SNOMED International

SNOMED CT

The case for investment

SNOMED CT

The global language of healthcare

September 2021


SNOMED CT
The global language of healthcare
POLICYMAKERS
MEMBERS
COLLABORATION PARTNERS
RESEARCH & KNOWLEDGE PRODUCERS
VENDORS
CARE PROVIDERS
IMPLEMENTORS
PATIENTS/CITIZENS

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The global language of healthcare

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Glossary of Terms

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SNOMED CT
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Glossary of Terms

Terms Used

- Aggregation Terminology: are systems of non-overlapping classes in single hierarchies, enhanced by classification rules, as commonly used for data aggregation and ordering. Aggregation terminologies are also known as classifications, (e.g. the WHO classifications ICPC, ICD, ICF, ATC and ICHI). Aggregation terminologies are typically used for epidemiological research, health statistics and reimbursement purposes.
- Algorithm: set of rules and instructions that an agent (e.g. computer, robot…) follows to solve a problem.
- Applied Research: For health care, applied research is the scientific study that seeks to answer specific clinical questions or solve practice-related problems, often in response to questions raised by policy makers (e.g. how do we reduce falls among the elderly so that emergency visits, repeat emergency visits and hospitalizations are also reduced?)
- Better Health: The patient/citizen perspective on a health outcome. Patients/Citizens would not use the term ‘health outcome’, but rather would state that they ‘are well’ or ‘are feeling better’ (i.e. they have better health).
- Care Providers: the physicians, nurses, pharmacists, therapists, dentists and other health care professionals that provide care to a patient, so that they can prevent or treat an illness or disability.
- Citizen: an inhabitant (resident) from a place, such as a town, city, province, state, nation, region.

Glossary of Terms

Terms Used

- Clinical Information System: a computer system(s) used by care providers for collecting, storing, processing and sharing patient clinical information. In this report, the term 'clinical information system' is used interchangeably with longitudinal health record, electronic health record (EHR), and electronic medical record (EMR).
- Clinical Research: the analysis of data and information to determine safety and effectiveness (efficacy) of medications, devices, diagnostic products and treatment regimens intended for human use.
- Clinical Terminology: a structured vocabulary used in clinical practice to support care providers with accessible and complete information regarding a patient's medical history, illnesses, treatments, laboratory results, and similar facts.
- Collaboration Partners: the professional (e.g. American Medical Association) and standards (e.g. Regenstrief Institute, HL7) organizations that work with SNOMED international to expand and extend the SNOMED CT product.
- Core Reference Terminology: is a large reference terminology that plays a pivotal role within a terminology ecosystem, in terms of conceptual coverage and linkage with other terminologies (e.g. SNOMED CT). The term "core" is used to indicate the primordial role of this terminology in the ecosystem. A Core Reference Terminology provides extensive coverage across multiple domains however, it is not expected to cover the totality of concepts.

Glossary of Terms

Terms Used

- CPOE: Computerized Provider Order Entry is where Care Providers' electronically enter and send orders (e.g. lab test order, a prescription, radiology test order) from a computer or mobile device to a laboratory, pharmacy or diagnostic centre for processing. The order is captured in a digital, structured, and computable format.
- Electronic Health Record: An electronic health record (EHR) is a digital version of a paper-based medical record for an patient/citizen. The EMR represents a medical record from multiple facilities, such as a doctor's offices, ambulatory clinics, and hospitals. Also see clinical information system (note: the use of the terms EHR and EMR is not standardized globally and they are often used interchangeably).
- Electronic Medical Record: An electronic medical record (EMR) is a digital version of a paper-based medical record for an patient/citizen. The EMR represents a medical record within a single facility, such as a doctor's office, an ambulatory clinic, or a hospital. Also see clinical information system (note: the use of the terms EHR and EMR is not standardized globally and they are often used interchangeably).
- Health Data & Analytics Platform: software and services that leverages data extracted from clinical information systems for point-of-care analytics, population analytics, management analytics and research.
- Health System Value: as defined by Michael Porter is “patient health outcomes achieved per dollar spent”.

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Glossary of Terms

Terms Used

- Longitudinal Health Record: An longitudinal health record is an electronic health record for a patient/citizen, that includes all clinical information recorded over time. Also see clinical information system.
- ICD: the International Classification of Diseases, a terminology from the World Health Organization for coding diseases, signs, symptoms, abnormal findings, complaints, social circumstances, and external causes of injury or diseases.
- Interoperability Solutions: computer systems or software that can exchange and make use of health data/information through syntactic and semantic interoperability.
- LOINC: Logical Observation Identifiers Names and Codes, a terminology from the Regenstrief Institute for identifying health measurements, observations, and documents to facilitate the exchange and aggregation of clinical results.
- Implementers: the health care professionals (e.g. CMIO, health informaticians, care providers) that work in health care organizations or care settings (e.g. a hospital or a primary care practice) to implement SNOMED CT, typically as part of a vendor's clinical information systems or health data & analytics platform deployment.
- Management Analytics: conducting trend analysis (e.g. hospital length of stay, surgery wait-times, number of citizens without a GP), and health system value analysis (e.g. patient health outcomes and the cost to achieve those outcomes)

Glossary of Terms

Terms Used

- Members: National members are typically a government agency (e.g. Ministry of Health) or another national organization (e.g. Canada Health Infoway) that hold a national license for SNOMED CT and support the adoption and use of the clinical terminology in their respective countries. Members also have a governance role in SNOMED International.
- Patients: citizens who receive health care services from care providers in order to achieve better health.
- Patient Outcomes: patient outcomes includes both patient service outcomes (e.g. improvements in access and productivity) and patient health outcomes (e.g. reduction in adverse events, morbidity and mortality). *Note: the mauve and yellow colour designations for patient service outcomes and patient health outcomes respectively, are used throughout the report.*
- Patient Health Outcomes: the change in a patient's health status as a result of a health care intervention or set of interventions. Patient health outcomes can be determined at an individual or population level of analysis.
- Patient Service Outcomes: the changes in access to care (e.g. availability of services) and the productivity of the health care system (e.g. efficiency gains from moving from paper to digital records) that are of benefit to patients.
- Patient Journey: the sequence of health care events (i.e. the pathway) which a patient follows from the point of entry into the health care system (i.e. typically a primary care physician) triggered by a health condition or illness until the patient is treated and discharged from care to his or her home, a care home, a hospice or in some cases due to death.

Glossary of Terms

Terms Used

- Personal Health Record: a patient/citizen's digital health record that may be either under the control of the patient/citizen, or the custodianship of the health care system.
- Point-of-Care (Clinical) Analytics: The analysis and creation of historical summaries, point-of-care reporting (e.g. reminders, identification of high-risk patients, reporting clinical data to disease registries) and clinical decision support (e.g. presenting evidence-based clinical guidelines and care pathways, patient safety alerting, as well as diagnostic support tools and automated order sets).
- Policy Makers: the individuals (e.g. elected officials, senior management) responsible for developing and setting the course of action for a government or a health organization.
- Population Analytics: conducting trend analysis (e.g. change in the incidence or prevalence of health outcomes, disease, treatment or procedure over time), pharmacovigilance (e.g. monitoring, detection, and prevention of adverse effects from drugs), and clinical audit (e.g. systematic review of care against defined standards) activities.
- PREMS: patient reported experience measures. PREMs are typically questionnaires that gather information on patients' views of their experience whilst receiving care.

