A review of Electronic Health Records systems around the world

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Introduction

Electronic Medical Records (EMR) are digitised versions of the paper charts in clinician offices, clinics and hospitals. The information in an EMR is usually stored locally at a practice or a hospital, and it contains the medical and treatment history of a patient. [1] [2] [3]

Electronic Health Records (EHR) focus on the total health of a patient, and are designed to reach out beyond the health organisation. The EHR systematically collate and store digitised data on patients from the different healthcare and medical organisations and providers. They also enable the secure electronic sharing of these data between the different healthcare settings, and in some instances, the patient. The information, which includes the EMR, moves with the patient between different healthcare settings, providing a more holistic view of the state of a patient across time. The EHR can also provide information on population health by aggregating relevant data (permissions providing). Sometimes EHR is also referred to as an Electronic Patient Record (EPR). [1] [2] [3]

About this report

The current study focusses on introducing different types of Electronic Health Record and Digital Record systems in use around the world. During this Horizon Scanning Exercise vast amounts of material relating to digital record systems have been reviewed: both academic studies and grey literature, such as governmental and vendor websites, policy documents, follow up reports, news items, technology reviews, user instructions for the various software, end user experience reports, expert presentations, etc. Most of the material falls into the grey literature category, given the nature of the research topic and the question.

This report focusses on countries internationally renowned as forerunners in implementing and using EHR systems, such as Estonia or the US [86]. Literature was also reviewed to assess regions, which are only in the early stages of adoption of EMR and EHR systems, such as Third World countries, Russia or China, but these were excluded from the scope of the report as unhelpful for the topic.

Summary

The review found that there are four main types of electronic health record systems:

EHR system type	Examples
1) "Closed system"	Cerner Millennium (UAE); Epic (US)
2) Open-source systems	VistA (US)
3) Cloud-based systems	Athenahealth (US); Taltioni (Finland); The data ecosystem being developed in New Zealand
4) Systems that function via a data exchange layer	KanTa (Finland, eArchive); e-tervis (Estonia, X-road); Canadian EHR (Infoway)

1) The so-called "closed" or "locked systems", usually developed by corporations for commercial gain without the involvement of the end users in the design process. These are commonly marketed with a license and require installation of software.
2) The so-called "open source" systems, which often engage the prospective end-users of the system in the design process. The code is open so that other software developers can utilise it in the development work, and create compatible additional features for the EHR. Some of these software require installation.
3) Open-source, cloud-based systems. These are the latest development in the EHR-market. These EHR can be accessed via a normal, up-to-date web-browser on an internet-connected computer or a mobile device. These systems require no software installations, nor cumbersome system updates, as all the system maintenance takes place in the cloud. The information in the cloud is accessible via various downloadable apps as well as via web portals, which makes the information available also to people who have no access to the internet.
4) Many countries with a national strategy for implementing a general EHR-system have chosen to develop or adopt a data exchange layer, which enables the different types of existing EHR/EMR to communicate with one another. The data exchange layer is developed an open-source code, which allows different EHR vendors/creators to use it to develop compatible software for different purposes (such as for care homes, wellness purposes, medical personnel etc).

The method and degree of implementation of these systems vary from country to country. For example, in the US the healthcare is organised primarily around private health insurance schemes [4], which has enabled the use of several parallel, non-interoperable EHR systems nationwide. EHR Vendors range from very small, local companies to global corporations, with just 10 companies[1] in the US accounting for 90% of the EHR market [5][6]. These health IT systems are not designed to talk to each other [7]. According to Kellerman et al. (2013) [8] the current generation of EHR systems in the US function less like "ATM cards" allowing users to access health care information anywhere at any time, and more like "frequent flyer cards" designed to enforce brand loyalty to a particular health care company.

