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Impact of a digital care logistics system on care duration, consumer satisfaction and shift leaders' workload in emergency departments

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Abstract

The primary goal of introducing digital information systems in healthcare organisations is to improve care processes and outcomes, however, studies that investigate the impact of digital information systems on the day-to-day operations management from the perspective of workflow and consumer satisfaction in emergency departments are scarce. Therefore, this study aimed to explore the impact of a digital clinical logistics system on the duration of patient care, consumer satisfaction and shift leaders' experience of workload in emergency departments.

A longitudinal prospective design was used. Three units participated in the study; an intervention unit, a control unit A (no implemented system) and a control unit B (system already in use). We collected data on care duration, consumer satisfaction and shift leaders' experience of workload for four weeks at five time points both before system implementation (summer 2015, spring 2016) and after system implementation (summer 2016, autumn 2016, winter 2016).

The average care duration time increased in the postimplementation period in the intervention and control B units ($p < 0.001$). Duration of care was higher in the intervention unit than control unit B in summer 2016 ($p < 0.001$) and winter 2016 ($p = 0.009$). Similarly, duration of care in control unit A was higher than control unit B in spring 2016 ($p < 0.001$). Consumer satisfaction decreased in the intervention unit, in winter 2016 ($p < 0.001$) and the experience of workload increased in the intervention unit, in summer 2016 and autumn 2016 ($p < 0.05$). However, the patients-to-nurses ratio was doubled in the intervention unit in the last time point postimplementation when compared to the first timepoint, while it remained similar in the control units throughout the study period.

This work demonstrated that a digital care logistics system may support in increasing the number of patients treated with the same nursing resources. However, this seems to connect to other outcome variables such as increased care duration, increased experience of workload and decreased consumer satisfaction in some postimplementation time points.

Keywords: emergency department, digital information system, duration of care, satisfaction, workload

Tiivistelmä

Digitaalisten tietojärjestelmien käyttöönoton ensisijainen tavoite terveydenhuollon organisaatioissa on parantaa hoitoprosesseja ja tuloksia, mutta tutkimuksia, joissa mitataan digitaalisten tietojärjestelmien vaikutusta päivittäisen toiminnan johtamiseen työnkulun näkökulmasta, on vielä vähän. Tämän tutkimuksen tarkoituksena oli selvittää digitaalisen hoidon logistiikkajärjestelmän vaikutusta potilaiden hoidon kestoon, palveluita käyttävien tyytyväisyyteen ja vuorovastaavien raportoimaan työn kuormitukseen päivystyksessä.

Tutkimus tehtiin pitkittäisellä asetelmalla. Kolme yksikköä osallistui tutkimukseen; interventioyksikkö, kontrolliyksikkö A (ei tietojärjestelmän käyttöönottoa) ja kontrolliyksikkö B (tietojärjestelmä jo käytössä). Aineistoa kerättiin potilaiden hoidon kestosta, kuluttajien tyytyväisyydestä palveluihin, sekä vuorovastaavien arvioimasta yksikön työkuormasta neljän viikon intervalleissa yhteensä viisi kertaa - ennen tietojärjestelmän käyttöönottoa (kesä 2015, kevät 2016) ja käyttöönoton jälkeen (kesä 2016, syksy 2016 ja talvi 2016).

Potilaiden keskimääräinen hoidon kesto kasvoi käyttöönoton jälkeisenä aikana interventio- ja kontrolli B -yksiköissä (p <0,001). Hoidon kesto oli interventioyksikössä pidempi kuin kontrolli B -yksikössä kesällä 2016 (p <0,001) ja talvella 2016 (p = 0,009). Vastaavasti hoidon kesto kontrolli A -yksikössä oli pidempi verrattuna kontrolli B -yksikköön keväällä 2016 (p <0,001). Kuluttajien tyytyväisyys laski interventioyksikössä talvella 2016 (p <0,001) ja heidän raportoima kokemus työkuormasta kasvoi kesällä 2016 ja syksyllä 2016 (p <0,05). Potilas per sairaanhoitaja -määrä kaksinkertaistui kuitenkin interventioyksikössä viimeisenä mittausajankohtana verrattuna ensimmäiseen ajankohtaan, kun luku pysyi samanlaisena molemmissa kontrolliyksiköissä koko tutkimuksen ajan.

Tämä työ osoitti, että digitaalinen hoidon logistiikkajärjestelmä voi auttaa lisäämään samoilla hoitoresursseilla hoidettavien potilaiden määrää. Tämä näyttää kuitenkin olevan yhteydessä muihin tulosmuuttujiin, kuten hoidon keston pidentymiseen, koetun työkuorman lisääntymiseen ja palveluita käyttävien tyytyväisyyden heikkenemiseen joissakin käyttöönoton jälkeisissä ajankohdissa.

Avainsanat: päivystysyksikkö, digitaalinen tietojärjestelmä, hoidon kesto, tyytyväisyys, työkuorma

Introduction

Emergency departments (EDs) provide acute care with a broad spectrum of illnesses to individuals without prior appointment. This makes the work in an ED prone to constant and sudden changes. Limited resources need to be coordinated efficiently to meet individual care needs. Unit managers are generally responsible for running an ED, but in bigger units and beyond office hours, the responsibility for the day-to-day operations management is often delegated on a shift by shift basis to designated members of staff, i.e. shift leaders [1]. Leadership models in EDs vary and depending on the unit size, the nursing profession shift leader role may typically be stand-alone or combined with a triage nurse role, while the model for the physician shift leader varies between organisations from one designated physician shift leader in the ED to distributed leadership by consultants per speciality [2-5]. Effective information management in this complex environment is a precondition for smooth organisational processes and professionals responsible should have all necessary information in an easily obtainable format for optimal managerial decision-making. The information needs in the day-to-day operations management concerns items regarding the number and competence of human resources, patients' health problems, planned care, as well as available material resources [6-8].

