Outcomes Assessment of the Regional Health Information Exchange

A Five-year Follow-up Study

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Keywords
Regional health information system (RHIS), regional health information exchange, health outcome, assessment

Summary
Background: The implementation of a technology such as health information exchange (HIE) through a Regional Health Information System (RHIS) may improve the mobilization of health care information electronically across organizations. There is a need to coordinate care and bring together regional and local stakeholders.

Objectives: To describe how HIE had influenced health care delivery in one hospital district area in Finland.

Method: Trend analysis was used to evaluate the influence of a regional HIE. We conducted a retrospective, longitudinal study for the period 2004–2008 for the eleven federations of municipalities in the study area. We reviewed statistical health data from the time of implementation of an RHIS. The t-test was used to determine statistical significance. The selected outcomes were the data obtained from the regional database on total appointments, emergency department visits, laboratory tests and radiology examinations, and selected laboratory tests and radiology examinations carried out in both primary care and special health care.

Results: Access to HIE may have influenced health care delivery in the study area. There are indications that there is a connection between access to regional HIE and the number of laboratory tests and radiology examinations performed in both primary care and specialized health care, as observed in the decreased frequency in outcomes such as radiology examinations, number of appointments, and emergency department visits in the study environment. The decreased frequencies of the latter suggest an increased efficiency of outpatient care, but we were not able to estimate to what extent the readily available comprehensive clinical information contributed to these trends.

Conclusion: Outcome assessment of HIE through an RHIS is essential for the success of health information technology (HIT) and as evidence to use in the decision-making process. As health care information becomes more digital, it increases the potential for a strong HIE effect on health care delivery.

1. Introduction

The needs to increase efficiency and quality in the health care sector have led, for example, to the development of regional health information systems (RHISs). These enable accessibility to information and services in the region without visible organizational boundaries, and provide health care through integrated services for seamless care and personalized, individual patient-centered care and information delivery [1–5]. The implementation of a technology such as health information exchange (HIE) through an RHIS should improve the mobilization of health care information electronically across organizations within a region, by coordinating care and bringing together local stakeholders. This would allow service providers to exchange clinically appropriate, patient-specific information between hospitals, health departments, health centers, physician’s offices, other ambulatory care providers, independent laboratories, radiology facilities, and possibly the patients themselves [2–11]. The most commonly exchanged coded information among stakeholders comprise laboratory test results and radiology examination reports, medication histories, discharge summaries, demographic and episode data on hospital patients, and administrative and financial data [3, 4, 7, 10, 12–14, 16, 21].

Increasingly, health care leaders and policy makers are realizing the importance of collaboration at regional level in driving improvements in health care quality, safety
and efficiency, and they are particularly interested in the role of HIE [9, 10, 13, 14, 17, 18]. However, decision makers require credible knowledge-based evidence on the ability of specific health interventions to influence health care that policymakers can use in the decision-making process within RHIS and HIE initiatives [17, 19, 20, 22–24]. Through selected outcomes, such as the frequencies of laboratory tests and referrals, the benefits from HIE through RHISs can be analyzed more carefully to assess, how information systems can support the positive impact of health care delivery [9, 14, 25, 26] for patients.

2. Background

HIE provides physicians and other health professionals with immediate and effective access to more complete and timely information for treatment at the point of care, which is where clinicians and their patients need it most. It also supports quality improvement and reporting, public health activities, and clinical research [1, 3–6, 9]. HIE promotes the collection of previously unavailable clinical data from patients’ disparate health records, which may be spread over multiple provider and payer networks, across all community health care facilities [11, 13–15, 21, 27–29]. The fragmentation of the health care system and the legal and organizational barriers between primary and secondary care and discontinuity of care is one of the challenges to overcome before an interoperable HIE can be achieved [4, 6, 8, 9, 30–32].