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Glossary of Terms

Terms Used

- PROMS: patient reported outcome measures. PROMs are standardized questionnaires that are completed by patients' to ascertain perceptions of their health status, perceived level of impairment, disability, and health-related quality of life.
- Reference Terminology: describe the meaning of terms in a domain, together with the properties of the objects that these terms denote, in a neutral sense (i.e. uncommitted to any specific purpose). Representational units of reference terminologies are commonly called "concepts". If underpinned by a formal foundation, Reference Terminologies (e.g. SNOMED CT) coincide with what is called formal ontologies.
- Researchers and Knowledge Producers: the individuals who take relevant data from clinical information systems and other sources to create value-added information, evidence and knowledge for point-of-care analytics, population analytics, management analytics and research to support the decision making of policy makers, care providers, patients and others. Researchers also focus on getting their research findings published in peer-reviewed journals (e.g. The Lancet, New England Journal of Medicine).
- RxNorm: RxNorm, which is produced by the National Library of Medicine, is a normalized naming system for generic and branded drugs; and a tool for supporting semantic interoperation between drug terminologies (e.g. SNOMED CT) and pharmacy knowledge base systems (e.g. First DataBank, Multum, Micromedex).

Glossary of Terms

Terms Used

- UMLS: the Unified Medical Language System consists of a meta-thesaurus and semantic network that integrates and distributes 150+ terminology (e.g. SNOMED CT, RxNorm, LOINC), classification and coding standards (e.g. ICD-10), to create effective and interoperable biomedical information systems and services, including electronic health records.
- User Interface Terminology: are collections of terms that are used in written and oral communication within a group of users, for example in a data entry form in a clinical information system or in clinical documents.
- Value Proposition: the innovation, features, and services intended to make a company (e.g. SNOMED international) or a product (e.g. SNOMED CT) attractive to its customers. For this project we are developing the segmented value propositions for the product, SNOMED CT.
- Vendors: the corporations that sell SNOMED CT-embedded, clinical information systems, health data and analytics platforms and/or supporting products.

Benefits Model

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SNOMED CT
The global language of healthcare

Benefits Model

Purpose

- The objective of the benefits model is to support the realization of SNOMED International's vision that "*By 2025 clinical terminologies will be used globally, which will result in better health and improved patient outcomes, supported by one language of health*".
- The benefits model will produce potential benefits estimates for a current SNOMED CT license holder or a prospective license holder. The model will be:
  - **Limited** to clinical information systems[1] and interoperability solutions[2] but will not include health data & analytics platforms.
  - **Evidence based**, using over 50 studies (see Appendix 4 here) that demonstrate both qualitative and quantitative patient service outcome and patient health outcome benefits from using SNOMED CT within a specific healthcare entity (e.g. healthcare network, healthcare organization) or at a national level.
  - **Generalizable**, so that it provides directional estimates of select benefits supported by SNOMED CT.
  - **Flexible**, and will generate potential benefit estimates for a given country or a sub-national entity, and
  - **Structured**, so some benefits will be measured in financial terms (e.g. dollars/euros saved) and other benefits will be measured in non-financial terms (e.g. deaths avoided).

1. Consistent with the definitions in the "Glossary of Terms" section of this report the term Clinical Information Systems includes Longitudinal Health Records, Electronic Medical Records (EMR), Electronic Health Records (EHR) and Computerized Provider Order Entry (CPOE).
2. The benefits model is based on the RAND study and assumes a fully deployment of clinical information systems and interoperability solutions in the United States.

Benefits Model

Data on the Impacts of Interoperable, Clinical Information Systems

- **Data Required for Developing a Benefits Model**
  - In order to develop an analytical benefits model, quantitative data linking SNOMED CT to patient service outcome and/or patient health outcome benefits is required.
- **Limitations in Data Quantifying the Benefits of SNOMED CT**
  - There are several studies available that describe the benefits of SNOMED CT in qualitative or descriptive terms.
  - However, rigorous[3] studies that quantified SNOMED CT's direct contribution to patient outcomes were not available.
- **Data Availability**
  - In contrast, several studies were identified that attempt to estimate both the patient service outcome and patient health outcome benefits from clinical information system and interoperability solution adoption for either a healthcare entity or a country.
  - Most studies that report quantified benefits linked to clinical information systems and interoperability solutions are not comprehensive. They most often focus on benefits that would accrue within specific care settings. (e.g. oncology, primary care, radiology, etc.).
  - However, there are a few reports that provide a (near) robust, quantification of the benefits of clinical information system and interoperability solution adoption.

3. Rigor requires that the data is derived from healthcare analysis or is based on transparent and validated assumptions from healthcare delivery organizations.

Benefits Model

The Modelling Approach

- The modelling approach uses quantifiable patient outcome benefits through the adoption of clinical information systems and interoperability solutions; benefits that SNOMED CT contributes to but is not exclusively responsible for producing.
- The rationale for using clinical information system and interoperability solution benefits is:
  - The research did not identify any studies that quantified the patient outcomes benefits directly caused by, or explicitly linked to SNOMED CT. In contrast, quantitative data is available on the broad benefits of clinical information systems and interoperability solutions (e.g. RAND Corporation).
  - Clinical information system and interoperability solution benefits can be used to assess the SNOMED CT benefits since:
    - a) SNOMED CT (and/or other clinical terminologies) **must** be embedded in clinical information systems and interoperability solutions for these systems to be effective[4],
    - a) Clinical information systems and interoperability solutions provide significant quantifiable patient outcome benefits.
  - SNOMED CT is embedded in approximately 72%[5] of the clinical information systems deployments globally
  - SNOMED CT is an important enabler to achieving a broad set of benefits that lead health organizations to invest heavily in clinical information systems and interoperability solutions.

4. SNOMED CT plays an essential role in healthcare ‘transactions’: facilitating the capture, use and sharing of clinical information to providers at the point of care. SNOMED CT also enables effective clinical information management to support analytics and research.
5. "U.S. Hospital EMR Market Share 2020" report by KLAS Research for 5,457 US acute care hospitals and Source: "Global Non-U.S. Acute Care EMR Market Share 2020 report" by KLAS Research for 6,798 Global hospital customer base, April 2020.