Electronic health record (EHR) systems are central information sources for patient related information needs in the day-to-day operations management. But clinicians have reported only moderate satisfaction with EHRs, although satisfaction regarding some characteristics seem to be on a slight increase [9]. Further, system usability varies by brand and setting [9-10] Previous research has explored the association of EHRs on workflow and quality of care. Some studies report improvements after EHR implementation [11] while others suggest that EHR implementation may impact clinicians' task allocation and reduce efficiency during and after implementation [12-14] indicating needs for improvements in usability, functionality and workflow optimisation [13]. Research on barriers to and strategies for successful implementation of digital information systems exists [see e.g. 15-19] and it is essential to understand workflow of all users when planning and implementing digital information systems.

Information regarding human and material resources needed in the day-to-day operations management is usually spread out in different sources. There are separate systems for diverse aspects of human resources (e.g. rosters, knowledge management and special skills of individual staff members) and information on materials (e.g. nutrition, medication and medical equipment systems). Much research has focused on technologies to support the allocation of workforce [20,21] and workload of patients [22], but yet there are discrepancies with the appropriate allocation of resources in the ED [23,24]. Scarce research exists on real-time based digital information systems that combine information about patients and their processes as well as human and material resources to improve professionals' information management in the day-to-day operations management although routine health information systems allow evidence-based managerial decisions that support healthcare core functions in planning, monitoring, evaluation and quality improvement [25]. Previous studies have explored the decision-making process, information needs and challenges concerning information management of shift leaders in the acute care setting [7,26]. Inadequate human resources have been associated with increased patient mortality [27], decreased patient safety

[28,29], and reduced quality of care [30]. Paying attention to shift leaders' information management is vital to ensure safe and efficient care provision; however, previous research has shown that modern digital information systems fail to support shift leaders' information processing sufficiently [31,32].

The aim of the study was to explore the impact of a digital clinical logistics system on the duration of patient care, consumer satisfaction and shift leaders' experience of workload in the ED. The following research questions guided the research:

1. What is the association before and after the implementation of the clinical logistics system on duration of care between and within the units?

2. What is the association before and after the implementation clinical logistics system on consumer satisfaction between and within the units?

3. What is the association before and after the implementation clinical logistics system on experience of workload between and within the units?

Materials and methods

Design

A longitudinal prospective design was used. ED work processes are complex and they cannot be measured with a single data point or by one statistical method but need to be explored from a combination of data gathered with multiple methods, and therefore, a sociotechnical systems framework and a mixed-methods approach have been suggested for implementing larger information technology projects [33]. Also, a longer-term follow-up on the effects of system implementation is recommended as a systematic review indicated that EHR system implementation first increased documentation time, but as staff become more familiar with the system it ultimately improved work flow [13]. Hence, data were collected with different methods during five time points - two before the system implementation and three after:

- 1. pre-implementation (summer 2015): 1st to June 30, 2015
- 2. pre-implementation (spring 2016): February 15 to March 15, 2016
- 1. post-implementation (summer 2016): 1st to June 30, 2016
- 2. post-implementation (autumn 2016): 15 August to 15, September 2016
- 3. post-implementation (winter 2016): November 15 to December 15, 2016

The reason for a longer interval between data collected in time points one and two was that the system implementation was delayed from autumn 2015 to spring 2016. Each data collection time point lasted four weeks. Data were collected on the duration of care, consumer satisfaction and shift leaders' experience of workload in the unit. An ethical statement was obtained from the Ethics Committee of the University of Turku (Ref. 39/2015-45/2015) and administrative approvals were obtained from each hospital district prior to data collection.

Intervention

The intervention was the Columna Clinical Logistics® system [34]. This digital information system has been designed to support care delivery and workflow within the ED by displaying information about staff (e.g. number and profession of staff on duty), patients and their care processes (e.g. the patients' main health problem, planned and completed interventions) as well as available resources (e.g. beds). Although the system contains information about patients and their care, it does not function as an EHR, but rather as a workflow and communication tool for professionals about e.g. distribution of work and patients in the unit, the stage of the care process of individual patients and tasks to be completed. This system has adjusted view options for different purposes and it works on large displays in professionals' workstations and service user waiting halls, personal computers around the organisation and mobile devices. It can integrate with different systems such as hospital information systems and clinicians' phones.

Setting and sample

Three EDs (control unit A, intervention unit and control unit B) from three hospital districts participated. Control unit A is in the southern part, the intervention unit is in the northern part, and control unit B is in the middle of Finland. The units were selected purposely for two reasons. First, the units were similar in function concerning the number and speciality of the professionals. Second, the units admit about the same number of patients (40000-60000) annually with similar health problems both to the general and specialised care pathways. The new digital information system was implemented during the study period in the intervention unit. The intervention unit was compared to the control units; control unit A which runs without a digital logistics information system, and control unit B in which the system was implemented in 2013.

Duration of care

Duration of patient care provided (in hours) for each patient was extracted from the hospital information systems. The number of patients who received care during each data collection time and the number of nurses actively participated in patients' care, were also obtained from each unit.