Countries, such as Canada, Estonia, Sweden, Finland, United Arab Emirates and New Zealand, where the healthcare is often free or heavily subsidised, have adopted various national strategies for implementing the EHR. The national strategy can mean a strive for the adoption of a single system, like in New Zealand (NZ), or enabling the interoperability of the diverse systems through creating a flexible interface layer, which enables the many different systems and databases is use to interoperate (Estonia's X-Road, Finland's KanTa-services, Canada's Infoway). Both strategies entail varying degrees of standardization of software code and a degree of control of the EHR vendors. However, the former strategy (a single system) will ultimately leave only one or two EHR vendors left, while linking multiple databases together via a central "spine" system means there is better choice of interoperable software available to meet the needs of each end user (whether the clinic, hospital, care-home, patient etc.).

The different EHR-types are introduced in the national contexts within which they are being used. Two closed systems, Cerner Millennium in the United Arab Emirates and Epic in the US, are introduced first. These are followed by an open-source system VistA and a cloud-based Athenahealth in the US. After that we will describe the cloud-based data ecosystem being planned in New Zealand. The last three cases, Canada, Finland and Estonia, all utilize a data exchange layer by way of creating a national EHR system. In addition, we will also take a tour of Taltioni, new cloud-based digital self-care services in Finland. The report finishes with a table summarizing the findings.

[1] Epic, MEDITECH, CPSI, Cerner, McKesson, Healthlands, Siemens, Healthcare Management Systems, Allscripts and NextGen Healthcare. Rating based on the Meaningful Use attestations [5][6].

Electronic Health Record systems around the world

Cerner Millennium – United Arab Emirates

Healthcare in the UAE

The United Arab Emirates (UAE), formed in 1971, is a federation of seven largely autonomous states governed by a Supreme Council of Rulers made up of seven emirs. The UAE has 9.2M inhabitants (in 2010), most of whom are expats. Citizens of UAE amount only to 19.2% of the entire population, with net migration rate at 23%. [9] [10] The UAE healthcare sector is divided between public and private healthcare providers. The public services are regulated and managed by federal and emirate level government entities. These commonly partner with foreign healthcare organisations to provide daily healthcare services in their area. Healthcare is free for the citizens of UAE. **In UAE healthcare sector is a top priority and a growth area. Back in 2006 the total expenditure on healthcare was 2.6% of the GPD.** [10][9] Healthcare services in the UAE are provided jointly among federal and local governments and the private sector [11]. A well-known digital health company, Nuviun, is based in the UAE [12].

Electronic Health Records in the UAE

The adoption of digital health records in the United Arab Emirates (UAE) may have started less than 10 years ago [13][14][15], but their progress has been phenomenal. The increasing population and rising prevalence in lifestyle diseases have contributed to the pace of development [16]. In 2008 the UAE Ministry of health started implementing Cerner Millennium healthcare information technology (HIT) system at 12 hospitals and 60 clinics [17]. Currently Cerner Millennium is used in several Middle Eastern countries. The system offers a wide range of solutions across the healthcare system, which improve patient safety and streamline care processes in medical facilities, enabling different departments to access patient data and interact with each other [14][16]. By 2014 nearly all hospitals (96.7%) in Dubai had started the process of becoming paperless [18]. In May 2015 the UAE cabinet endorsed the initiative to establish a national unified database of all patients' medical records by 2019 in order to enable easy flow of patients between healthcare providers, as well as to connect public hospitals and clinics [11][18]. In 2015 the Cleveland Clinic in Abu Dhabi reached the stage 6 of the 8-stage (0-7) HIMSS Electronic Medical Record Adoption Model (EMRAM), an international benchmark for the use of advanced IT to improve patient care. There are in total 15 HIMSS EMRAM stage 6 hospitals in the Middle East but none in the highest category stage 7 [19] [84].

The EHR provided by Cerner is a multifunctional system, which strives for person centred care through, for example, automate processes across department, digital clinical communication, documentation and laboratory results, by providing immediate access to clinical information and best practice, and by generally integrating workflows around patients' Electronic Health Records [16].