According to the previous literature, HIE improves the processing of laboratory and radiology information. Access to data enables more efficient delivery of hospital test results to physicians, which could decrease the number of laboratory tests and radiographic examinations, reducing redundant and duplicate examinations [7, 8, 13, 16, 21, 27, 28, 30, 33–35, 37, 41]. Duplicate laboratory tests have been reported to range from 13–20% [30], and approximately 25% [27] of similar radiology procedures have been performed by another institution in the region. HIE should improve communication among providers and public health service information processing and reduce emergency department visits, and re-appointments and result in fewer admissions for observation [8, 13, 28–30, 33, 36, 37]. Additionally, primary and secondary care visits should decrease [27, 31, 35, 37] and referral processes be improved. [7, 27, 37] Overhage et al. [38] reported a significant reduction in emergency department visits. Between 14% and 25% of emergency department visits were due to missing information that was stored in another hospital system in the region [39, 40]. One quarter of the patients according to Shapiro et al. [32] could benefit from external health information and one fifth would benefit according to Maass et al. [36]. An updated and well-functioning HIE can also improve patient safety, improve medication information processing, and prevent medical errors [1, 7, 28, 34, 42].

HIE projects concerning clinical data compiled by various health care providers and public health organizations in particular geographical regions to improve the quality of care and public health are becoming common in several countries and local communities. However, as yet, the literature provides little evidence to prove these effects. To date, there is a lack of substantial and consistent empirical demonstration of the effectiveness of HIE, the systematic assessment of the benefits of HIE is incomplete, and there is little real-world experience [7, 10, 18, 19, 24–27, 29, 43–44]. There is a significant need for evaluation and research to understand the effects and the value of HIE initiatives [8, 19, 22, 23, 25–27, 32, 43, 44]. Furthermore, measurements of the impact of HIE on health outcomes [2, 15, 24, 43, 45] should be part of the implementation process [45].

2.1 Objectives of the Study

The purpose of this five-year follow-up study was to describe how HIE had influenced health care delivery in one hospital district area in Finland. The objective was to investigate the collected data on laboratory tests, radiography examinations, appointments, emergency department visits and referrals to find out the changes in the studied region. The specific research questions addressed in this study were a) How does regional health information exchange influence the selected outcomes: laboratory tests, radiology examinations, referrals, appointments, and emergency department visits in the five-year follow-up period? b) What is the relationship between the availability of regional health information exchange and the number of laboratory tests and radiology examinations performed in both primary care and special health care?

3. Study Context

3.1 Organizational Setting

In Finland, public health services are divided into primary health care and specialized medical and hospital care. Primary health care is provided by municipal health centers. Municipalities may have their own health centers, or one health center may serve several municipalities. Each municipality has to join a hospital district. Each hospital district contains a central hospital and other specialized units. Municipal health center services include physical examinations and other basic services. Physicians may refer patients to specialized health care units in the hospital, when necessary [46].

3.2 System Details and System in Use

A Regional Health Information System (RHIS) for health information exchange (HIE) between primary, secondary and tertiary care had implemented in this hospital district prior to 2004–2008 (the period for which this study was conducted). The purpose of the RHIS was to enable primary care professional’s access to specialised health care information and vice versa across organizational boundaries. Through the RHIS, documents of medical reports, laboratory and radiology tests, treatments and courses of treatment can be viewed regardless of time and place [47].

The implementation of an RHIS is based on a registry of references or pointers to the patient’s data that resides in the different electronic health record (EHR) sys-
tems of the health care service providers. The approach to use registries and repositories is further developed and standardised in the Integrating the Healthcare Enterprise (IHE) Cross-Enterprise Document Sharing (XDS) Profile. There are two main regional flows of data. The first flow of data is reflected in the continuous creation and update of references from the EHR systems to the regional reference repository. This is a background flow with no human intervention. For the second flow of data access and retrieval of the client data from the EHR systems to an RHIS for viewing. The updating process occurs automatically in a regular manner. This flow is always initiated by a human user. The data from the source systems is presented using Health Level Seven Inc. (HL7) Clinical Document Architecture (CDA) documents. Using the references and referenced data the clinician or nurse can compose an overall picture of the client’s history and situation. [47]

