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Assessing the relationship between hospital process digitalization and quality of care – learnings from an evaluation of the German hospital landscape

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From insight to impact.

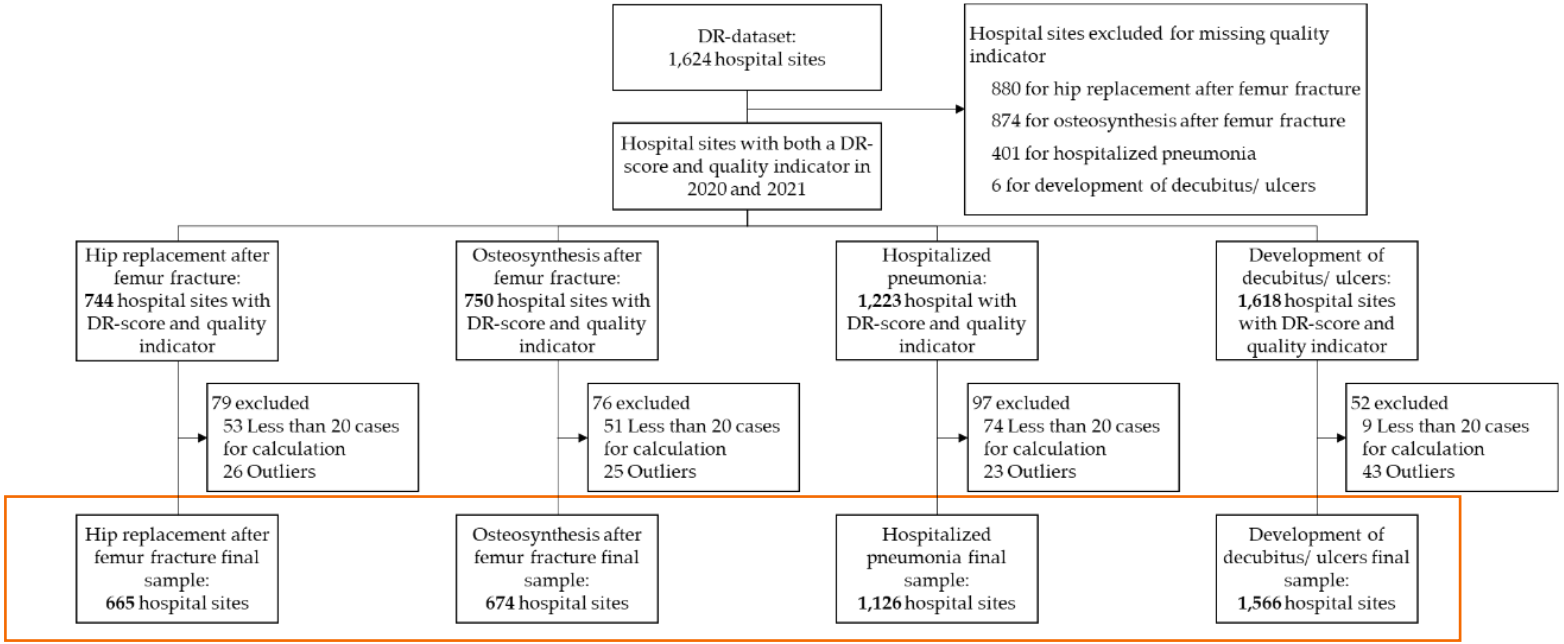
Is a higher level of process digitalization associated with better process quality?

Is a higher level of process digitalization associated with better outcome quality?

Data | We use data from two different sources and match all variables on hospital site level

Category	Source	Variable(s)	Year(s)	Description/ measurement
Process quality	esQS	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 replacement surgery later than 24 hours after a fracture of the femur.
		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 osteosynthesis surgery later than 24 hours after a fracture of the femur.
Outcome quality	esQS	Risk-adjusted inpatient mortality ratio of patients hospitalized for outpatient-acquired pneumonia (dependent variable III)	2020; 2021	Continuous variable describing a hospital's observed to expected ratio of inpatient deaths of patients hospitalized for pneumonia.
		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 observed 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, depending on quality indicator: Documentation and diagnosis, decision support, access to information, telehealth emergency department, data management, order management, order and medication management, flexible working	2021	Continuous variables between 0 and 1 representing the hospital's share of total points attained. 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-teristics	Digital-Radar	Hospital size measured in number of beds	2021	Four dummy variables categorizing hospitals by their number of beds (less than 250, 250 to 500, 501 to 700, more than 700).
		Ownership	2021	Three dummy variables indicating ownership (public, private for profit, private not-for-profit).
		Federal state	2021	Sixteen dummy variables indicating a hospital's state.
		Emergency level	2021	Four dummy variables indicating the level of emergency services and of the emergency department.
		Teaching hospital, university hospital	2021	Dummy variable indicating whether a hospital is a teaching hospital training residents or not, or university medical center or not.

