professional associations, cancer registers or health insurance companies, via interoperable interfaces. - (1) Not implemented to (5) Fully implemented; (6) Don't know		
			Documen- tation/ di- agnosis	The hospital uses text recognition systems to automatically convert, process and evaluate analog documents into digital information (e.g. medical data). - (1) Not implemented to (5) Fully implemented; (6) Don't know		
umonia		-	Decision support	Is there at least one Clinical Decision Support rule in place that is trig- gered by Physician Documentation? - (1) Not implemented to (5) Fully implemented; (6) Don't know		
d pneu		ses	Acc. to in- form.	See hip replacement and osteosynthesis surgery after fracture of the femur above		
t-acquire	Risk-ad- justed inpa- tient mor-	al proces	Order mgt.	An overview of all services requested within the hospital for patients is provided via the HIS. - (1) Not implemented to (5) Fully implemented; (6) Don't know		
or outpatien	tality ratio of patients hospitalized for outpa-	Clinic	Order & med. mgt.	For employees, it is possible to control clinical work processes digi- tally with the help of workflows and to be automatically informed about treatment steps (status management). - (1) Not implemented to (5) Fully implemented; (6) Don't know		
italized f	tient-ac- quired pneumonia		location ent flexi- rking	Is information in the HIS available for inquiry outside the organiza- tion (i.e. remote access by clinicians)? - (1) Yes, (2) No, (3) Don't know		
ents hosp			Device & independ ble wç	The hospital enables clinical staff to access and process clinical infor- mation from the HIS or PDMS regardless of the device From (1) Not implemented to (5) Fully implemented, (6) Don't know		
Pat		Organizational control & data management	Data manage- ment	The hospital uses data analysis and evaluation tools to forecast medi- cal risks for patients. Detected risks are communicated to clinical em- ployees via automated warnings or notices (as decision support) so that they can intervene at an early stage, reduce risks and optimize care.		
			Documen- tation/ di- agnosis	See other quality indicators		
6		S		The digital care and treatment documentation includes checklists, re- minder aids or signal functions if necessary (mandatory) entries are incorrect or incomplete. - (1) Not implemented to (5) Fully implemented; (6) Don't know		
of decubitus/ ulcers	Risk-ad- justed ratio of inpatient cases with a new bed- sore/ decu-	Clinical process	Decision sur	Nurses have automated clinical decision support capabilities triggered by nursing documentation. Examples include automatic risk detection for falls, decubitus, pain, malnutrition, incontinence, recommenda- tions regarding appropriate nursing measures, medical guidelines, clinical pathways, evidence from nursing research. - (1) Not implemented to (5) Fully implemented; (6) Don't know		
oment o	bitus (excl. decubitus/		Order mgt.	See other quality indicators		
Develop	level/ cate- gory 1)	-	Order & med. mgt.	For employees, it is possible to control clinical work processes digi- tally with the help of workflows and to be automatically informed about treatment steps (status management). - (1) Not implemented to (5) Fully implemented; (6) Don't know		
			Organizational control & data management	Data manage- ment	The hospital uses data analysis and evaluation tools to forecast medi- cal risks for patients. Detected risks are communicated to clinical em- ployees via automated warnings or notices (as decision support) so that they can intervene at an early stage, reduce risks and optimize care. - (1) Not implemented to (5) Fully implemented; (6) Don't know	

Indica- tion/ treat- ment	Quality in- dicator	DR- DR- sub-di- dimen- men- sion sion		Examples of relevant DR question(s) and answers
				Is HIS capable of reporting the timeliness of scheduled orders and tasks for physicians, nurses and other clinical staff? - (1) Yes, is technically possible, but is currently not used (e.g. due to works council agreements); (2) Yes, is technically possible and is used for process optimization; (3) No, not technically possible (4) Don't Know

Annotations: All DR questions can be found in [30].