Cerner Millennium – closed design

In 2015 Cerner launched the first patient portal in the Middle East in the UAE. The residents of Dubai and Northern Emirates can access their health records through a secure, bilingual member portal. This allows them to schedule appointments, see their lab tests and the prescription history, as well as securely message their physician or have a video consultation with them [20].

Cerner Millennium software, introduced in 1997, is produced by a private company Cerner Corporation, designed in-house by a software engineers. The code cannot be modified to suit the needs of the users, who have not been part of the development process, unlike with for example the open source VistA system. [20][22]

In 2013 Cerner was ranked the largest independent Health IT company in the world with a revenue of $2.67 billion, and as the "Most Admired" company by Fortune in 2015 [23]. In the US the Cerner EHR-systems are used by some of the largest hospitals, of whom 523 hospitals have been able to attest to Meaningful Use stage 1 [22] but the systems installed by Cerner have not reached stage 2 Meaningful use attestations [24]. 37 Cerner clients have reached HIMSS Analytic stage 7. According to Becker's hospital review Cerner has consistently received high marks in independent user satisfaction surveys, but they have also faced severe criticism from the users and some lawsuits regarding the functionality of their EHR [22][25]. For example, the disastrous effect of the poor implementation of Cerner HER at a Children's hospital in Pittsburgh [21], at the Girard Medical Centre in Kansas [26] [24], or at the North Bristol NHS Trust in the UK in 2011 [27][28].

Cerner has acquired several companies, including a workforce management software vendor Clairvia in 2012 [5], and Siemens Health Services in Germany in 2015, increasing their global presence by 50%. The system is now being used in 30 countries worldwide. [29] Cerner Millennium system is facing stiff competition from the cloud-based Athenahealth and other US based competitors (Quality Systems, Allscripts-Misys) [30].

There are no actual reviews of how the implementation of the Cerner EHR has taken place in the UAE.

Epic – United States

US Health care system

US Health care system

In an international comparison of health care systems with Canada and Germany [4] and England [31], the US stands out as the country with the highest expenditure on health care whether by GDP or in absolute terms per capita terms, with 17.9% of its GDP going towards health care [31]. The US health care system is based on purchasing health insurance, most of which are private. About one sixth of the nation's population is not covered by health insurance. [4].

Electronic Health Records in the US

The Electronic Health Records arrived in the US "with fanfare" in 2005 after RAND research report[2] promised huge cost savings, better accuracy and efficiency for healthcare services derived from using EHR. However, the evidence of the progress made by 2012 is mixed, with the health care costs rising to $800 Billion [32][33][8] and the adoption rates lagging behind Western Europe [34][35]. Many health care professionals are disappointed in the systems, claiming they are poorly integrated and not user friendly [32][33] [21]. According to Molly Porter (2013) [36] from Kaiser Permanente in 2012 only 27% of U.S. primary care physicians reported using a multifunctional[3] EHR.

The adoption of EHR in the US has been accelerating since 2009 after the passing of the HITECH Act, which offers significant financial incentives for hospitals and doctors' surgeries for the adoption of EHR [21][36][37]. In addition, financial sanctions put in place for those hospitals which had failed to meet the federal "Meaningful Use" criteria by the end of the fiscal year 2014 have accelerated the adoption of the EHR in the US [37].

Epic – closed design

Epic is rapidly becoming the choice of system among large academic medical centres and multispecialty group practices. Epic was founded in 1979, but its commercial breakthrough took place in 2003, when Kaiser Permanente chose it over Cerner and IBM as the EHR provider for their 36 hospitals. Epic has

[2] Paid for by a group of companies, including an EHR vendor Cerner [40] [33].

[3] To be considered multifunctional, EHRs had to have at least two of the following four capabilities:

1. Generation of patient information, such as lists of patients' medications
2. Generation of patient registry and panel information, such as lists of patients due for preventive care
3. Order entry management, such as electronic prescribing
4. Decision support, such as alerts about potential adverse drug interactions [36, p. 3].

also won many honours for both inpatient and outpatient electronic health records, and for the software used in scheduling, billing and collections. [38] In total, by 2014 Epic had 315 customers. More than 70% could attest to the highest analytic stage 7 in the HIMSS evaluation [5].