Consumer satisfaction

A questionnaire was developed based on literature, where items associated with consumer satisfaction and information management were collected [35-37]. Face validity was assessed by a total of ten researchers including two professors with hospital leadership positions - one in nursing science and the other in acute medicine, 2 postdoctoral researchers, and 6 doctoral candidates in nursing science with leadership positions or clinical work experience in acute care. All patients and escorts from the three EDs who had been admitted during the data collection time points and volunteered to respond were targeted. Questionnaires were placed in the "waiting hall" of each ED. The questionnaire for satisfaction had five items, including my satisfaction with 1) the visit to the ED, 2) the length of the waiting time, 3) the informing about the waiting time, 4) how I was encountered, and 5) the arrangements for my care in general. Each item was rated on a scale of 1 to 5 (1= poor, 2 = satisfactory, 3 = good, 4 = very good, and 5 = excellent). The mean value was calculated by summing up the items and dividing the number with the total number of items. The minimum average score was 5 and the maximum average score was 25. The internal consistency in this sample was excellent, as the Cronbach's α for the scale was 0.95 [38].

Workload in the unit

Nursing shift leaders manually documented their estimation of the workload in the units every shift. Workload was documented on a rating scale from 0 to 5 (0 = no hurry in unit, 5 = extremely busy in unit). This rating scale has been used in EDs in other studies [39] where the ED workload has been considered as none; very light, where available resources exceed the demand (1); light, where the resources somewhat exceed the demand (2); moderate, where demand and resources approximately match (3); heavy, where the demand somewhat exceeds the available resources (4); and overwhelming, where the demand greatly exceeds the available resources (5).

Confounding factors

The total number of patients cared for and the total number of nurses during each data collection period were extracted from the hospital information systems. Patients to nurse ratios are presented. The three participating units did not undergo significant organisational changes during the study, which may have interfered with the collected data or its interpretation. One researcher from the team shadowed nursing and medical shift leaders for 3-5 days during data collection time points in all units and documented workflow to ensure consistency.

Data analysis

In the descriptive statistics, indices of central tendency and dispersion, such as mean, frequency and standard deviation were presented as appropriate. Factorial ANOVA [40,41] was used to explore if an interaction existed between means of two or more independent variables across a single dependent variable. One-way ANOVA was computed to test the difference of more than two means of one dependent variable, while the Students T-test was used to examine the difference of two means of a single dependent variable. Pairwise analysis of variance using Tukey-Kramer adjustment was done if differences between means were found when performing factorial and one-way ANOVA. Statistical analysis was performed using SAS® version 9.4 and p-values < 0.05 were considered as significant.

Results

Duration of care

An interaction was found between the units and time points when exploring differences in duration of patient care, $F = 3.91$, $P < 0.001$. Pairwise analysis showed a difference in the duration of care between the units (Figure 1). The intervention unit had a higher duration of care than control unit B both in summer 2016 (95% CI = 0.20 to 1.47: $p < 0.001$) and winter 2016 (95% CI = 0.08 to 1.26; $p = 0.009$) (Figure1-A and Table 2). Control unit A had significantly higher duration of patient care compared to control unit B in autumn 2016 (95% CI = 0.20 to 1.47; $p = < 0.00$) (Figure1-A and Table 2).

Table 1. Mean and standard deviation of duration of care, consumer satisfaction and unit workload.

Time	Control unit A				Intervention unit				Control unit B			
Duration of care (hours)	**N**	**P: N**	**Mean**	**SD**	**N**	**P: N**	**Mean**	**SD**	**N**	**P: N**	**Mean**	**SD**
Summer 2015	4331	55.5	3.77	3.09	1491	46.6	3.65	3.32	3552	57.2	3.35	2.75
Spring 2016	4223	54.1	4.44	3.19	2821	88.2	3.76	3.74	3872	62.5	3.55	5.35
Summer 2016	4576	58.7	4.81	3.13	2796	87.4	5.32	6.09	3739	60.3	4.49	8.35
Autumn 2016	4659	59.7	5.02	3.72	3011	94.1	5.04	7.92	4485	72.3	4.56	9.73
Winter 2016	4613	59.1	5.28	3.79	3158	98.7	5.39	9.43	4533	73.1	4.73	14.59
Consumer satisfaction	**N**		**Mean**	**SD**	**N**		**Mean**	**SD**	**N**		**Mean**	**SD**
Summer 2015	10		10.60	5.72	47		12.53	6.09	41		9.61	5.29
Spring 2016	7		8.86	3.76	15		9.73	3.69	62		11.53	6.37
Summer 2016	9		9.33	6.71	21		10.29	4.90	53		13.09	7.48
Autumn 2016	13		12.15	5.21	21		13.81	6.51	30		10.50	5.06
Winter 2016	9		10.56	3.71	35		5.74	1.59	52		10.6	4.55
Unit workload	**N**		**Mean**	**SD**	**N**		**Mean**	**SD**	**N**		**Mean**	**SD**
Summer 2015	84		2.85	0.92	34		2.71	1.24	79		2.55	1.23
Spring 2016	69		2.64	0.83	8		3.19	1.49	74		2.51	0.97
Summer 2016	49		3.09	0.64	25		3.44	1.01	74		2.34	0.99
Autumn 2016	94		2.74	0.91	15		3.73	0.88	76		2.83	0.97
Winter 2016	67		3.13	0.86	19		2.95	1.27	56		3.13	0.82

P: N = patients to nurses' ratio, SD = standard deviation, N in duration = number of patients, N in satisfaction = number of consumers (Patients and escorts), N in workload = number of shift leaders

Table 2. Pairwise analysis of variance between and within units for care duration (in hours).