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Benefits Model

Using the Most Comprehensive Data Sources

- For the SNOMED CT benefits model, "***Can Electronic Medical Record Systems Transform Health Care? Potential Health Benefits, Savings, and Costs***"[6] from the RAND Corporation has been leveraged as the anchor study.
    - The RAND model and data are in the public domain, including a detailed data and modelling methodology available for general analysis and use.
    - RAND provides a relatively comprehensive and robust estimation of potential patient service outcomes in the form of productivity gains from clinical information systems and interoperability solutions. RAND also provides patient health outcomes impacts, in the form of lower morbidity and mortality for select diseases and from improved patient safety.
    - The RAND analysis is limited to the United States for an country-wide clinical information system and interoperability solution adoption based on the 2005 U.S health care spend of $2.024 trillion (i.e. 16% of the 2005 GDP).
- The data assembled by RAND[7] and the modelling framework has been adapted so that our model can provide directional or indicative benefit estimates for certain types of benefit streams at a national or sub-national health entity, and for any level of clinical information system and interoperability solution adoption.

6. Girosi et al, "Extrapolating Evidence of Health Information Technology Savings and Costs", RAND Corp. 2005. (See Extrapolating Evidence of Health Information Technology Savings and Costs | RAND). Also see associated companion studies, from RAND Corporation.
7. The majority of evidence was collected from the peer-reviewed literature. The primary search of the peer-reviewed literature was limited to articles published in the years 1995 through 2004. In total, 1,418 articles were screened using the short form, and 202 articles were coded according to taxonomies, yielding 581 preliminary findings, of which 42 were ultimately included in the models.

Benefits Model

Limitations of the RAND Study

- The RAND study has certain limitations that were considered and addressed:
  1. The study was not intended to be an estimate of savings measured against the total rates of adoption, but rather against the level of adoption relative to a 2004 baseline.
  2. It measures the potential impact of widespread adoption of health IT assuming the occurrence of "appropriate changes in health care" rather than the likely impact. This limitation deliberately does not consider present-day payment incentives that would constrain the effective utilization of health IT, even if the technology was widely adopted.
  3. In several specific parts of the RAND analysis, the savings that would accrue from the widespread adoption of health IT appear to be overstated[8].
- Each of RAND's[9] model framework/methodology was modified and enhanced.
- The clinical information system benefits estimation study developed by McKinsey and Company was leveraged to pressure test the reasonability of the patient outcomes benefits generated by our adapted, enhanced and refreshed Model 1.

8. The U.S. Congressional Budget Office indicated that the RAND analysis was based on empirical studies from the literature that found positive effects for the implementation of health IT systems; it excluded the studies, even those published in peer reviewed journals, that failed to find favorable results. This biases the estimate of the actual impact of health IT on spending.
9. The majority of evidence was collected from the peer-reviewed literature. The primary search of the peer-reviewed literature was limited to articles published in the years 1995 through 2004. In total, 1,418 articles were screened using the short form, and 202 articles were coded according to taxonomies, yielding 581 preliminary findings, of which 42 were ultimately included in the models.

Benefits Model

Application of the RAND Model Components

The red-shaded domains represent the RAND-modelled healthcare ‘transaction’ capabilities enabled by clinical information systems and interoperability solutions, used in in-patient and out-patient care settings.

The RAND Model consists of three sub-models:

1. **Productivity Gains** - the patient service outcome benefits from efficiency gains associated with the adoption of clinical information systems in both inpatient and outpatient settings.
2. **Disease Prevention Benefits** - the patient service outcome and patient health outcome benefits from disease prevention improvements resulting from select vaccination and screening protocols.
3. **Quality of Care Benefits** - select patient service outcome and patient health outcome benefits from the decision support capabilities in a clinical information system that improves patient safety.

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Benefits Model

The Structure of the SNOMED CT Benefits Model

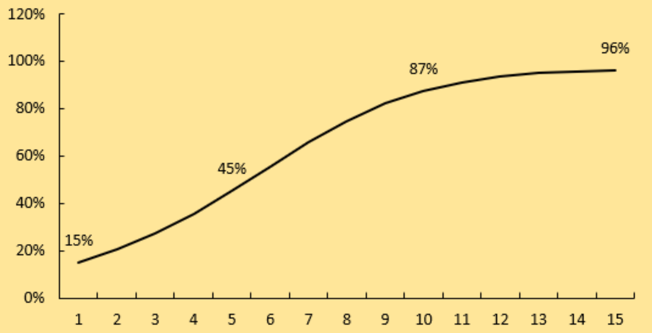
- The three SNOMED CT benefits sub-models (i.e. productivity gains, disease prevention benefits and quality of care benefits) are each structured as follows:
    1. **The Model Purpose** – Identification of the type of patient service and health benefits estimated by the model.
    2. **The Model Inputs** – Country or health entity specific information required to generate the above-mentioned benefits.
    3. **The Model Calculation Engine** – Outline of the approach, data manipulation, and assumptions made to estimate the benefits.
    4. **The Model Outputs** – Summary of financial savings, beneficial patient service and health outcomes, and corresponding GNI benefits to a country's economy.
- Further information about the calculation methodology, assumptions and approaches used in the Benefits Model is detailed in a separate 46 page Technical Document.

Benefits Model

Model 1: Select Productivity Benefits Enabled by SNOMED CT

Input Tables

1	Country spend on health care (annual):	2024.0
	Currency:	US Dollar
	Units:	Billions
2	Projected CIS adoption	
	○ Value by year	
	◉ Value by current and end adoption	
	Current	15%
	Year 5	
	Year 10	
	Year 15	97%
	Projected adoption rate	



3	Savings range low and high percentiles	
	Range low end	1%
	Range high end	67%

Update Model

1. **Model 1 Purpose:**
   - The model enables a user to estimate the potential multi-year total patient service outcomes benefits associated with deploying a SNOMED CT-embedded, integrated, clinical information system.
   - SNOMED CT is an important enabler of the integrated, clinical information system benefits.
2. **Model 1 Inputs:**
   - A User inputs the subject country's or health entity's current annual healthcare system spend in the local currency, plus the expected level of clinical information system adoption over time (5, 10 and 15 years).

Benefits Model

Model 1: Select Productivity Benefits Enabled by SNOMED CT

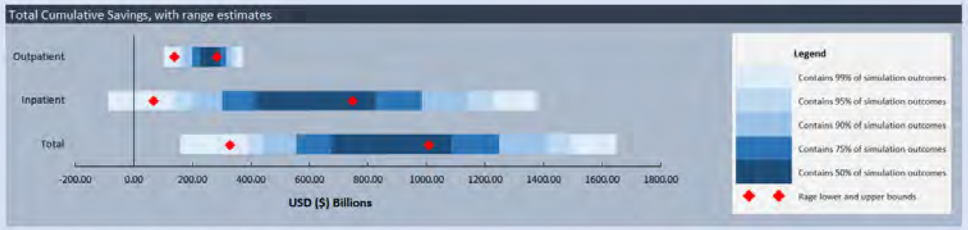
Potential Service Outcomes

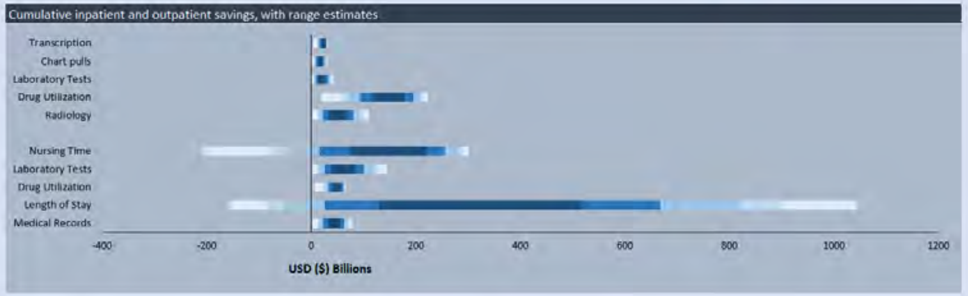
Click column heading for the savings definition.