Data | Our sample consist of 665 to 1,566 hospitals, depending on the investigated indication/ treatment



Methods | We follow a three-step explorative approach employing OLS linear regressions to answer our two research questions

1. Main model: Set of seven multivariate linear regressions for each indication/ treatment adding control variables, quality indicators dependent and sub-dimensions explanatory variables

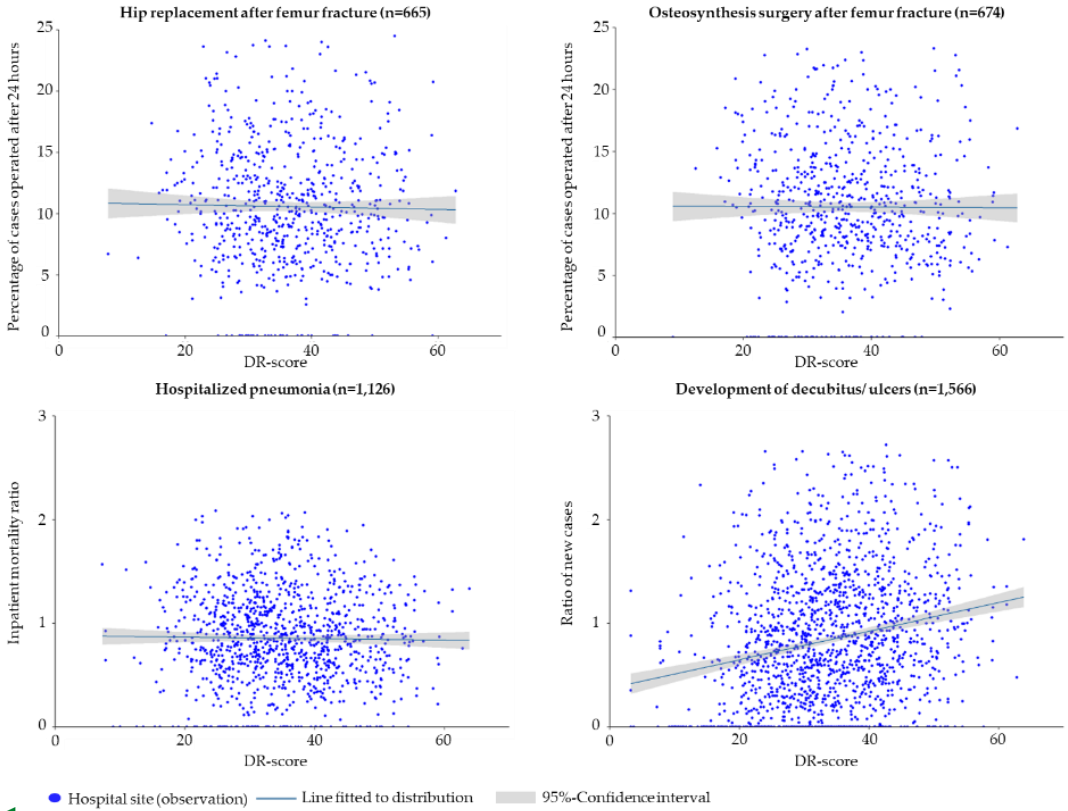
2. Second model: Sum of the DR-score sub-dimensions instead of the score for each relevant sub-dimension alone

3. Third model: Total DR-score instead of sub-dimensions

Descriptive results | Digital maturity between 34 and 36 points out of 100 – process and outcome quality on average "fairly good"

	Hip replacement after femur fracture (n=665)		Osteosynthesis after femur fracture (n=674)		Hospitalized pneumonia (n=1,126)		Development of decubitus/ ulcers (n=1,566)	
	Mean (SD) or n (%)	Min, Max	Mean (SD) or n (%)	Min, Max	Mean (SD) or n (%)	Min, Max	Mean (SD) 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
DR-score and sub-dimensions								
Total score	36.48 (9.33)	12.58, 62.79	36.18 (9.37)	12.58, 62.79	35.08 (9.51)	7.26, 63.87	33.82 (10.16)	3.27, 63.87
Sum of sub-dimensions	1.88 (0.53)	0.55, 3.54	1.86 (0.54)	0.60, 3.62	3.30 (0.87)	0.33, 5.47	1.75 (0.69)	0.03, 3.59
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	0.23 (0.18)	0.01, 0.84	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