Effect						
Between units	**Units**	**Units**	**MD**	**SE**	**95%CI**	**p-value**
Summer 2015	Control Unit A	Intervention unit	0.12	0.24	-0.67-0.92	1.000
	Control Unit A	Control unit B	0.42	0.18	-0.21-1.04	0.611
	Intervention unit	Control unit B	0.29	0.23	-0.49-1.08	0.995
Spring 2016	Control Unit A	Intervention unit	0.68	0.21	-0.02-1.39	0.070
	Control Unit A	Control unit B	0.89	0.19	0.23-1.55	**<0.001**
	Intervention unit	Control unit B	0.21	0.18	-0.42-0.84	0.998
Summer 2016	Control Unit A	Intervention unit	-0.51	0.21	-1.22-0.19	0.469
	Control Unit A	Control unit B	0.32	0.19	-0.34-0.99	0.950
	Intervention unit	Control unit B	0.83	0.19	0.20-1.47	**<0.001**
Autumn 2016	Control Unit A	Intervention unit	-0.02	0.21	-0.72-0.68	1.000
	Control Unit A	Control unit B	0.46	0.19	-0.19-1.11	0.517
	Intervention unit	Control unit B	0.48	0.18	-0.12-1.08	0.283
Winter 2016	Control Unit A	Intervention unit	-0.12	0.20	-0.81-0.57	1.000
	Control Unit A	Control unit B	0.55	0.19	-0.09-1.20	0.194
	Intervention unit	Control unit B	0.67	0.17	0.08-1.26	**0.009**
Within units	**Units**	**Units**	**MD**	**SE**	**95%CI**	**p-value**
Control Unit A	Summer 2015	Spring 2016	-0.67	0.20	-1.36-0.019	0.0665
	Summer 2015	Summer 2016	-1.04	0.20	-1.73 - -0.35	**<0.001**
	Summer 2015	Autumn 2016	-1.25	0.21	-1.95 - -0.55	**<0.001**
	Summer 2015	Winter 2016	-1.51	0.20	-2.20 - -0.82	**<0.001**
	Spring 2016	Summer 2016	-0.37	0.22	-1.11-0.37	0.932
	Spring 2016	Autumn 2016	-0.58	0.22	-1.32-0.164	0.342
	Spring 2016	Winter 2016	-0.84	0.22	-1.58 - -0.10	**0.010**
	Summer 2016	Autumn 2016	-0.21	0.22	-0.95-0.53	0.999
	Summer 2016	Winter 2916	-0.47	0.22	-1.21-0.27	0.698
	Autumn 2016	Winter 2016	-0.26	0.22	-1.01-0.48	0.998
Intervention Unit	Summer 2015	Spring 2016	-0.11	0.24	-0.92-0.70	1.000
	Summer 2015	Summer 2016	-1.68	0.24	-2.49 - -0.86	**<0.001**
	Summer 2015	Autumn 2016	-1.39	0.24	-2.19 - -0.59	**<0.001**
	Summer 2015	Winter 2016	-1.75	0.23	-2.55 - -0.96	**<0.001**
	Spring 2016	Summer 2016	-1.57	0.20	-2.24 - -0.89	**<0.001**
	Spring 2016	Autumn 2016	-1.28	0.20	-1.94 - -0.62	**<0.001**
	Spring 2016	Winter 2016	-1.64	0.19	-2.30 - -0.98	**<0.001**
	Summer 2016	Autumn 2016	0.28	0.19	-0.38-0.95	0.983
	Summer 2016	Winter 2016	-0.07	0.19	-0.73-0.58	1.000
	Autumn 2016	Winter 2016	-0.36	0.19	-1.00-0.29	0.860
Control unit B	Summer 2015	Spring 2016	-0.19	0.17	-0.78-0.39	0.9987
	Summer 2015	Summer 2016	-1.14	0.17	-1.73- -0.54	**<0.001**
	Summer 2015	Autumn 2016	-1.21	0.17	-1.77 - -0.68	**<0.001**
	Summer 2015	Winter 2016	-1.37	0.17	-1.94 - -0.81	**<0.001**
	Spring 2016	Summer 2016	-0.94	0.17	-1.52 - -0.36	**<0.001**
	Spring 2016	Autumn 2016	-1.01	0.16	-1.57 - -0.46	**<0.001**
	Spring 2016	Winter 2016	-1.18	0.16	-1.73 - -0.63	**<0.001**
	Summer 2016	Autumn 2016	-0.07	0.17	-0.63-0.49	1.000
	Summer 2016	Winter 2016	-0.24	0.16	-0.80-0.32	0.983
	Autumn 2016	Winter 2016	-0.17	0.16	-0.70-0.36	0.999

MD = Mean Difference, SE = Standard Error, CI = Confidence Interval

Consumer satisfaction

Responses from 425 consumer satisfaction questionnaires were analysed. We found an interaction within the three units in the different time points (F = 4.21, p < 0.001). The pairwise analysis revealed that satisfaction was lower in the intervention unit when compared to control unit B in winter 2016 (95% CI = -9.058 to -0.726; p = 0.006) (Figure 2-A and Table 3). There were no differences in satisfaction between the three units in the other time points. When we looked at the difference within the units, satisfaction in the intervention unit was lower in winter 2016 compared to summer 2015 (95% CI = 2.53 to11.04; p <0.0001) and autumn 2016 (95% CI = 2.81 to 13.33; p <0.0001) (Figure 1.2-B and Table 3). No difference was found within the other units in the different time points.

Table 3. Pairwise analysis of variance between and within units for consumer satisfaction.