Outpatient savings	*Potential Savings*	*Mean Yearly Savings*	*Cumulative Savings*	*Savings Year 5*	*Savings Year 10*	*Savings Year 15*
Transcription	2.36	1.61	24.08	1.19	2.10	2.27
Chart pulls	1.74	1.18	17.74	0.88	1.55	1.68
Laboratory Tests	1.94	1.32	19.81	0.98	1.73	1.87
Drug Utilization	14.71	10.01	150.22	7.41	13.13	14.19
Radiology	4.90	3.34	50.05	2.47	4.37	4.73
Inpatient savings						
Nursing Time	14.17	10.37	155.48	8.54	13.00	13.69
Laboratory Tests	5.41	3.96	59.35	3.26	4.96	5.23
Drug Utilization	4.57	3.34	50.17	2.76	4.19	4.42
Length of Stay	27.65	20.23	303.38	16.67	25.36	26.72
Medical Records	3.96	2.89	43.41	2.39	3.63	3.82
Simulation totals						
Total Outpatient	25.65	17.46	261.90	12.92	22.89	24.73
Total Inpatient	55.76	40.79	611.80	33.61	51.15	53.88
Grand Total	**$81.41B**	**$58.25B**	**$873.7B**	**$46.53B**	**$74.04B**	**$78.62B**

[1] Ranges in the simulation totals tab shows the Monte Carlo estimate generated ranges in total saving groups which will differ from summing ranges across each savings category. For more information see the 'Dice Example' sheet

☐ Show range estimates





3. **Model 1 Calculation Engine:**
   - Leverages RAND data and a modified analytical framework to create a multi-year clinical information system adoption curve and the estimated potential patient service outcome benefits that could accrue to a country or a health entity over time.
   - Converts the RAND estimated patient service outcome benefits from subject activities into a series of independent factors eliminating the need for a user to normalize for currency, GDP, population, per capita income, or other unique national characteristics.

Benefits Model

Model 1: Select Productivity Benefits Enabled by SNOMED CT

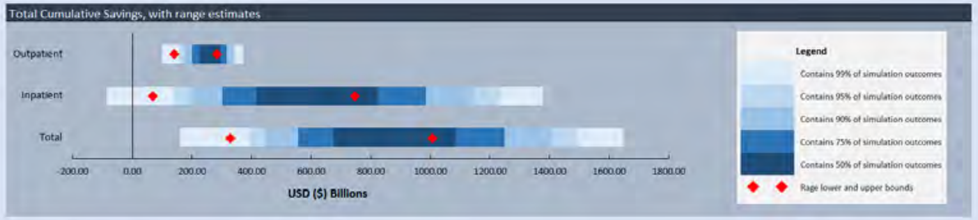
Potential Service Outcomes

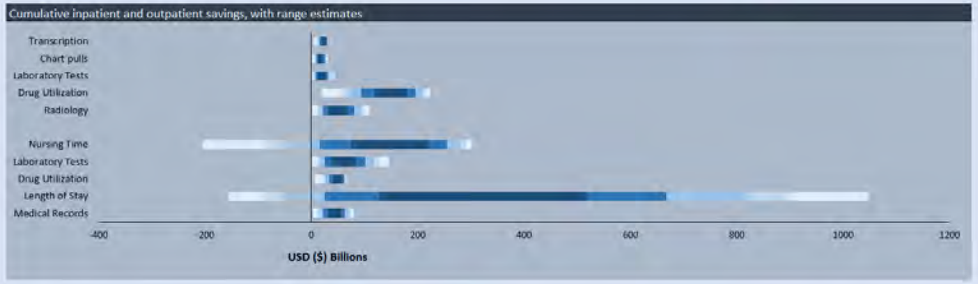
Click column heading for the savings definition

Outpatient savings	*Potential Savings*	*Mean Yearly Savings*	*Cumulative Savings*	*Savings Year 5*	*Savings Year 10*	*Savings Year 15*
Transcription	2.35, [0.87 - 2.58]	1.6, [0.59 - 1.76]	23.99, [8.88 - 26.33]	1.18, [0.44 - 1.3]	2.1, [0.78 - 2.3]	2.27, [0.84 - 2.49]
Chart pulls	1.71, [0.4 - 2.01]	1.16, [0.27 - 1.37]	17.47, [4.12 - 20.52]	0.86, [0.2 - 1.01]	1.53, [0.36 - 1.79]	1.65, [0.39 - 1.94]
Laboratory Tests	1.92, [0.29 - 2.37]	1.31, [0.2 - 1.61]	19.64, [2.98 - 24.2]	0.97, [0.15 - 1.19]	1.72, [0.26 - 2.12]	1.85, [0.28 - 2.29]
Drug Utilization	14.86, [4.59 - 16.67]	10.12, [3.13 - 11.35]	151.77, [46.9 - 170.25]	7.49, [2.31 - 8.4]	13.27, [4.1 - 14.88]	14.33, [4.43 - 16.08]
Radiology	4.91, [0.73 - 6.06]	3.34, [0.5 - 4.13]	50.15, [7.48 - 61.89]	2.47, [0.37 - 3.05]	4.38, [0.65 - 5.41]	4.74, [0.71 - 5.84]
Inpatient savings						
Nursing Time	14.28, [-10.86 - 18.28]	10.45, [-7.94 - 13.37]	156.7, [-119.12 - 200.57]	8.61, [-6.54 - 11.02]	13.1, [-9.96 - 16.77]	13.8, [-10.49 - 17.66]
Laboratory Tests	5.42, [0.73 - 6.95]	3.97, [0.53 - 5.08]	59.48, [8.02 - 76.24]	3.27, [0.44 - 4.19]	4.97, [0.67 - 6.37]	5.24, [0.71 - 6.71]
Drug Utilization	4.58, [1.68 - 5.03]	3.35, [1.23 - 3.68]	50.2, [18.44 - 55.2]	2.76, [1.01 - 3.03]	4.2, [1.54 - 4.61]	4.42, [1.62 - 4.86]
Length of Stay	27.58, [-10.8 - 39.95]	20.17, [-7.9 - 29.22]	302.58, [-118.45 - 438.36]	16.62, [-6.51 - 24.08]	25.3, [-9.9 - 36.65]	26.65, [-10.43 - 38.61]
Medical Records	3.96, [0.78 - 4.69]	2.9, [0.57 - 3.43]	43.48, [8.61 - 51.49]	2.39, [0.47 - 2.83]	3.63, [0.72 - 4.3]	3.83, [0.76 - 4.54]
Simulation totals						
Total Outpatient	25.76, [13.66 - 27.96]	17.53, [9.3 - 19.04]	263.02, [139.45 - 285.57]	12.98, [6.88 - 14.09]	22.99, [12.19 - 24.96]	24.84, [13.17 - 26.97]
Total Inpatient	55.82, [6.17 - 68.61]	40.83, [4.51 - 50.18]	612.44, [67.7 - 752.77]	33.65, [3.72 - 41.36]	51.2, [5.66 - 62.93]	53.94, [5.96 - 66.3]
Grand Total	**$81.58B, [95.17 - 31.04]**	**$58.36B, [68.09 - 22.21]**	**$875.46B, [1021.35 - 333.15]**	**$46.62B, [54.39 - 17.74]**	**$74.19B, [86.55 - 28.23]**	**$78.78B, [91.91 - 29.98]**