The privacy of the patient is a key requirement in this exchange of information. Two use cases are used: the professional asks for consent from the patient to view data of that patient, the patient gives informed consent to the professional to view patient’s data. The patient can decide which data is disclosed to the professional by giving consent for accessing the references and referenced data. The consent and list of the references accessed by each user are stored in a log file in the regional system. Emergency situations may override the need for consent but that is also recorded in the log file. The patient can check who has accessed his or her references, based on what consent and for what reason. The composition of an RHIS is based on grouping data and functions into modules which have clear interfaces: the content about regional service providers and their services, retrieving and accessing the references and referenced data, patient’s consent management, identification and authentication of users, adapters to source systems, which send references to registry and which reply to queries by sending the actual referenced document. [47]

4. Methods
4.1 Study Design
To evaluate the influence of the regional health information exchange, we conducted a retrospective, longitudinal five-year follow-up study for the years 2004 to 2008 for all the eleven federations of municipalities in one hospital district in Finland. There are a total of twenty hospital districts in Finland and the one in this study had a medium-size population of about 234 000 inhabitants. A federation of municipalities may include one or more municipalities. The health information exchange (HIE) occurs at federation level within the RHIS. The RHIS is meant for the use of social and health care professionals when there is a need to utilize patient care data from other organizations to ensure the continuity and coordination of care and to achieve efficient and effective care.

4.2 Data Collection
We reviewed the data from the time of implementation of the Regional Health Information System (RHIS) in all municipalities of the hospital district. The RHIS was implemented in 2004–2008 and had therefore been in use in the region for five years by the start of the study. The use of HIE increased steadily during the follow-up period [48]. We collected statistical information data using routinely collected information from the electronic patient health care records (EHRs) in primary and special health care concerning selected outcomes in the follow-up period 2004–2008. The selected outcomes were the data obtained from the regional database on total appointments, emergency department visits, laboratory tests and radiology examinations, and selected laboratory tests and radiology examinations carried out in both primary care and special health care. The selected laboratory tests were limited to the clinical chemistry department and the selected radiology examinations to the imaging department performed in special care, since these tests and examinations are performed in both primary care and special health care. The outcomes were based on availability and on the theoretical knowledge that they are expected to have an impact through the HIE. [e.g. 7, 8, 27, 37]

The statistical data was gathered at municipal level by a contact person in each municipality who forwarded the data to the researchers. The researchers collected statistical data manually, and transferred it to a separate table. There was no statistical program that could be used to obtain all municipal statistics in hospital region at once. Therefore, the data was collected manually because each EHR produced its own data and a variety of statistical reports. The statistical recording method did not change in the municipalities during data collection and the statistics were comparable both in the five-year follow-up study and the various municipalities.

All the municipality federations and hospital district managers were asked permission to research and view their statistics for 2004–2008. None of the individual municipality or the municipal federations’ data is revealed in the study, not any individual patient data.

4.3 Data Analysis
Trend analysis was used in the retrospective, longitudinal five-year follow-up study. Firstly, the primary care outcomes of laboratory tests, radiology examinations, appointments and emergency department visits and referrals relating to the inhabitants of the all eleven federations of municipalities were collected annually for a five-year period. The primary care outcomes were compared to the total number of appointments and to the number of inhabitants of the municipality federation for each year. Secondly, the special care data on the same outcomes related to the inhabitants of hospital district was collected annually for the five-year study period. The special care outcomes were proportioned to the total appointments and inhabitants of the hospital district. Thirdly, proportional annual change figures were calculated for the outcomes per total appointments, the number of municipality inhabitants in primary care, total appointments and the hospital district inhabitants per year in special care.
Finally, the total change on outcomes in the five-year period was calculated in both primary and special care. The figures for selected laboratory tests and radiology examinations were collected from the five-year follow-up period in all the eleven municipality federations in primary and special care. The figures were compiled by the municipality federations and adjusted in proportion to the total number of appointments and the number of municipality inhabitants per year; the specialty care figures were adjusted for the total number of appointments and the hospital district inhabitants per year. In addition, the figures were calculated for the proportional annual change in the selected tests and examinations per total appointments, number of municipality inhabitants, and hospital district inhabitants per year. Also, the total changes for the five-year study period were calculated for all the selected laboratory tests and radiology examinations. These rates were further plotted over time, enabling the visualization of the trend data, and both the annual and total changes of these rates were calculated. The t-test was used to determine the statistical significance and confidence intervals of the changes in rates over the five-year follow-up period.