Like Cerner Millennium, Epic operates on a closed platform. This makes the system expensive and exclusive, and it is difficult for the hospitals to interface with other external software [38][5], effectively locking the users into using the Epic software. However, the popularity of the system stems from with its customer-service model that includes an individual, customised installations for each client and with that, a near-flawless implementation of the system [39]. In other words, Epic works.

By 2009 Epic was in a good position to compete for new contracts after the HITECH Act 2009 state financed incentives for hospitals to adopt and implement EHR. It also helps its users to meet the Meaningful Use criteria. For example, Epic has played an important role in improving the quality of care for Kaiser Permanente system through best practice alerts, standardized order sets and chart abstraction tools, or by enabling the identification of high-risk patients. [38]

As with any implementation of an EHR, Epic has faced complaints relating to slowing down of care processes, workflow interruptions and extra time needed for data input. However, the greatest problem with Epic is its limited interoperability and poor capacity to communicate with other EHR systems arising from the diversity of system installations tailored for the needs of each client. [38][41]

Vista – open-source design

VistA, developed in the mid to late 1990s for the Veteran Administration, was the largest integrated health care delivery system in the US. It has received several awards for reducing costs, improving patient care and enhancing clinical outcomes, and its users are largely satisfied with it compared with other EHR systems. By 2009 almost 50% of the US hospitals using enterprise-wide health IT systems were using VistA or its derivatives. It has also been adopted by the Indian Health Service and a number of private care providers. [21][38]

The VistA system has been developed in collaboration with clinicians and IT-experts, who have designed its user interfaces and the patient record system. VistA is based on standard code and it utilises an open-source design, which have encouraged innovation while ensuring interoperability between the different parts of the system, and the different sites using it. VistA enables easy data-sharing, data retrieval and analysis of clinical data, which are powerful tools for improving quality of care as well as health services research. [42] [21][38]

David Brailer, the first national coordinator for health IT at HHS has described VistA as "probably the most stress-tested and life-tested EHR in the world" [43].

Despite its relative ease of use, interoperability and impact, the success of VistA's private-sector counterpart, Open Vista, has been limited. [38][41]

Athenahealth – cloud-based design

Athenahealth is a comprehensive and cloud-based Electronic Medical Record, Practice Management and Care Coordination system, which operates with a team of real people behind the scenes to support the users of the system [44][45][46]. The users only need a computer and an internet browser to get started, but the system also works through apps on the mobile and smart devices. This makes the system accessible and easy to use. There are no software- or hardware costs or licensing fees involved [44], as the company charges based on what it accomplishes for the customers, such as taking a percentage of the billings collected [45]. The system is recognised as a health IT industry leader, having been ranked the top overall software vendor and top overall physician practice vendor in 2013 by KLAS research. The user satisfaction with the system is high with 95.4% of the medical providers using AthenaClinicals successfully attesting for Meaningful Use stage 1 in 2013. [47]. In 2015 there were 69M patients using Athenahealth system [48], and by 2014 more than 50000 medical providers went live with Athenahealth in all 50 states [47].

The Athenahealth follows a commercial model derived from retail and other health service providers. The ERM has a real human team behind the software to support the EMR user, including digitising incoming material for the EMR, matching clinical documents to existing patients, entering select data, routing information to appropriate staff members and storing documents in a readily accessible format. The team also support the users in realising the Meaningful Use goal set by the government. In other words Athenahealth "provides an EMR / EHR with a shadow coaching team". [45][46]

Jonathan Bush, the CEO of Athenahealth, Inc. envisions future hospitals as a network, connected to patients, new health care service providers such as smart phone apps used to remotely check vital signs, or pharmacies providing urgent care [49]. Bush's mission is to create the health care internet to drive efficiency and improve patient care [48].