Time						
Between units	**Unit**	**Unit**	**MD**	**SE**	**95% CI**	**p-value**
Summer 2015	Control Unit A	Intervention unit	-1.93	1.94	-8.57-4.70	0.999
	Control Unit A	Control unit B	0.99	1.97	-5.73-7.71	1.000
	Intervention unit	Control unit B	2.92	1.19	-1.150-7.00	0.4801
Spring 2016	Control Unit A	Intervention unit	-0.88	2.56	-9.61-7.85	1.00
	Control Unit A	Control unit B	-2.68	2.23	-10.27-4.92	0.997
	Intervention unit	Control unit B	-1.79	1.61	-7.28-3.68	0.999
Summer 2016	Control Unit A	Intervention unit	-0.95	2.22	-8.54-6.64	1.000
	Control Unit A	Control unit B	-3.76	2.01	-10.63-3.11	0.868
	Intervention unit	Control unit B	-2.81	1.44	-7.72-2.11	0.826
Autumn 2016	Control Unit A	Intervention unit	-1.66	1.97	-8.38-5.07	1.000
	Control Unit A	Control unit B	1.65	1.85	-4.67-7.98	0.999
	Intervention unit	Control unit B	3.31	1.59	-2.11-8.73	0.7456
Winter 2016	Control Unit A	Intervention unit	4.81	2.09	-2.31 -11.93	0.5867
	Control Unit A	Control unit B	-0.08	2.02	-6.96-6.80	1.000
	Intervention unit	Control unit B	-4.89	1.22	-9.06 - -0.73	**0.006**
Within units	**Unit**	**Unit**	**MD**	**SE**	**95% CI**	**p-value**
Control unit A	Summer 2015	Spring 2016	1.74	2.75	-7.65-11.13	1.000
	Summer 2015	Summer 2016	1.27	2.57	-7.49-10.02	1.000
	Summer 2015	Autumn 2016	-1.55	2.35	-9.57-6.46	1.000
	Summer 2015	Winter 2016	0.04	2.57	-8.71-8.80	1.000
	Spring 2016	Summer 2016	-0.48	2.81	-10.08-9.13	1.000
	Spring 2016	Autumn 2016	-3.30	2.62	-12.23-5.63	0.995
	Spring 2016	Winter 2016	-1.70	2.81	-11.30-7.90	1.000
	Summer 2016	Autumn 2016	-2.82	2.42	-11.08-5.44	0.9979
	Summer 2016	Winter 2016	-1.22	2.63	-10.21-7.76	1.00
	Autumn 2016	Winter 2016	1.60	2.42	-6.66-9.86	1.00
Intervention unit	Summer 2015	Spring 2016	2.80	1.66	-2.85-8.45	0.93
	Summer 2015	Summer 2016	2.25	1.47	-2.76-7.25	0.97
	Summer 2015	Autumn 2016	-1.28	1.47	-6.28-3.72	0.99
	Summer 2015	Winter 2016	6.79	1.25	2.54-11.04	**<0.001**
	Spring 2016	Summer 2016	-0.55	1.89	-6.99-5.89	1.00
	Spring 2016	Autumn 2016	-4.08	1.89	-10.52-2.37	0.69
	Spring 2016	Winter 2016	3.99	1.72	-1.89-9.87	0.57
	Summer 2016	Autumn 2016	-3.52	1.72	-9.40-2.36	0.77
	Summer 2016	Winter 2016	4.54	1.54	-0.72-9.80	0.17
	Autumn 2016	Winter 2016	8.07	1.54	2.81-13.33	**<0.001**
Control unit B	Summer 2015	Spring 2016	-1.92	1.12	-5.76-1.91	0.92
	Summer 2015	Summer 2016	-3.48	1.16	-7.48-2.47	0.15
	Summer 2015	Autumn 2016	-0.89	1.34	-5.47-3.69	1.00
	Summer 2015	Winter 2016	-1.02	1.17	-5.01-2.96	0.99
	Spring 2016	Summer 2016	-1.56	1.04	-5.13-2.00	0.97
	Spring 2016	Autumn 2016	1.03	1.24	-3.21-5.27	1.00
	Spring 2016	Winter 2016	0.90	1.05	-2.68-4.48	0.99
	Summer 2016	Autumn 2016	2.59	1.28	-1.76-6.95	0.77
	Summer 2016	Winter 2016	2.46	1.09	-1.26-6.18	0.62
	Autumn 2016	Winter 2016	-0.13	1.28	-4.50-4.23	1.00

MD = Mean Difference, SE = Standard Error, CI = Confidence Interval

Workload in the unit

There was no significant interaction between time-points, units and shifts, F = 1.574, P = 0.07. Similarly, there was no interaction between time-points and shifts, F= 1.010, P = 0.427, or between units and shifts, F= 1.00, P = 0.407. However, an interaction was found between time-points and units, F = 4.1, P < 0.001. A pairwise analysis demonstrated that workload was higher in the intervention unit compared to the control unit B in summer 2016 (95% CI = 0.337 to1.867; p < 0.001) and control unit A in Autumn 2016 (95% CI = 0.069 to 1.908; p < 0.021) (Figure 3-A and table 4). Similarly, workload in control unit A was higher than control unit B in Summer 2016 (95% CI = 0.145 to 1.362; p = 0.003) (Figure1.3-A and table 4).

Differences within each unit in different time-points were also seen. In the intervention unit, workload was higher in autumn 2016 when compared to summer 2015 (95 % CI = 0.003 to 2.052; p = 0.049) (Figure 3-B and Table 4). On the other hand, workload in control unit B was lower in winter 2016 compared to the summer 2015 (95 % CI =-1.160 to -0.006; P =0.045), the spring 2016 (95 % CI = -1.205 to -0.035; p = 0.026) and the summer 2016 (95 % CI = -1.381 to -0.210; p = 0.001) (Figure 1.3-B and Table 4).

Shift had no interaction with the time points and units on workload. However, shift alone had significant effect on the workload (F = 15.76, p < 0.001); the average workload being the highest in evening shift (3.12, SD = 0.876) compared to morning shift (M = 2.77, SD = 0.897) and night shifts (M = 2.52, SD = 1.133), F = 26.63, P < 0.001.