5. Results

5.1 Influence of Regional Health Information Exchange on Selected Outcomes

5.1.1 Laboratory Services

The number of primary care laboratory tests per appointment increased in each year of the five-year review period, 19.0% altogether. There was an increase in the number of laboratory tests in seven out of the ten municipality federations reviewed (Table I). Compared to the starting point, the number of tests increased by 0.46 tests per appointment (p < 0.05, CI: 0.16, 0.75) (Fig. 1). The increase in laboratory tests per inhabitant for the municipality federations was also 19.0% (Table 1). Compared to the starting point the number of tests increased by 0.89 per inhabitant (p < 0.05, CI: 0.72, 1.05) (Fig. 1).

The total amount of special care laboratory tests per appointment increased by 7.0% in the five-year period, and the number of clinical chemistry tests by 6.6% (Table I). Compared to the starting point the increase in the number of tests was 0.36 laboratory tests per appointment (p < 0.05, CI: 0.28, 0.43) and 0.33 clinical chemistry tests per appointment (p < 0.05, CI: 0.20, 0.46) (Fig. 1). The number of laboratory tests per inhabitant increased by 17.9% and the number of clinical chemistry tests by 17.5% (Table 1). Compared to the starting point the number of tests increased by 0.78 laboratory tests (p < 0.05, CI: 0.65, 0.90) and by 0.73 clinical chemistry tests per inhabitant of the hospital district (p < 0.05, CI: 0.65, 0.81) during the study period (Fig. 1).

5.1.2 Radiology Examinations

The number of radiology examinations decreased in each of the review years. The number of radiology examinations in primary care per appointment decreased in each year of the five-year review period, by 16.4% altogether in all the municipality federations reviewed (Table 1). Compared to the starting point, the number of examinations decreased by 0.02 examinations per appointment (p < 0.05, CI: –0.04, –0.01) (Fig. 1). The decrease in radiology examinations per inhabitant for the
municipality federations was 18.9% in the eleven federations (Table 1). Compared to the starting point, the decrease in the number of examinations per inhabitant of the region was 0.05 examinations (p < 0.05, CI: –0.09, –0.01) (Fig. 1).

The total number of special care radiology examinations per appointment decreased by 11.0% in the five-year period, as did the number of imaging examinations (Table 1). Compared to the starting point, the decrease in the number of examinations was 0.04 imaging examinations per appointment (p < 0.05, CI: –0.05, –0.03) and 0.03 radiology examinations (p < 0.05, CI: –0.04, –0.03) (Fig. 1). The number of radiology examinations per inhabitant decreased by 1.9%, and that of imaging examinations by 2.0% (Table 1). Compared to the starting point, the number of examinations decreased by 0.9 radiology examinations (p < 0.05, CI: –1.2, –0.5) and 0.8 imaging examinations per 100 inhabitants of the hospital district (p < 0.05, CI: –1.3, –0.3) during the study period (Fig. 1).

5.1.3 Appointments and Emergency Department Visits

The mean amount of primary care appointments per inhabitant for the municipality federations decreased in the five-year review period, by 3.0% altogether. There was a decrease in the number of appointments in six out of the eleven municipality