[1] Ranges in the simulation totals tab shows the Monte Carlo estimate generated ranges in total saving groups which will differ from summing ranges across each savings category. For more information see the 'Dice Example' sheet

☑ Show range estimates





4. **Model 1 Outputs:**
   - Provides a range of both the estimated potential annual mean and potential cumulative patient service outcome benefits in the country's local currency.
   - The distribution of benefits are estimated for the reduction in administrative and other health system costs for both Inpatient (i.e. nurse shortage, lab tests, drug utilization, length of stay and medical records savings) and Outpatient services (i.e. transcription, chart pulls, lab and radiology tests, and drug utilization savings).
   - Results are expected to be generalizable (e.g. across nations).
   - Results should be considered directional/indicative of potential benefits.

Benefits Model

Model 1: Addressing Key Limitations of the RAND Study

- The RAND study has certain limitations that we have addressed in our modelling approach to enhance the reliability of the benefits estimates generated by our models. Key limitations and their proposed solutions are as follows:
- Limitation 1 – The RAND model was not intended to be an estimate of benefits measured against the total rates of adoption, but rather against the level of adoption relative to a 2004 baseline.
- Solution 1 – Our Model 1 has been modified to provides the total gross annual benefits of the adoption rate at 5-, 10- and 15-years.
- Limitation 2 – The RAND model was based solely on empirical studies from the literature that found positive effects for the implementation of clinical information systems and interoperability solutions; it excluded studies, even those published in peer reviewed journals, that failed to find favorable results.
- Solution 2 – We have addressed this bias by:
  - Introducing estimates/data from other studies (ignored or unavailable to RAND) that show lower, zero or negative benefits, and by allowing the possibility that our estimates will have zero and negative benefits.
  - Leveraging Monte Carlo simulations to generate a range of patient benefits outcomes (from the 1^{st} to 67^{th} percentile) retaining low probability downside scenarios and discarding the top third of the upside scenarios.

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Benefits Model

Model 1: Validate the Reasonability of the Benefits Estimates

- We used the clinical information system benefit estimation study developed by McKinsey and Company for Canada Health Infoway, in 2015, to test the outputs of our Model 1.
- The RAND study defines clinical information systems as:
    1. Electronic Medical Record (EMR) including current and historical patient information.
    2. Central Data Repository (CDR), which stores the EMR information.
    3. Information technology–enabled functions such as Computerized Provider Order Entry (CPOE), which facilitates orders tied to patient information and treatment pathways.
    4. Clinical Decision Support (CDS), which provides reminders and best-practice guidance for treatment.
- The McKinsey study defines clinical information systems as:
    1. EMR, EHR, inpatient CPOE (i.e. hCPOE), and
    2. Digital health solutions (e.g. e-visits, e-booking, e-views, e-referral, e-ICU, RFID, bar-coding etc.).

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Benefits Model

Model 1: McKinsey's Study Methodology and Benefits

1. Solutions were defined based predominantly on literature review.
2. Specific modes of action (a function of the technology, or the mechanism of how it impacts the provision of healthcare: e.g. CPOE helps to reduce test spend) were attributed to each solution based on literature review.
3. Modes of action were mapped to health care settings based on literature review and available quantifiable and reliable evidence.
4. Three different care settings were defined for the model: Hospital and Mental Healthcare; Primary Care & Community and Social Care.
5. An evidence scan was completed for each solution through a literature review and research process.
6. For every benefit, a baseline reference of the Canadian healthcare costs was used to determine spending.
7. The benefit ranges were applied to the Canadian healthcare costs to determine total gross annual benefits for all technologies.

Savings from Computerized Information Systems for Canada's National Healthcare System at Target Adoption & Maturity Levels per McKinsey Study[1]

Empowered Patients	**Annual Gross Savings Range ($B)**		**Target Adoption & Maturity**
e-Visits	1.26	1.44	80%
e-Booking	0.10	0.10	90%
e-Views	0.40	0.40	80%
Remote patient care	0.90	1.18	90%
Virtual video calls	-	-	-
Chromic disease management	0.19	0.33	90%
Sub Total	**2.85**	**3.45**	-
Seamless Services			
e-Referral	0.35	0.36	75%
EMR	0.26	0.59	100%
EHR	0.74	1.09	100%
e-Prescribing	0.61	1.34	95%
hCPOE	0.69	0.78	100%
eICU	0.26	0.45	60%
Teleophthalmology	0.01	0.01	75%
Telepathology	0.04	0.04	90%
Sub Total	**2.96**	**4.66**	
Informed Care			
Patient Flow Management	0.67	1.17	90%
Transparency of clinician performance	0.56	0.72	90%
Sub Total	**1.23**	**1.89**	
Economic Prosperity			
Bar-coding	0.47	0.87	90%
RFID	0.13	0.26	90%
Vaccine Inventory Management	0.02	0.03	90%
Sub Total	**0.62**	**1.16**	-
Total	**7.64**	**11.16**	-

1. Based on 2015 Canadian National Healthcare Expenditure of $214B

Benefits Model

Model 1: Mapping Between RAND and McKinsey

RAND Categories	Annual Gross Savings Range ($B) (2)	McKinsey Categories	Annual Gross Savings Range ($B)(3)
Outpatient - Transcription	0.10 - 0.21 - 0.26	EMR and EHR	1.00 - 1.68
Outpatient - Chart pulls	0.09 - 0.21 - 0.26	EMR and EHR	
Outpatient - Laboratory tests	0.09 - 0.25 - 0.34	EMR and EHR	
Outpatient - Drug utilization	0.73 - 1.57 - 1.95	e-Prescribing	0.61 - 1.34
Outpatient - Radiology	0.15 - 0.52 - 0.76	EHR	
Outpatient - Subtotal	**1.16 - 2.76 - 3.57**		
Inpatient - Nurse time	(1.05) - 0.84 - 1.75	EMR and EHR	
Inpatient - Laboratory tests	0.19 - 0.63 - 0.93	EMR and EHR	
Inpatient - Drug utilization	0.26 - 0.49 - 0.57	hCPOE, vaccine inventory management, bar-coding	1.18 - 1.68
Inpatient - Reduction in Length of Stay	0.49 - 4.73 - 7.25	Chronic disease management, patient flow management, transparency of clinician performance	1.43 - 2.22
Inpatient - Medical records	0.16 - 0.42 - 0.56	EMR and EHR	
Inpatient - Subtotal	**0.05 - 7.11 - 11.06**		
Total	**1.21 - 9.87 - 14.63**		**4.22 - 6.92**
Total Inpatient	**1.82 - 2.76 - 3.20**		
Total Outpatient	**2.42 - 7.10 - 9.80**		
Grand Total	**5.05 - 9.87 - 12.59**		