According to the CTS guides review [46], the full EHR has 4 major parts (plus many apps):

1. *Athenaclinicals* is the electronic medical record clinical charting portion of the EMR. This offers flexible charting options and back-office document support staff that scans and faxes incoming orders, test and lab results and puts them into the patient charts.

   Since the whole EMR is in the cloud, updates never have to be installed. The rules based Quality Management Engine stay up to date with new regulations and clinical information that includes a continuously updated database that injects clinical knowledge into the patient encounters. A strong Quality Performance Team of real people is constantly looking for and incorporating new Pay-for-Performance changes and rules keeping the user up to date clinically and regulation-wise.

2. *AthenaCollector* is the practice management portion of the EMR. Athenahealth is hosted on Athenanet and managed by Athenahealth personnel. All hardware and software upgrades are handled internally. The PM portion of AthenaHealth includes scheduling, billing, patient registration, practice management and practice metric tools.
3. *AthenaCommunicator* handles communications between patients and doctors has four parts: a messaging platform; a patient web portal; live operator services; and self-pay reminder service.
4. *Athenacoordinator* is aimed at simplifying order transmission. It makes the sharing of information much easier by allowing caregivers to send physicians orders right from their workflow. Facilities that received doctors' orders get clear, legible messages. The receiving organizations pay only $1 nominal fee for each order.
5. *AthenaClarity* is a data analytics module offering Financial and Operations Management help as well as Population Health Management and Care Management.

Future

Large, integrated delivery systems such as the VistA and Epic provide company-wide EHR, but the information cannot travel with the patient beyond that system. Interoperability can become an issue even when two organisations use the an EHR provided by the same vendor, as the local customization changes the system so extensively the two cannot communicate with one another anymore. [50]

Cobb and Sauser [38, p.39] predict two future trends for the EHR in the US:

1) The systems continue to consolidate into large integrated delivery systems, sucking in the smaller practices, becoming the dominant model for Health IT.

2) “Open data” scenario: The American healthcare will adapt to health IT’s “productivity paradox” (like the financial services, airlines etc.). Agile HealthIT providers, who rely on improving interoperability standards and user friendly systems, which do not distance the physician from the patient will forge ahead of the large, consolidated companies.

Garbner et al., (2014) [41], Kellerman et al. (2013) [8] and Nordqvist (2012) [32] emphasize that for future EMR smooth interoperability (assumes high degree of standardization on how messages are sent and received, the format of information and terms used within the messages), ease of use and person centeredness – patients having access to their own data - are key characteristics.

New Zealand – creating a data ecosystem

Healthcare in NZ

The New Zealand (NZ) has been a world leader in health IT since 1980s [3]. The health system underwent a radical reform in 1990s, and another one in 2001 [51][52]. Until then the system was funded on a fee-for-service basis and had no supporting infrastructure. In 1992 the NZ adopted an NHI number, a unique patient identifier within National Health Index, which every citizen and visitor to NZ are issued with. Today NZ has a universal health coverage funded through general taxation. Public hospital and inpatient services are free, and the healthcare is delivered using a mix of public and private providers. The country is divided in 21 district health boards, which have Primary Health Organisations (PHO), local structures for implementing the national health strategy. 95% of the population is enrolled into one of the local PHOs. By 2000 99.9% of the healthcare settings were using an EMR system. [51]

Electronic Health Records in NZ

In November 2015 the NZ government announced a plan to create a single national EHR by 2020 [53][54]. The drive is based on an independent report delivered by Deloitte (2015) [3], which highlighted the growing international support for adopting a single EHR to join up information currently held in a smaller number of EMR systems [54][53][3]. It is envisaged that the EHR will provide information via a patient portal and allow clinicians a comprehensive view of patient information in one place. These data will be accessible via portals and apps that run on diverse devices. Most of the information in the National Health Index is ready to be transferred in to a single EHR, and the aim is to concentrate data currently dispersed in a number of different EMR systems into the same single system. [3][53] [85] As a result of the drive to standardize and unify the system there will be fewer EHR vendors on the market. [53].