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Primary and special health care laboratory tests and radiology examinations specialized medical imaging and clinical chemistry tests in the five-year follow-up.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary care</td>
<td>Laboratory tests total per total appointments *</td>
</tr>
<tr>
<td>Total</td>
<td>3.07</td>
</tr>
<tr>
<td>Annual Change</td>
<td>1.3%</td>
</tr>
<tr>
<td>Change in 5 years</td>
<td>19.0%</td>
</tr>
<tr>
<td>Special care</td>
<td>Laboratory tests total per total appointments</td>
</tr>
<tr>
<td>Total</td>
<td>4.63</td>
</tr>
<tr>
<td>Annual Change</td>
<td>1.1%</td>
</tr>
<tr>
<td>Change in 5 years</td>
<td>7.0%</td>
</tr>
<tr>
<td>Special care</td>
<td>Clinical chemistry tests per total appointments</td>
</tr>
<tr>
<td>Total</td>
<td>4.19</td>
</tr>
<tr>
<td>Annual Change</td>
<td>1.0%</td>
</tr>
<tr>
<td>Change in 5 years</td>
<td>6.6%</td>
</tr>
<tr>
<td>Primary care</td>
<td>Radiology examinations total per total appointments</td>
</tr>
<tr>
<td>Total</td>
<td>0.17</td>
</tr>
<tr>
<td>Annual Change</td>
<td>–4.5%</td>
</tr>
<tr>
<td>Change in 5 years</td>
<td>–16.4%</td>
</tr>
<tr>
<td>Special care</td>
<td>Radiology examinations total per total appointments</td>
</tr>
<tr>
<td>Total</td>
<td>0.43</td>
</tr>
<tr>
<td>Annual Change</td>
<td>–2.6%</td>
</tr>
<tr>
<td>Change in 5 years</td>
<td>–11.0%</td>
</tr>
<tr>
<td>Special care</td>
<td>Imaging examinations per total appointments</td>
</tr>
<tr>
<td>Total</td>
<td>0.35</td>
</tr>
<tr>
<td>Annual Change</td>
<td>–2.4%</td>
</tr>
<tr>
<td>Change in 5 years</td>
<td>–11.0%</td>
</tr>
</tbody>
</table>

* calculated without VII municipality federation


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Federations reviewed (Table 2). Comparing the final situation in 2008 to the starting point, the number of appointments decreased by 0.07 appointments per inhabitant (p < 0.05, CI: –0.04, –0.11) (Fig. 2).

The number of primary care emergency department visits per 100 inhabitants for the municipality federations decreased in the five-year review period, by 1.0% altogether. The numbers have decreased in the two last review periods. There was a decrease in the number of specialty care emergency department visits per 100 inhabitants of the hospital district decreased in each year of the five-year review period, by 16.2% altogether. There was also an increase in the number of emergency department visits decreased by 2.38 visits per 100 inhabitants of the hospital district (p < 0.05, CI: –1.60, –3.17) (Fig. 2).

### 5.1.4 Referrals

The number of primary care emergency referrals to special care per 100 appointments increased in each year of the five-year review period, by 12.2% altogether. There was an increase in the amount of referrals in five out of the eleven municipality federations reviewed (Table 2). Compared to the starting point, the number of referrals per 100 inhabitants of the region was 2.10 referrals (p < 0.05, CI: 1.71, 2.49) (Fig. 2).

The number of primary care emergency referrals to special care per emergency department visit increased by 12.8% altogether. There was also an increase in the amount of emergency referrals in five out of the eleven municipal federations reviewed (Table 2). Compared to the starting point, the number of referrals increased by 0.023 emergency referrals per emergency department visit (p < 0.05, CI: 1.71, 2.49) (Fig. 2).

The number of primary care emergency referrals to special care per 100 inhabitants increased in each year of the five-year review period, by 35.2% altogether. There was an increase in the amount of referrals in nine out of the eleven municipality federations reviewed (Table 2). Compared to the starting point, the increase in the number of referrals per 100 inhabitants of the region was 2.10 referrals (p < 0.05, CI: 1.71, 2.49) (Fig. 2).

### Table 2

Five-year follow-up of the primary and special care appointments and emergency department visits, and primary care referrals to special care.