- Benefits excluded in mapping $3.5 - 4.2B.
- Functionalities and corresponding benefits that do not map from the McKinsey to the RAND study are:
  - e-visits ($1.26 – 1.44B),
  - e-booking ($0.10B),
  - e-views ($0.40B),
  - remote patient care ($0.90 -1.18B),
  - e-referral ($0.35 - 0.36B),
  - e-ICU ($0.26 – 0.45B)
  - teleophthalmology ($0.01B),
  - telepathology ($0.04B),
  - RFID ($0.13-0.26B).

2. Saving ranges generated from Model 1 (Productivity Gains) based on Canadian National Healthcare Expenditure of $214B in 2015 at a targeted adoption of 100%.
3. Saving ranges based on Canadian National Healthcare Expenditure of $214B in 2015 at a targeted adoption rate of 100% for EHR, EMR, inpatient CPOE.

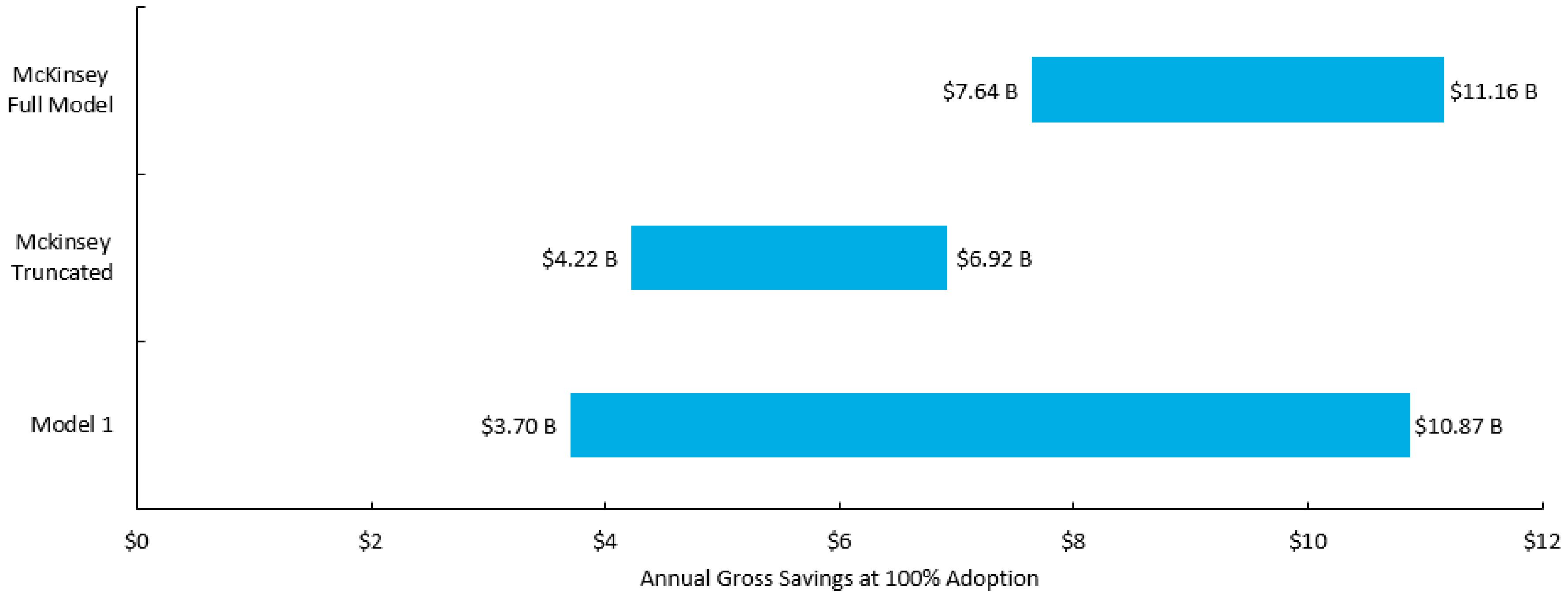
Benefits Model

Model 1: Mapping the Benefits to the McKinsey Study

- The RAND study had minimal line of sight into the new generation of digital health solutions (e.g. e-visits, e-booking, e-views, e-referral, e-ICU, RFID, bar-coding etc.) in 2005.
- The savings from these capabilities were not incorporated into the RAND study and are therefore not captured in our Model 1.
- Given that the McKinsey study took place in 2015, it was able to estimate savings from the new generation of digital health solutions (e.g. e-visits, e-booking, e-views, e-referral, e-ICU, RFID, bar-coding etc.).