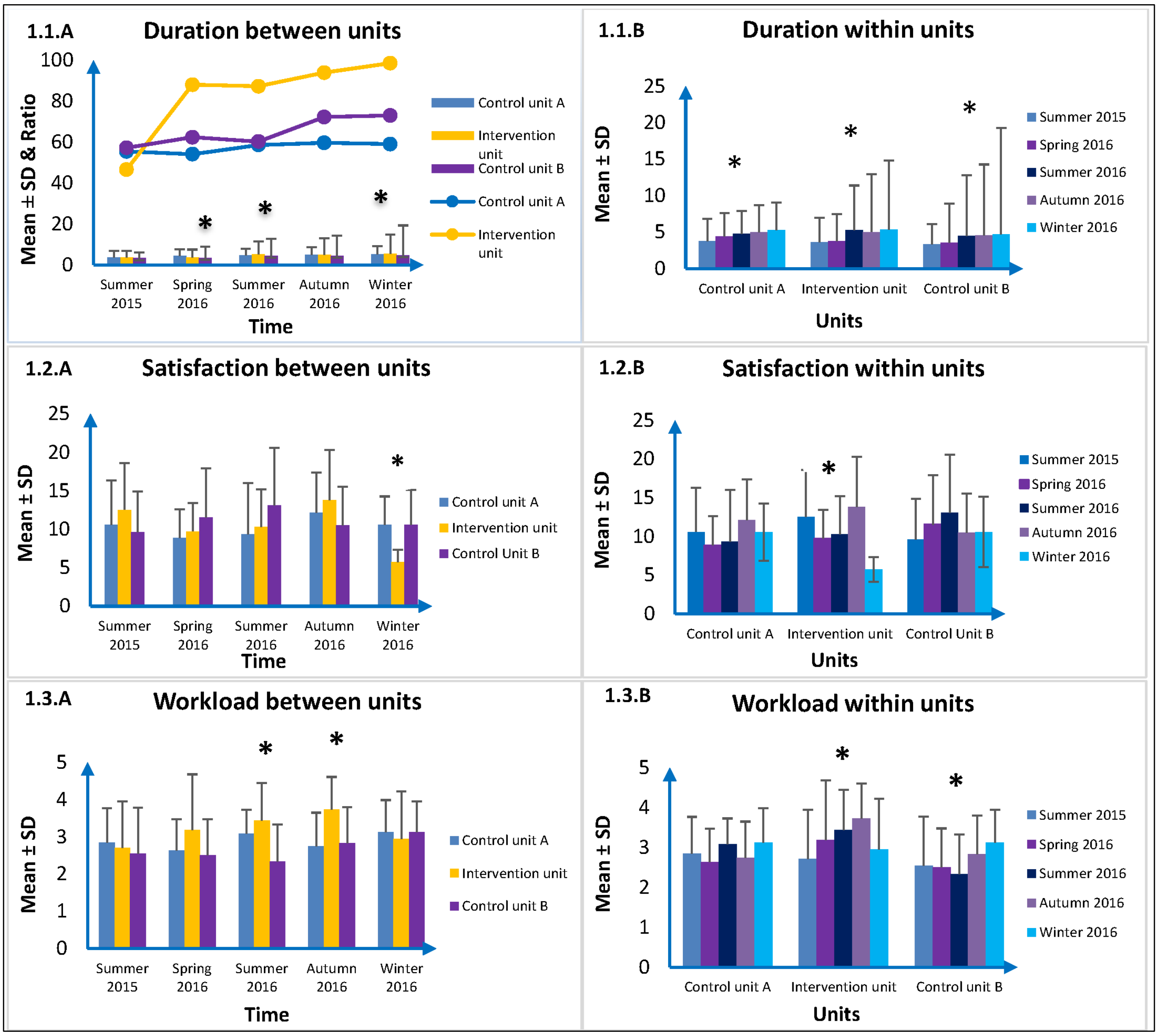

Figure 1. Duration of care, consumer satisfaction and shift leaders' experience of workload presented between and within units.

Figure 1.1.A shows the ratio of patients to nurses as well as the average care duration in hours between units, and Figure 1.1.B, shows the average care duration in hours within each unit. Boxes represent mean, and the middle line (error bars) on each box represents standard deviation. The three lines above the error bars in "A" represent the number of patients cared for by one nurse in each unit in the five-time paints. *indicates significance, $p < 0.05$. Figure 1.2.A shows the mean and standard deviation of consumers satisfaction between the three units, and Figure 1.2.B shows the mean and standard deviation of consumers satisfaction within each unit in different time-points. Boxes represent mean, and the middle line (error bars) on each box represents standard deviation. *indicates significance, $p < 0.05$. Figure 1.3.A shows the mean and standard deviation of shift leaders experience of workload between the three units, and Figure 1.3.B shows mean and standard deviation of shift leaders experience of workload within each unit in the different time-paints. Boxes represent mean, and the middle line (error bars) on each box represents standard deviation. *indicates significance, $p < 0.05$.

Table 4. Pairwise analysis of variance between and within units for workload.