Table 5: Robustness check

		Dependent variable: Value for respective quality indicator							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)		
Hip replacement aft	ter femur fractu	ure (N=728)							
Clinical Processes									
Document./ Diagn.	-3.558 (2.435)	-2.573 (2.395)	-2.591 (2.379)	-2.431 (2.368)	-2.491 (2.355)	-2.289 (2.359)	-2.087 (2.367)		
Decision support	-1.278 (1.742)	-0.937 (1.809)	-0.808 (1.802)	-0.752 (1.788)	-0.81 (1.805)	-0.775 (1.808)	-0.938 (1.8)		
Access to inform.	3.731 (2.321)	2.788 (2.264)	2.843 (2.338)	2.824 (2.323)	2.644 (2.38)	2.687 (2.366)	2.799 (2.367)		
Telehealth									
Emergency dept.	-0.117 (1.524)	0.096 (1.734)	-0.075 (1.761)	-0.122 (1.75)	-0.131 (1.751)	-0.181 (1.755)	0.015 (1.728)		
Organizational Contr	rol & Data Mana	igement							
Data management	0.691 (2.271)	0.16 (2.21)	0.127 (2.221)	0.598 (2.265)	0.68 (2.276)	0.602 (2.28)	0.067 (2.302)		
R² (adj.)	0.001	0.049	0.048	0.049	0.047	0.048	0.054		
Osteosynthesis afte	r femur fractur	e (N=674)							
Clinical Processes									
Document./ Diagn.	-3.520 (2.343)	-4.273* (2.366)	-4.170* (2.353)	-4.163* (2.355)	-4.219* (2.356)	-4.031* (2.339)	-3.907* (2.34)		
Decision support	-1.367 (1.657)	-0.524 (1.685)	-0.383 (1.684)	-0.391 (1.701)	-0.403 (1.704)	-0.364 (1.709)	-0.433 (1.7)		
Access to inform.	2.323 (2.055)	2.330 (2.061)	2.58 (2.117)	2.616 (2.127)	2.722 (2.152)	2.74 (2.154)	2.797 (2.155)		
Telehealth									
Emergency dept.	0.605 (1.644)	-0.22 (1.751)	-0.326 (1.755)	-0.327 (1.747)	-0.339 (1.748)	-0.399 (1.751)	-0.291 (1.744)		
Organizational Contr	rol & Data Mana	igement							
Data management	0.533 (2.201)	0.564 (2.207)	0.571 (2.229)	0.669 (2.249)	0.694 (2.252)	0.679 (2.255)	0.366 (2.273)		
R² (adj.)	0.000	0.035	0.035	0.033	0.031	0.031	0.032		
Hospitalized pneun	nonia (N = 1,12)	7)							
Clinical Processes	-0.297 (0.246)	-0.245 (0.242)	-0.233 (0.241)	-0.225 (0.238)	-0.243 (0.242)	-0.232 (0.248)	-0.232 (0.251)		
Document./ Diagn.	0.107 (0.176)	0.100 (0.17)	0.132 (0.177)	0.118 (0.178)	0.087 (0.181)	0.086 (0.180)	0.086 (0.184)		
Decision support	0.033 (0.342)	0.004 (0.334)	-0.06 (0.316)	-0.059 (0.314)	-0.119 (0.364)	-0.117 (0.370)	-0.117 (0.37)		
Access to inform.	0.239 (0.212)	0.226 (0.196)	0.235 (0.197)	0.228 (0.19)	0.189 (0.188)	0.188 (0.189)	0.188 (0.189)		
Order mgt.	0.063 (0.144)	0.099 (0.154)	0.016 (0.144)	-0.003 (0.148)	0.064 (0.142)	0.066 (0.141)	0.066 (0.142)		
Order & med. mgt.	-0.175 (0.121)	-0.176 (0.122)	-0.197 (0.127)	-0.192 (0.127)	-0.201 (0.123)	-0.204 (0.125)	-0.204 (0.124)		
Flexible working	-0.297 (0.246)	-0.245 (0.242)	-0.233 (0.241)	-0.225 (0.238)	-0.243 (0.242)	-0.232 (0.248)	-0.232 (0.251)		
Organizational Contr	rol & Data Mana	igement							
Data management	-0.148 (0.213)	-0.194 (0.229)	-0.225 (0.226)	-0.205 (0.237)	-0.201 (0.238)	-0.202 (0.237)	-0.201 (0.239)		
R ² (adj.)	-0.002	0.001	0.001	0.000	0.006	0.005	0.004		
Development of dee	cubitus/ ulcers	(N=1,566)							
Clinical Processes									
Document./ Diagn.	0.243 (0.185)	0.278 (0.195)	0.243 (0.196)	0.245 (0.192)	0.248 (0.192)	0.257 (0.197)	0.283 (0.198)		
Decision support	0.314** (0.152)	0.304** (0.149)	0.313** (0.147)	0.289* (0.152)	0.298* (0.154)	0.295* (0.153)	0.293* (0.154)		
Order mgt.	0.245** (0.122)	0.186 (0.122)	0.09 (0.125)	0.081 (0.137)	0.107 (0.148)	0.109 (0.149)	0.113 (0.149)		
Order & med. mgt.	-0.024 (0.157)	0.0001 (0.155)	-0.168 (0.151)	-0.206 (0.143)	-0.223 (0.149)	-0.223 (0.149)	-0.246* (0.149)		
Organizational Contr	rol & Data Mana	igement							
Data management	0.124 (0.207)	0.08 (0.199)	0.025 (0.194)	0.054 (0.209)	0.052 (0.209)	0.053 (0.209)	0.025 (0.21)		
R ² (adj.)	0.015	0.023	0.042	0.042	0.041	0.040	0.042		
Federal states	No	Yes	Yes	Yes	Yes	Yes	Yes		
Bed category	No	No	Yes	Yes	Yes	Yes	Yes		
Ownership	NO	NO	NO	Yes	Yes	Yes	Yes		
Emergency level	INO	INO	INO	INO	res	res	res		
Teaching nospital	INO N-	INO N-	INO NI-	INO N-	INO N-	res	res		
Annetation and Demonstral	INO			1NO	1NO	100	res		

Annotations: Document./ Diagn. = Documentation and Diagnosis; Access to inform. = Access to information; Order & med. Mgt. = Order & medication management. Asterisks indicate the significance level: *** p < 0.01, ** p < 0.05, * p < 0.10.