On 2nd of December 2015 three NZ health technology leaders - Orion, Medtech and CSC - announced that they have teamed up to develop a “world-leading, integrated, precision medicine solution” for New

Zealand, which would also provide “an obvious” platform on which to build the nationwide EHR [55]. The vision, according to the CEO of Orion Health, Ian McCrae, is to deliver a collective data ecosystem in support of health and social investment in NZ. This would enable early intervention to support people in need, identifying and predicting negative health trajectories of those at risk and supporting people’s health throughout their lives. [56] The companies endeavour to work together to join hospital-level clinical data with primary care data and personal health data, which, “when linked to genomics, microbiomics, proteomics and other new health information types, will enable a truly personalised healthcare system for New Zealanders”. This is a ground-breaking area of development in EHR, and it is expected to fundamentally change the way healthcare is delivered in the next decade. [55][56].

Canada – using a data exchange layer

Healthcare in Canada

The Canadian healthcare provision is based on a public health insurance, through which healthcare is available free of charge to all citizens and permanent residents of the country [57]. While the healthcare is devolved into Regional Health Authorities in the provinces, Canada has a centralised policy for rolling out an effective and interoperable digital healthcare system and Electronic Health Records [58][59]. In 2001 the Federal Government set up an independent, not-for-profit organisation, Infoway, to share strategic direction for digital health across the country. The purpose of the organisation is to re-use existing compatible systems and implement an effective and interoperable EPR solution for Canada together with its partner organisations. Infoway funds up to 75% of eligible costs of approved health IT projects, which are funded on first-come, first-served basis. [59][60][61]

Infoway connecting different EMR-systems

While each province may have a different EHR-system, there is a standardised EHR Infostructure (EHRi), the Blueprint, used by each jurisdiction in Canada. Infoway (2009) [57] describes this as “an enterprise systems architecture that uses the well accepted principles of a Services Oriented Architecture to enable the applications at the many points of service to use one standards-based set of interfaces to exchange information.” This means that different applications can connect directly to the shared infostructure using a common set of interface standards, rather than hooking up directly with one another. The interfaces are handled by the Health Information Access Layer (HIAL), which provides common services support, such as authorization and authentication of users and logging accesses. Longitudinal Record Services manage shared information repositories, which receive information about

clients/patients from different point of service applications across care settings, different disciplines and provinces. These applications can then request EHR information from Infostructure using the same mechanism. Each Infostructure can communicate with other Infostructures, and collaborate to deliver clinically relevant information where and when it is needed, regardless of where it was originally captured. This is comparable to the Estonian X-roads service. Infosystem architecture offers a cost effective way for integrating EHR systems by leveraging existing information systems as well as offering a scalable, extensible and adaptive base for new and better EHR capabilities. [57]
The benefits of the Blueprint include a shared view and timely access to relevant clinical information regardless of time or place, or method of electronic acquisition; secure and appropriate sharing, secure storage of information and uniform support of users. [57]

The implementation and uptake of eHealth solutions vary greatly by province. Currently EHR data is available for 91% of Canadians [58][57], with a 100% coverage expected by 2016 [57][59]. The number of Canadian physicians using EMR systems has tripled from 25% in 2007 to 75% in 2014 [62].
The CanadianEMR [63] rates Canadian Electronic Medical Record vendors. Vendor ratings are submitted by physicians who are verified as legitimate users of an EMR system by the vendor. CanadianEMR enters into a contraction agreement with all participating EMR vendors listed on the site. This agreement outlines expectations regarding maintenance and updates on product information, verification of raters etc. This list includes both open source, privately developed and cloud-based systems, such as MOIS, AccuroEMR or Nightingale on Demand. The site also lists, but does not rate, vendors who are outside of the list.