Time						
Between units	**Unit**	**Unit**	**MD**	**SE**	**95%CI**	**p-value**
Summer 2015	Control Unit A	Intervention unit	0.14	0.20	-0.533-0.811	1.00
	Control Unit A	Control unit B	0.29	0.15	-0.2240.813	0.83
	Intervention unit	Control unit B	0.16	0.20	-0.523-0.833	1.00
Spring 2016	Control Unit A	Intervention unit	-0.54	0.36	-1.778-0.692	0.97
	Control Unit A	Control unit B	0.13	0.16	-0.422-0.685	1.00
	Intervention unit	Control unit B	0.67	0.36	-0.556-1.904	0.87
Summer 2016	Control Unit A	Intervention unit	-0.35	0.24	-1.161-0.464	0.98
	Control Unit A	Control unit B	0.75	0.18	0.145-1.363	**0.003**
	Intervention unit	Control unit B	1.10	0.22	0.337-1.867	**<0.001**
Autumn 2016	Control Unit A	Intervention unit	-0.99	0.27	-1.908--0.070	**0.021**
	Control Unit A	Control unit B	-0.08	0.15	-0.594-0.426	1.00
	Intervention unit	Control unit B	0.90	0.27	-0.030-1.838	0.06
Winter 2016	Control Unit A	Intervention unit	0.19	0.25	-0.672-1.046	1.00
	Control Unit A	Control unit B	0.00	0.18	-0.598-0.599	1.00
	Intervention unit	Control unit B	-0.19	0.26	-1.064-0.691	1.00
Within units	**Unit**	**Unit**	**MD**	**SE**	**95%CI**	**p-value**
Control unit A	Summer 2015	Spring 2016	0.20	0.16	-0.34-0.74	0.99
	Summer 2015	Summer 2016	-0.25	0.17	-0.84-0.35	0.98
	Summer 2015	Autumn 2016	0.10	0.15	-0.40-0.60	1.00
	Summer 2015	Winter 2016	-0.29	0.16	-0.83-0.25	0.89
	Spring 2016	Summer 2016	-0.45	0.18	-1.07.17	0.47
	Spring 2016	Autumn 2016	-0.10	0.15	-0.62-0.42	1.00
	Spring 2016	Winter 2016	-0.49	0.17	-1.06-0.08	0.18
	Summer 2016	Autumn 2016	0.35	0.17	-0.24-0.93	0.78
	Summer 2016	Winter 2016	-0.04	0.18	-0.66-0.58	1.00
	Autumn 2016	Winter 2016	-0.39	0.16	-0.92-0.14	0.43
Intervention unit	Summer 2015	Spring 2016	-0.48	0.38	-1.78-0.82	0.99
	Summer 2015	Summer 2016	-0.73	0.26	-1.61-0.14	0.21
	Summer 2015	Autumn 2016	-1.03	0.30	-2.05- 0.01	**0.049**
	Summer 2015	Winter 2016	-0.24	0.28	-1.19-0.71	1.00
	Spring 2016	Summer 2016	-0.25	0.39	-1.60-1.09	1.00
	Spring 2016	Autumn 2016	-0.55	0.43	-1.99-0.90	0.99
	Spring 2016	Winter 2016	0.24	0.41	-1.15-1.63	1.00
	Summer 2016	Autumn 2016	-0.29	0.32	-1.37-0.79	1.00
	Summer 2016	Winter 2016	0.49	0.30	-0.51-1.50	0.94
	Autumn 2016	Winter 2016	0.79	0.34	-0.36-1.93	0.55
Control unit B	Summer 2015	Spring 2016	0.04	0.16	-0.50-0.57	1.00
	Summer 2015	Summer 2016	0.21	0.16	-0.32-0.75	0.99
	Summer 2015	Autumn 2016	-0.28	0.16	-0.81-0.25	0.90
	Summer 2015	Winter 2016	-0.58	0.17	-1.16-0.01	**0.045**
	Spring 2016	Summer 2016	0.18	0.16	-0.37-0.72	0.99
	Spring 2016	Autumn 2016	-0.32	0.16	-0.86-0.22	0.80
	Spring 2016	Winter 2016	-0.62	0.17	-1.21- 0.04	0.02
	Summer 2016	Autumn 2016	-0.49	0.16	-1.03-0.05	0.12
	Summer 2016	Winter 2016	-0.80	0.17	-1.38- 0.21	**<0.001**
	Autumn 2016	Winter 2016	-0.31	0.17	-0.89-0.28	0.90

MD = Mean Difference, SE = Standard Error, CI = Confidence Interval

Discussion

The average duration of care increased in the post-implementation period in the intervention unit, and consumers' satisfaction decreased in the intervention unit in the last postimplementation time point (winter 2016). Moreover, the workload increased in the intervention unit in two-time points postimplementation. However, the patient-to-nurse ratio was doubled in the intervention unit in the last time point postimplementation when compared to the first, while this number remained relatively similar in both control units.

Duration of care

Duration of care is considered one of the crucial indicators of the quality of care [42]. Prolonged ED stay is often associated with overcrowding, delay in care, dissatisfaction and poor outcomes [43,44]. In the current study, the duration of patients' care in the EDs was in a pattern of continuous increase. Also, the number of patients in the EDs were on the increase; the increase being more significant in the intervention unit, while it remained more stable in the control units. This difference might indicate that the intervention unit was able to double the number of admitted patients without an increase in the number of nurses during the study time.

Contrary to our expectation, care duration was increased in the intervention unit and the control unit B. Because the effectiveness of care is affected both by internal and external factors [45], implementing a digital information system alone might not be a solution to reduce the duration of care. Further studies are needed to identify other factors that impact duration of care. One reason for increased duration of care is that care is getting more complicated [46]. Previous work has shown that use of digital information systems can change working inappropriately, and as a result, the steps required to accomplish a task may increase [47]. Similarly, working with the hospital information system might slow down the normal flow of care [47], and therefore, increase the workload of care providers [28]. Another point of view is that the 8-month follow-up used in this study was not enough to show all advantages of the implemented system, as learning how to use such systems may take a long time for the whole unit [13] and hence future research should extend the follow-up times. Research has shown that more complex organisations have more fragmented workflow, which decreases clinicians' efficiency, but these effects may be mitigated by better information management [49]. More research is needed to explore if the positive impact of digital information systems is superior in more complex healthcare environments, such as large EDs when compared to more simple environments.