More descriptives | High variation of both DR-score and QI values



Kendall's rank correlation analysis

(1) For all four quality indicators, there are many hospitals with values equal to 0

(2) Most quality indicator values are below 10 for the two process quality indicators and below 1.0 for the two outcome quality indicators,

(3) Regarding the DR-score the vast majority of hospitals score between 15 and 60 points (or even between 20 and 55 points 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

Main model process quality | No association observable

	Dependent variable: Value for respective quality indicator						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Hip replacement after femur fracture (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 Control & Data Management							
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 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 Control & Data Management							
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
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

Asterisks indicate the significance level

*** $p < 0.01$

** $p < 0.05$

* $p < 0.10$

Main model outcome quality | Some significant associations but no clear tendency, partially counterintuitive results

	Dependent variable: Value for respective quality indicator						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Hospitalized pneumonia (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 Control & Data Management							
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 decubitus/ 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 Control & Data Management							
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

Asterisks indicate the significance level

*** $p < 0.01$

** $p < 0.05$

* $p < 0.10$

Second and third model | No association with process quality indicators – significant but small association with outcome quality

	Dependent variable: Value for respective quality indicator						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Hip replacement after femur fracture (N=665)							
Sub-dimen.	0.011 (0.367)	-0.069 (0.373)	0.007 (0.378)	0.123 (0.378)	0.125 (0.387)	0.156 (0.387)	0.120 (0.386)
R^2 (adj.)	-0.002	0.061	0.063	0.068	0.066	0.067	0.072
Total DR-score	-0.010 (0.020)	-0.005 (0.020)	-0.002 (0.021)	0.008 (0.021)	0.009 (0.022)	0.011 (0.022)	0.007 (0.022)
R^2 (adj.)	-0.001	0.061	0.063	0.068	0.066	0.067	0.072
Osteosynthesis after femur fracture (N=665)							
Sub-dimen.	-0.376 (0.361)	-0.303 (0.373)	-0.557 (0.388)	-0.576 (0.390)	-0.502 (0.396)	-0.457 (0.396)	-0.492 (0.395)
R^2 (adj.)	0.000	0.024	0.032	0.029	0.029	0.030	0.036
Total DR-score	-0.004 (0.021)	0.008 (0.022)	-0.004 (0.023)	-0.004 (0.023)	0.002 (0.023)	0.005 (0.023)	-0.001 (0.023)
R^2 (adj.)	-0.001	0.023	0.029	0.026	0.026	0.029	0.034
Hospitalized pneumonia (N = 1,127)							
Sub-dimen.	-0.007 (0.016)	0.0003 (0.016)	-0.033* (0.017)	-0.036** (0.017)	-0.042** (0.016)	-0.040** (0.017)	-0.040** (0.017)
R^2 (adj.)	-0.001	0.046	0.081	0.084	0.127	0.127	0.126
Total DR-score	-0.001 (0.001)	-0.0003 (0.001)	-0.004** (0.002)	-0.004** (0.002)	-0.004*** (0.002)	-0.004*** (0.002)	-0.004*** (0.002)
R^2 (adj.)	-0.001	0.047	0.083	0.085	0.128	0.128	0.127
Development of decubitus/ ulcers (N=1,566)							
Sub-dimen.	0.196*** (0.023)	0.183*** (0.023)	0.117*** (0.023)	0.105*** (0.024)	0.093*** (0.024)	0.090*** (0.024)	0.089*** (0.024)
R^2 (adj.)	0.044	0.081	0.122	0.128	0.139	0.139	0.140
Total DR-score	0.014*** (0.002)	0.013*** (0.002)	0.008*** (0.002)	0.008*** (0.002)	0.007*** (0.002)	0.007*** (0.002)	0.007*** (0.002)
R^2 (adj.)	0.048	0.085	0.123	0.130	0.141	0.141	0.141
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 lv.	No	No	No	No	Yes	Yes	Yes
Teaching hosp.	No	No	No	No	No	Yes	Yes
Univers. hosp.	No	No	No	No	No	No	Yes

Asterisks indicate the significance level

*** $p < 0.01$

** $p < 0.05$

* $p < 0.10$

Discussion and conclusion | Were all conditions for detecting a digitalization-quality relationship fulfilled for our study?

1. Quality indicators and process digitalization "matched" correctly?
2. Is the practical digitalization-quality match expressible with existing quality and digitalization measures?
3. Is the digitalization measure sensitive to detect differences in digitalization between hospitals?
4. Is the quality measure sensitive to detect differences in quality between hospitals?

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

Limitations: Self-reported data and COVID-19

Thanks!

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