Finland - using a data exchange layer

Healthcare and the development of EHR in Finland

Finland is a country roughly the size of Scotland in terms of population (5,4M people), with high levels of internet coverage and digital literacy among its population [64]. The first roadmap for using ICT in health and welfare services was drawn already in 1996, and by 2008 most public and private sector health and care providers were using electronic patient records. [65] The health care system in Finland, however, is highly de-centralised with municipalities being responsible for providing local health care. Twenty-five years of developing localised solutions for providing electronic patient records (EPR) has resulted in serious problems with interoperability. To solve this issue, a large scale project for centralising the health care information systems was set up in 2002 by the Finnish government. The outcome of this initiative is an information management system eArchive, completed in 2011. The system was made mandatory

for the health care professionals to use. The purpose of eArchive is not to replace the local EPR systems but to provide a unified platform for accessing patients' electronic records regardless of location or time. eArchive forms a part of the National Archive of Health Information, the KanTa-services. The other components of the KanTa system are an electronic prescription system, ePrescription, a large pharmaceutical database, an electronic archive of health records and information management system (eArchive), including a portal allowing the citizens to view as well as add to their own information (blood glucose, blood pressure or pulse readings) to their own records (eAccess). [66][65][67][68] [82].

e-Archive data exchange layer and KanTa-Services

The eArchive will contain all coded information held in the local EHRs, including a log of all information and who has accessed these data. The eArchive will keep patient data for 30-plus years, providing a longitudinal patient record over time as information is added to the system. [69]

Each citizen and permanent resident in Finland is issued with a personal ID number. The EPR systems works on the basis of the personal ID cards, launched in 2003. The eArchive and the KanTa-system are part of a larger e-Government system in Finland, where most governmental and administrative systems are run electronically. The KanTa pages are available to all adults (over 18) with a Finnish ID number. The providers of this service are the Ministry of Social Affairs and Health (STM), the National Institute for Health and Welfare (THL) and the Social Insurance Institution of Finland (Kela). [69]

The Kanta-services also launched MyKanta (Oma Kanta) services in 2015, which the citizens can use to transfer their personal data from national or other databases into their own account seamlessly. These data will also link to a pool of wellbeing data. [70][69]. The national patient data management service allows healthcare professionals to view the patient data, provided the owner of the data has consented to sharing these with healthcare professionals. The healthcare professionals can access these data using their healthcare professional cards. Every access is logged, and data transfer between systems is encrypted. [69][82]

Taltioni – a cloud based service for digital self-care services

In addition to the KanTa-services oriented more for organisations, *Taltioni* is an open-source, Cloud-based platform for digital self-care services. Using this service citizens can create their own health accounts with e.g. their secure bankID to record, store, access and share their own health data using various compatible apps linked to the service. These services can be accessed through mobile apps and through the web browser. The information uploaded into the system is owned by the user, and can be

shared with health professionals or other users. The information can be retrieved from diverse sources, such as prescription data, vaccinations, laboratory results, personal blood pressure measurements, etc. and stored securely in a central location. An individual is able to get a more holistic view of their health, and find all of their records in one place. The data stored in a Taltioni account does not replace actual patient records, but supports and supplements these. [71][67][72][73][74] [83]

The not-for-profit cooperative (established in 2012) behind Taltioni brings together public, private and third sector health operators with ICT companies. The platform offers a business environment, an appstore with eHealth solutions, an innovation environment, proof of quality, a secured database and a lifelong health account. The philosophy behind the Taltioni ecosystem is to empower the citizens to take more responsibility for their own health and to engage them in activity that promotes health rather than focusses on treating illnesses. Healthcare professionals can make use of the wealth of background data stored in Taltioni, which also enables a smooth information flow between professionals and systems. Taltioni also allows carers to keep better track of the health of the person they care for. [71][72][83]

Taltioni includes services like iPana, an electronic maternity card, and Kasvuseula – an online service for measuring and visualising the growth charts of children over time and comparing these to others'; Wellmo, a mobile wellness application. [71][72]