<table>
<thead>
<tr>
<th>Year</th>
<th>Primary care appointments per inhabitant of the municipality</th>
<th>Primary care referrals to special care per 100 appointments</th>
<th>Emergency department visits per 100 inhabitants of the hospital district</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>1.73</td>
<td>6.45</td>
<td>29.01</td>
</tr>
<tr>
<td>2005</td>
<td>1.73</td>
<td>7.29</td>
<td>29.94</td>
</tr>
<tr>
<td>2006</td>
<td>1.78</td>
<td>8.41</td>
<td>31.26</td>
</tr>
<tr>
<td>2007</td>
<td>1.74</td>
<td>13.1%</td>
<td>16.2</td>
</tr>
<tr>
<td>2008</td>
<td>1.67</td>
<td>15.4%</td>
<td>14.1</td>
</tr>
</tbody>
</table>

*Calculated without XII federation municipality, ** calculated without X** federation municipality.
There was an increase in the number of emergency referrals in nine out of the eleven municipality federations reviewed (Table 2). Compared to the starting point, the number of emergency referrals increased by 0.54 per 100 inhabitants for the municipality federations (p < 0.05, CI: 0.29, 0.78) (Fig. 2).

5.2 Relationship between Regional Health Information Exchange and the Number of Individual Tests

5.2.1 Laboratory Tests

We continued the review on the level of individual laboratory tests and noticed that the largest change that occurred in the review period was in special care Plasma Low Blood Counts (P-LBC). The number of the most commonly carried out laboratory tests (P-LBC) increased by 11.9% per 100 appointments in primary care but decreased in special care by 6.9%. In comparison with the starting point in primary care, the number of tests increased by 1.7 tests per 100 appointments. Correspondingly in special care, compared to the starting point, the number of tests fell substantially. The decrease was 2.4 tests per 100 appointments. (p < 0.05, CI: –3.85, –0.91) (Fig. 3a).

Regarding laboratory tests, plasma C-reactive protein (P-CRP) tests decreased by 3.9% both per appointment and per inhabitant during the review period in primary care. In special care, P-CRP tests decreased by 2.7% per appointment but increased by 7.3% per inhabitant of the hospital district. In the case of fasting plasma glucose (fP-Gluc) sampling, there was an increase of 10.0% both per appointment and per inhabitant in primary care, but a decrease of 29.0% and 21.7% in special care per appointment and inhabitant of the hospital district, respectively (Fig. 3a).

5.2.2 Radiology Examinations

We reviewed the level of individual radiology examinations and noticed that the largest change that occurred during the review period in primary and special care was in chest X-rays. In primary care and special care, the number of the most commonly carried out radiology examinations, chest X-ray, per 100 appointments decreased during the five-year review period in primary care by 17.6% and in special care by 20.7%. In comparison with the starting point in primary care, the number of examinations decreased by 1.0 examination per 100 appointments (p < 0.05, CI: –1.38, –0.61) and in special care by 1.4 examinations per 100 appointments (p < 0.05, CI: –2.33, –0.55) (Fig. 3b).

The number of chest X-ray examinations per 100 municipality inhabitants decreased during the review period by 20.1%, and by 12.7%, when reviewed per 100 inhabitants of the hospital district. Compared to the starting point, the decrease was 1.7 examinations in primary care per 100 inhabitants (p < 0.05, CI: –2.19, –1.17) and in special care 0.80 examinations per 100 inhabitants of the hospital district (p < 0.05, CI: –1.51, –0.10) (Fig. 3b).

Regarding radiology examinations, wrist X-ray examinations also decreased by 20.6% per appointment and by 23.0% per
inhabitant during the review period in primary care (Fig. 3b). In special care, wrist X-ray examinations decreased by 19.7% per appointment and 11.5% per inhabitant of the hospital district. Lumbar spine X-ray examinations decreased by 3.7% per appointment and by 6.6% per inhabitant during the review period in primary care. Furthermore, the number of lumbar spine X-ray examinations decreased in special care by 38.2% per appointment and by 31.8% per inhabitant of the hospital district, respectively (Fig. 3b).

6. Discussion

6.1 Discussion Related to the Results

There has not been much research on the impact of the use of electronic clinical information from HIE initiatives to date [9, 15]. Several follow-up studies, however, have previously been carried out in relation to evaluating the effects of HIE, such as a one-year period to evaluate the benefits of HIE [40], a follow-up survey of RHISs to assess the state of HIE [10], and a retrospective, cross-sectional study to evaluate the effects of integrated electronic health records [35]. According to the previous studies, HIE provides the additional clinical value of multiple independent institutional EHRs. Further opportunities exist for HIE to directly influence medical care [40], such as decreased primary care visits, radiology and laboratory services [35]. Although the amount of operational HIE is growing, its scope remains limited and its viability uncertain [10].