Benefits Model

Model 1: Comparison of Model 1 and McKinsey Results

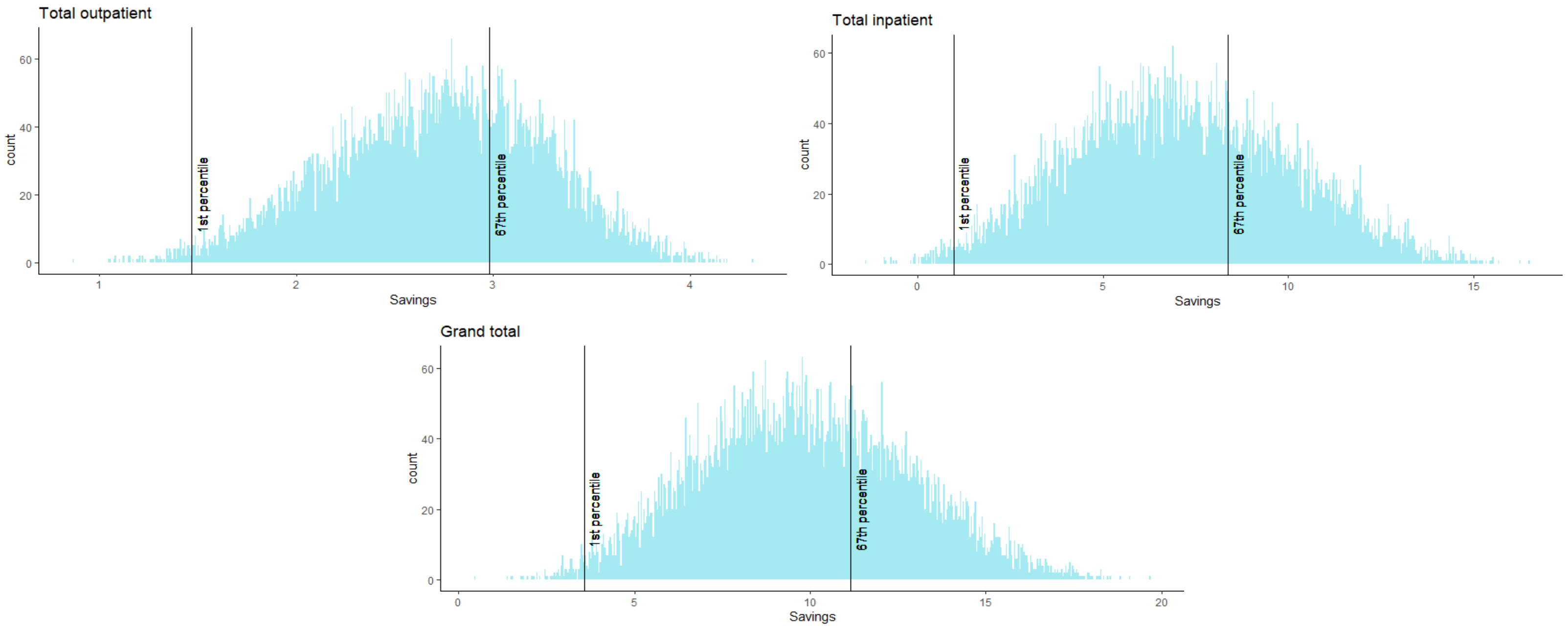


- When Model 1 is run with the same parameters as the McKinsey model (i.e. 2015 Canadian national healthcare expenditure of $214B) the results are generally consistent.
- The greater dispersion of Model 1 is by design to allow for a broader range of outcomes across nations and healthcare entities.

4. The McKinsey truncated benefits remove the benefits from the digital solutions (e.g. e-visits, e-booking, e-views, e-referral, e-ICU, RFID, bar-coding etc.).

Model 1: Benefit Estimates with ACI[5]

- Each model run generates 10k simulations of the benefits for annual inpatient, outpatient and total savings at 100% adoption.
- An asymmetric confidence interval of the 1st to 67th percentiles was selected from the Monte Carlo simulations in order to retain low probability downside scenarios and discard the top third of the lower probability upside scenarios.



5. ACI = Asymmetric Confidence Interval - An asymmetric confidence interval is one where the point estimate isn't the center of the confidence interval. For example, the point estimate may be 0.2 but the confidence interval is {0,0.8} because it happens to be that the values can not be less than zero. There are a few reasons a confidence interval could be asymmetric: Random error is included; the data has been transformed; positive or negative systemic bias incorporated.

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Benefits Model

Model 2: Select Disease Prevention Benefits Enabled by SNOMED CT

Patient health parameters

1	Preventative services to include	
	☑ Influenza vaccination ☑ Breast cancer screening	
	☑ Pneumococcal vaccination ☑ Cervical cancer screening	
	☑ Colorectal cancer screening	
2	Total annual deaths per disease	#
	Influenza	20,000
	Pneumococcal diseases	40,000
	Breast cancer	41,394
	Cervical cancer	4,100
	Colorectal cancer	57,000
3	Population over 65 with annual diagnosis	#
	Influenza	1,220,641
	Pneumococcal diseases	1,389,907
4	Proportion vaccinated	%
	Influenza vaccination	65%
	Pneumococcal vaccination	53%
5	Proportion screened	%
	Breast cancer	70%
	Cervical cancer	85%
	Colorectal cancer	34%
6	CIS Adoption	%
	Current adoption	15%
	Future adoption	97%

Submit

1. **Model 2 Purpose:**
   - The model enables a user to estimate the potential patient service outcomes and patient health outcome benefits from five disease prevention opportunities associated with deploying an integrated clinical information system, specifically vaccination and screening protocols.

2. **Model 2 Inputs:**
   - The User inputs the non-compliant subject population across five preventive health services protocols, including:
     1. influenza vaccination,
     2. pneumococcal vaccination,
     3. screening for breast cancer,
     4. screening for cervical cancer,
     5. screening for colorectal cancer.

Note: the RAND study also included benefit estimates for a number of chronic diseases (e.g. diabetes, COPD and Congestive Heart Failure), however their calculation method is not easily generalizable across multiple countries, so was not included in this study

SNOMED International

Benefits Model

Model 2: Select Disease Prevention Benefits Enabled by SNOMED CT

Summary of Estimated Incremental Patient Health Benefits for Five Preventative Services

Influenza Vaccination	Low	High
Reduced bed days	107,616	477,231
Reduced workdays missed	18,956	84,060
Deaths avoided	461	2,134

Pneumococcal Vaccination	Low	High
Reduced bed days	301,229	615,801
Reduced workdays missed	21,915	44,801
Deaths avoided	628	1,284

Screening for breast cancer	Low	High
Deaths avoided	1,660	2,292

Screening for cervical cancer	Point estimate
Deaths avoided	338
Life years gained	8,437

Screening for colorectal cancer	Low	High
Deaths avoided	1,322	1,461
Life years gained	37,664	41,643

3. **Model 2 Calculation Engine:**
   - The model estimates the potential patient outcome benefits of moving from non-compliance to compliance for the target population (e.g. in the case of the influenza vaccination the non-compliant population age 65+).
   - The potential patient service outcome and patient health outcome benefits of increased compliance are calculated based on the RAND methodology.
   - Increased use of clinical information systems and interoperability solutions is modelled as the driver for increased compliance with the disease prevention protocols.

4. **Model 2 Outputs:**
   - Provides potential patient service outcome benefits (i.e. reduction in workdays missed and reduction in bed days) and patient health outcome benefits (i.e. deaths avoided, and life-years gained) from improving compliance to the protocols across five diseases.
   - Results are expected to be generalizable (e.g. across nations).
   - Results should be considered directional/indicative of potential benefits.

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Benefits Model

Model 2: Addressing Key Limitations[1] of the RAND Study

- The RAND study has certain limitations that we have addressed in our modelling approach to enhance the reliability of the benefits estimates generated by our models. Key limitations and their proposed solutions are as follows:
- **Limitation 1** - The RAND study assumes 100% compliance by the affected groups to clinical information system supported reminders for influenza and pneumococcal vaccination as well as breast, cervical and colorectal cancer screening. This is not a sensible or realistic assumption as there are several reasons why patients would not take the vaccination or get screened despite automated electronic reminders (e.g. anti-vaxxers, travel cost from remote locations, apathy etc.)
- **Solution 1** – Our Model 2 assumes a 25.3% increase in the screening and vaccination compliance from the start rate, in response to clinical information system supported reminders. The model also includes a ceiling on the upper end of the vaccination and screening compliance at 95%. We arrived at a 25.3% growth rate by using a meta-analysis which averaged over 42 studies.
- **Limitation 2** – The RAND report calculates the efficacy of screening and vaccinations using data from 2005 and prior.
- **Solution 2 –** We've refreshed these estimates with recent sources where possible and used the recent sources to generate statistical ranges at a 95% confidence interval. This refresh of data sources resulted in more conservative efficacy rates than the ones used by RAND.