Estonia - using a data exchange layer

Healthcare in Estonia

Estonia, a small country of 1.4M people in northern Europe, is widely seen as a global leader in the adoption of digital technology. The Estonian healthcare is based on a health insurance, which covers approximately 95% of the population [75]. The health insurance operates on a principle of solidarity: healthcare is free at the point of delivery to everyone regardless of their taxpayer status. The Health Insurance Fund covers the cost of the care. The quality of healthcare in Estonia is among the highest in Europe, with OECD and the EC ranking Estonia as number one in Europe in terms of adoption and implementation of ICT in healthcare and the availability of e-health services. [76][75]

X-Road data exchange layer and e-tervis

Key to the national success story has been the development of a flexible, highly interoperable, open-source e-infrastructure (e-Estonia 2015). This includes the adoption of national ID-cards and the locally developed (in 2001) X-Road Data Exchange Layer, an infrastructure enabling a secure interoperability of the various, separate digital systems and databases used by the Estonian state and the Estonians.

Public and private sector enterprises alike can connect their information systems with the X-Road enabling sharing of information and services with their clients. [77][78][79]

X-road infrastructure layer enables the use of diverse, de-centralised e-solutions, suitable for each service or business provider, but interoperable with other relevant services and users via the X-road. This also enables adding new and emerging services to the existing system easily. No single actor owns or controls the databases linked into the infrastructure. All outgoing data from the X-road is digitally signed and encrypted. All incoming data is authenticated and logged. [77][78].
The users of the X-Road system authenticate themselves through an ID-card or via an Internet bank (similarly to the Finns and the Swedes). Jointly with public sector initiatives, the nation's banks introduced online services that were claimed to be "ahead of anything in the west" at their inception. NATO's Cyber Defence Centre is based in Estonia, which is now considered to be a "demonstrator" for countries wishing to introduce digital solutions such as internet-voting [81] or e-Health systems [80][77].

Estonian EHR, e-Tervis, was launched in 2008. The system may look like a centralised, national data-base but in fact it retrieves information on the patient from several different databases via the X-road network, presenting the patient data in a standard format as a single electronic file [78][77]. The end-users of the system own their personal health records, and those of their children. They can access their full personal health record on the EHR using their ID cards or e-banking credentials. The same information is visible to the medical professionals. In an emergency, the medical staff can use the patient's ID card to gain access to time-critical information, such as blood type, allergies, recent treatments, ongoing medication or pregnancy. [78][80].

Uptake of the system has been fast, almost 95% of the doctors using it by 2011. Creating the Estonian EHR has been relatively cheap, costing just 10M euros. It includes various services, such as health insurance system for claims, reimbursement and prescription management. [77]

EHR system type	Examples	Developer	Participatory design	Method of use/installation	+	-
"Closed system"	Cerner Millennium (UAE) Epic (US)	A corporation	No	Requires specific software to be installed	Strong in-house support for users; custom installation	Expensive; Cannot communicate with other HER or other installations of the system; Locks users in one system
Open-source systems	VistA (US),	A corporation or a cooperative	Yes; open code	Requires specific software to be installed	Flexible design; Good interoperability between different parts of the system	
Cloud-based systems	Athenahealth (US); Taltioni (Finland); The data ecosystem being developed in	A corporation or a Cooperative	Yes; Open code	No software required; The system sits in the cloud	-An up-to-date web browser is enough to use the system. -Works with mobile and smart devices – gives more equal access to users. -Easy to use -No extra installation costs involved	-More complex data security issues

	New Zealand				-no system updates needed, as updates take place in the cloud.	
EHR based on a data exchange layer	KanTa (Finland, eArchive), e-tervis (Estonia, X-road), Canadian EHR (Infoway)	Development based on a national strategy; can be combined with cloud-based services (access via apps, mobile devices, web-browsers)	Yes	May require specific software to be installed	The data exchange layer allows for existing EMR/EHR to be used; enables the interoperability of many systems; Allows for a variety of EHR systems to co-exists -> reduces cost of overhaul of the system	-Data security based on the use of an IDcard

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