The aim of this paper was to assess the effect of the implementation of one instance of regional health information exchange (HIE). For this purpose, the influence of the HIE on health care delivery and changes in investigated outcomes were assessed. According to the analysis in this retrospective, longitudinal five-year follow-up study, we found substantial changes in the outcomes investigated in both primary and special care. The HIE may have influenced health care delivery in the hospital district in question. There might also have been a connection between the regional HIE and the number of laboratory tests and radiology examinations performed in both primary care and special health care. The changes observed in the use of regional HIE services have many possible explanations. The efficiency of outpatient care may have been increased by the readily available comprehensive clinical information. This conclusion is supported by the decreased frequency of radiology examinations, appointments and emergency department visits. Also Maass et al. [36] estimated a 20% reduction in redundant examinations and repeat appointments. It is vital to investigate whether the population are receiving the health care services that they need, and if this has been affected by the progress in HIE. Outcome assessment is essential for the success of health information technology. Decision makers also require evidence to use in the decision-making process, so we must be able to measure the outcomes within RHIS and HIE initiatives [2, 45].

We investigated the effect of one regional HIE and found that the numbers of
primary care laboratory tests seem to have increased in each year of the five-year review period in seven out of the ten municipality federations reviewed. Furthermore, the numbers of special care laboratory tests also seems to have increased over the five-year period. Compared to the starting point, the number of laboratory tests increased significantly. No study to date has found clear evidence that the presentation of prior laboratory tests decreases the ordering of laboratory tests [38]. Neither is there conclusive evidence that the improved availability of complete laboratory data eliminates redundant testing [35]. However, according to a previous study, there are indications that HIE may have decreased laboratory tests and reduced the number of redundant tests [8, 13, 36]. Also, professionals have expressed the opinion that the numbers of tests ordered would decrease with HIE [33].

HIE could improve radiology information processing and decrease radiology examinations [28, 37]. One reviewed outcome that may have influenced health care delivery was radiology examinations. The number of radiology examinations decreased both in special and primary care. Radiology examinations even decreased in primary care in all the municipality federations reviewed here. Likewise, the number of special care radiology examinations decreased during the five-year period, and so did the number of imaging examinations. Compared to the starting year, the number of imaging examinations decreased substantially. In other studies, the use of radiology services decreased by 14% in the two years after implementation of HIE [35]. This led to a decreased number of radiology examinations [27].

Health information exchange among providers makes previously inaccessible data available to clinicians, resulting in more complete information and improved public health information processing [29]. In this study, one reviewed outcome that may have influenced health care delivery was primary and special care appointments. The trend in primary care appointments showed a decrease during the study period. Correspondingly, the number of specialty care appointments increased, but only by 3%. Frisse and Holmes [27] also estimated that reductions are related to fewer admissions for observation, and that HIE may decrease unnecessary admissions [8]. Reduced utilization in the form of encounters has been shown in the literature as an expected outcome of HIE implementation [28].

The immediate availability of patient information at the point of care should increase effective coordination of care in disease management and continuity of care, and also support clinicians in decision-making and benefit their patients [14]. The trend for primary care emergency department visits that may have influenced health care delivery was analyzed, and found to have decreased during the five-year review period. There was an increasing trend for specialty care appointments. Similarly, Overhage et al. [38] reported reduced emergency department visits in a randomized controlled HIE pilot and found that professionals felt that the emergency department would benefit from an HIE system [33]. Also, according to Vest [29], HIE information access was associated with the number of emergency department room visits.

Regional HIE is expected to reduce referrals between providers [39] and improve referral processes [7]. When reviewing the outcomes of primary care referrals and emergency referrals to special care, we observed an increasing trend in most of the municipality federations reviewed. We did not find any impact on health care delivery regarding the investigated outcomes.