Consumers satisfaction

Consumer satisfaction showed a pattern of fluctuation in the different time-points in all units. However, consumer satisfaction was only reduced in the winter of 2016 in the intervention unit. Limited articles were found related to consumer satisfaction after system implementation, and inconsistent findings were reported. In line with our finding, Meyerhoefer et al. reported a drop in satisfaction of obstetrics/gynaecology patients after the implementation of a digital hospital information system [50]. A study by Wali et al. revealed no difference in satisfaction between patients in the intervention and the control group [51]. In contrast to our finding, Lee et al. and Mysen et al. reported an increased satisfaction level of consumers after the implementation of a new EHR system [52,53].

A probable reason for the low consumer satisfaction in the last time point in the intervention unit, is be the substantial increase in the number of patients compared to the number of nurses. This imbalance might have increased the workload and nurses would have less time available to give care to each patient. Previous studies indicate that hospitals with a high patient-to-nurse ratio suffer from an excessive workload, with higher risk for increased mortality rates, burnouts and job dissatisfaction [54,55]. In contrast, an increase in nurse-to-patient ratio is associated with positive nursing and patient outcomes [56,57].

The intervention unit is located in the northern part of the country where daylight time in winter months is scarce. This might have an impact on the mood of people. Kaldenberg reported that patients admitted to a hospital already feeling depressed due to the winter weather are more likely to rate their satisfaction for their hospital stay lower [58]. In contrast, enough natural daylight in hospitals has been associated with increased patients' satisfaction, decreased depression, improved sleep, as well as decreased hospital stay [59-61]. Unfortunately, we do not have data from winter 2015, which would have helped us to compare the effect of winter in different locations. Nonetheless, an average higher satisfaction level in summer 2015 (Table 1) in the same unit seems to support this argument.

Lapland, where the intervention unit is located, emerges in winter as a Finnish destination for tourists [62]. Christmas is a special time, as many tourists from different countries with different cultures flock to the arctic town to meet Santa Claus and experience the joyous season in extraordinary snowy surroundings [62,63]. Statistic shows that 21% of the tourists in Lapland in winter 2019 were foreigners, while they were only 5% in summer [64]. This increase in the number of tourists might contribute to the increased ratio of patients-to-nurses in the intervention unit in the winter season compared to the summer season. This might decrease consumer satisfaction in a crowded ED, particularly for those hospitalised with a different culture and language. A previous study indicated that treatment by foreign nurses is negatively associated with satisfaction regarding communication and overall perception of care [65]. Interventions to improve consumers information regarding their wait time in the ED are needed as patients have reported having access to wait time information positively impacts on their overall satisfaction with care in the ED [12].

Workload in the unit

Workload increased in the intervention unit relative to the control units during the first months of system implementation. This increase can be partly explained by the substantial increase of patients-to-nurses ratio in the intervention unit. Besides, in the first months of system implementation, professionals were probably overwhelmed with learning a new system, as well as fulfilling their duty to care for patients. In the last time point, the workload returned to its pre-implementation level. Indicating that professionals probably were able to learn the new system and system benefits started showing.

This finding is in line with one study that reported a productivity loss of 20% in the first month, 10% a second month and 5% in the third month of system implementation, with subsequent restoration of productivity to its original level [66]. Besides, another study estimated that each professional spent an average of 134.2 nonclinical hours related to implementation activities including learning a new digital information system [67]. Implementation of a digital information system might cause temporary disruption in workflow and loss of productivity while the end-users learn the new technology [68]. In turn, heavy workload and workflow interruptions have been associated with negative patient outcomes, including medication errors, urinary tract infections and fall, mainly during implementation of a new system [69].

In contrast to the reported loss of productivity and increased workload during and after initial implementation, reduced documentation errors and improved safety of patients have been cited in many previous studies, especially months after the implementation of an electronic medical record [42,70,71] For this reason, an increased number of professionals during the implementation and first post-implementation months might reduce the negative consequences of introducing a new system. But, effective and efficient assignment of clinicians to deliver the desired care has many challenges [72]. Shift work might influence the psychological and physical well-being of the clinicians that might affect the care outcomes [73]. We found that shift had no interaction with the different seasons and units to affect the workload; however, in general, workload was highest in the afternoon, followed by the morning shift (Figure 3). Even though a direct study that assessed the effect of shift on the workload was not found, one study reported lower scores of patient-doctor interactions in the afternoon shift, which suggested an increased workload for clinicians in the afternoon shift [74].

Limitations

This type of design might be susceptible to season variability as some health-related outcomes are known to have a seasonal pattern. Unfortunately, we had an uneven distribution of months before and after implementation of the digital information system, with winter months missing before the implementation even though it was included after the implementation. We were unable to collect data on waiting time to receive treatment and transfer delay after patients complete their treatment in the ED, which are vital information to estimate patients' flow, overcrowding and providers workload. When the ratio of physician-to-patient increases, patient flow in the ED increases; this, in turn, increases patients' satisfaction and decreases waiting time and workload. However, the ratio of physician to patients was not collected, which might act as a confounder to affect the result. Similarly, response rates for satisfaction and experience of workload were low, which may influence the soundness of the findings.

Conclusions

Our findings indicated that the intervention unit was able to double the number of admitted patients without an increase in the number of nurses during the study period. However, the duration of care and workload increased. Similarly, the satisfaction of consumers reduced in the last data collection time. Hence, it is crucial to ensure an adequate number of professionals during the implementation of a new digital information system, to decrease excessive work stress of nurses and increase consumer satisfaction. This study has shown the complexity in measuring the impact of information management in organising care on unit level in EDs. There is a clear need to further explore means of measuring the effectiveness of information management on professionals’ work and patient outcomes.

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Conflict of interest

The authors declared no conflicts of interest.

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