We investigated the influence of a regional HIE on the level of the individual number of laboratory tests and radiology examinations in both primary care and special health care. HIE should reduce duplicate tests and thus reduce the use of health care services [13, 27]. We found that the number of individual laboratory tests e.g. P-LBC, mainly increased during the five-year review period. However, we also found a decrease in the number of other laboratory tests e.g. P-CRP. The examination of ordering patterns for specific tests may better reflect the effect of laboratory systems than overall trends [35]. Redundant tests lead to a counter-intuitive trend to repeat tests rather than relying on information recently obtained [33]. Also, difficulties in trying to change work habits and the time required to search for information were significant barriers to accessing clinical information online [18].

The number of individual radiology examinations e.g. chest X-rays, seems to have decreased during the five-year review period in both primary and special care. Also, wrist X-ray examinations decreased during the five-year review period in primary and special care. In the review, it was assumed that radiology examinations are connected to regional HIE systems. Walker et al. [7] have similarly proposed that HIE would reduce redundant radiology examinations and thus also reduce delays and save the costs associated with paper- and film-based processes.

### 6.2 Limitations

There are some limitations to this study. It is difficult to set up a control group for the phenomenon under research and this lack of control group was a major limitation. Comparative design was not appropriate in this situation because of different sizes and function of hospital district, and they may have different information system in use. In future studies the study design with a control group would be challenged in the case if same RHIS is going to be used in various hospital districts in future in Finland. A second limitation was that the electronic patient health records (EHRs) were different in the various municipality federations, and it was time-consuming to find the correct follow-up outcome results in the different statistical report formats. All the outcome results were collected manually by searching through statistical reports. All this data was collected using similar criteria and instructions, and no changes in compiling the statistics were notified during the study period. Additionally, the special health care laboratory tests were limited to the clinical chemistry department and the radiology examinations to the imaging department because only these were performed in both special and primary health care and were thus comparable. Furthermore, there were usually only a few contact persons in the municipalities who knew how to use the differing statistical systems connected to electronic health rec-
ors. The other limitations are that these results are limited in scope geographically to one hospital district in Finland, and while the data covers total numbers of inhabitants, appointments and tests in the district, the numbers of tests per appointment or per inhabitant were unavailable. Therefore the access to variability in test rates is limited.

There were no regional structural changes in the hospital district area in the follow-up period 2004–2008. However, there was some organizational pressure to reduce the use of ambulatory care, which might have caused similar effects than HIE. For example, better emergency department triage may have led to fewer admissions. It should be noted that the picture archives and communication system (PACS), which uses digital data in distributed databases and is accessible through a network offering interfaces to health care facilities, could also have caused a decrease in the number of radiology examinations. There may be other factors and developments changes that may have affected the results in the same way like HIE e.g. general trends towards more effective health care and political changes in area. Also other developments in science, technology, treatments and services may also have contributed on the results.

7. Conclusion

The objective was to describe how HIE had influenced health care delivery in one hospital district area in Finland. It is assumed that HIE has an impact on the results, which are supported by decreased frequency of radiology examinations, appointments, and emergency department visits. There are only a limited number of studies regarding the effect of HIE initiatives. Generally this study was designed as a follow-up study. Outcome assessment of HIE through an RHIS is essential for the success of health information technology (HIT) and as evidence to use in the decision-making process. The contribution to literature on this topic would be strengthened by future studies that could be structured to provide clear evidence of the effects of RHIS implementation. In an ideal situation, the evaluation should be done by using a carefully chosen control area.

As health care information becomes more digital, the potential for HIE to have a strong impact on health care delivery is increasing. HIE allows a tighter integration of public health information flows within clinical information, increasing the feasibility of creating a truly nationwide health information network.

Acknowledgments
This study was partly funded by the Satakunta Hospital District (EVO 81086) and the Finnish Cultural Foundation, Satakunta Regional Fund in Finland 2009. Thanks also go to Timo Itäli M.Sc., a researcher at the Aalto University, Department of Computer Sciences, for the description of RHIS.

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