1. For example, as indicated by the U.S. Congressional Budget Office , the RAND study estimates health IT benefits based on certain assumptions that in some cases are not practical or pragmatic.

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Benefits Model

Model 3: Select Patient Safety Benefits Enabled by SNOMED CT

Input Tables

1	Inpatient hospital days	
	Number of patient days	167,199,099
	[i] Percentage of patient days 65+	
2	Outpatient Visits	
	Number of visits	823,541,999
	[i] Percentage of visits 65+	
3	Confidence interval	
	Range low end	1%
	Range high end	67%
4	CPOE Adoption	
	Current adoption	4%
	Future adoption	74%
		Submit

[i] Optional parameter

1. **Model 3 Purpose:**
   - The model enables a user to estimate the potential patient service outcome and patient health outcome benefits from the deployment and adoption of integrated and Computerized Provider Order Entry (CPOE) functionality in both inpatient and outpatient settings.
   - Increased safety results largely from the alerts and reminders generated by CPOE systems for medications. Such systems provide immediate information to physicians (e.g. warning about a potential adverse reaction with the patient's other drugs).
2. **Model 3 Inputs:**
   - The User inputs the total annual number of national or entity inpatient patient days, outpatient patient visits, the desired confidence interval, and the CPOE adoption levels.

Benefits Model

Model 3: Select Patient Safety Benefits Enabled by SNOMED CT

Inpatient Benefits	Reduction in Adverse Drug Events	Bed Days Reduced	Deaths Avoided
Panel A: Incremental benefits			
0-64	38,723	120,486	781
65+	62,250	193,690	1,256
Total	100,974	314,176	2,037
Panel B: Cumulative benefits			
0-64	40,750	126,792	822
65+	65,508	203,826	1,322
Total	106,258	330,618	2,144

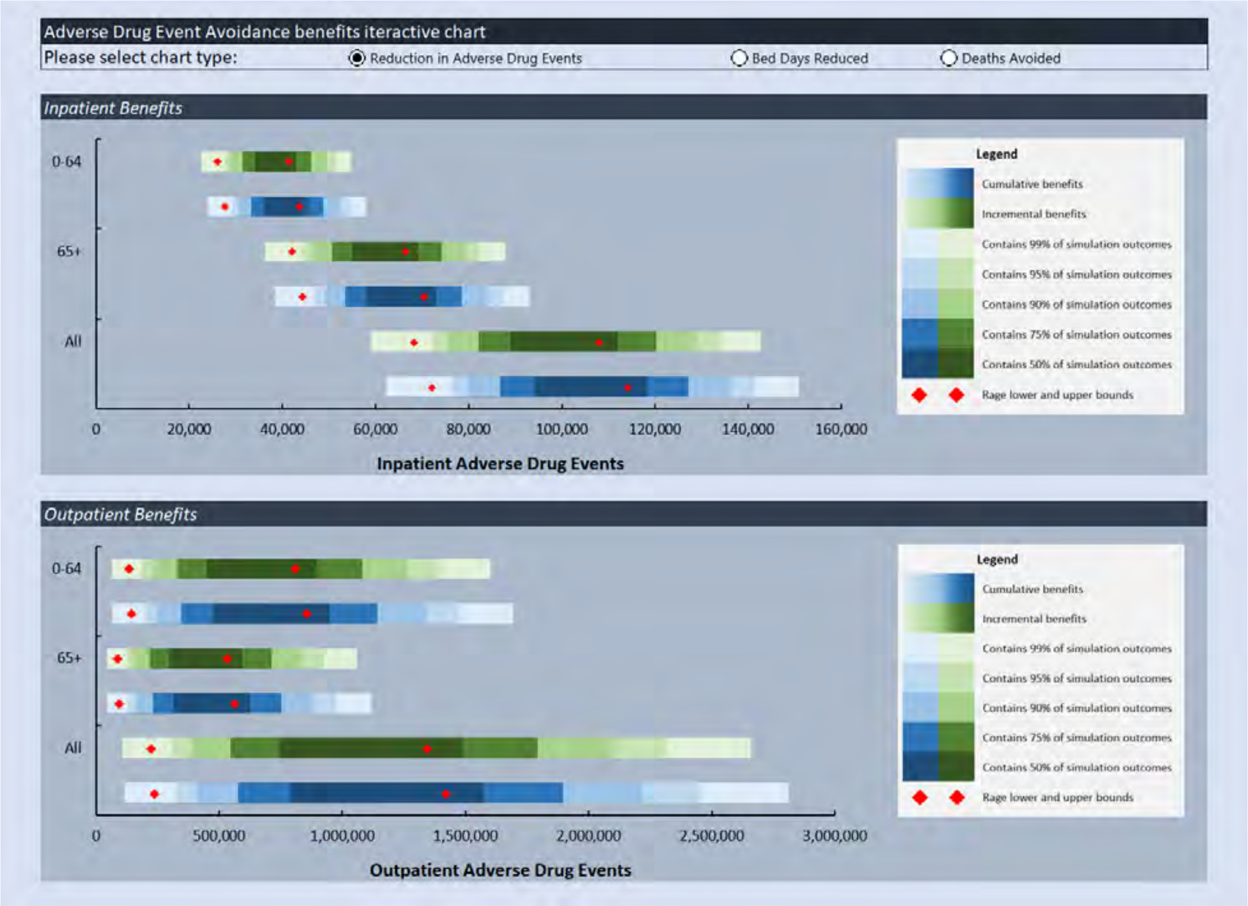
Outpatient Benefits	Reduction in Adverse Drug Events	Bed Days Reduced	Deaths Avoided
Panel A: Incremental benefits			
0-64	650,294	3,698,004	3,850
65+	428,659	2,437,639	2,538
Total	1,078,953	6,135,644	6,387
Panel B: Cumulative benefits			
0-64	684,326	3,891,535	4,051
65+	451,092	2,565,210	2,670
Total	1,135,418	6,456,745	6,721

3. **Model 3 Calculation Engine:**

- The model estimates the potential patient service outcome and patient health outcome benefits of deploying CPOE across a nation or an entity (e.g. hospital or health authority) thereby reducing the number of adverse drug events (ADEs) in both inpatient and outpatient settings.
- The inpatient component of the model takes the total number of inpatient hospital days for a nation or entity and then converts them into susceptible patient days.
- The outpatient component of the model takes the number of total annual outpatient visits and estimates the number of susceptible visits that present a risk of an ADE.
- The model then estimates the number of preventable ADEs with current and future CPOE adoption. The model uses the difference in preventable ADEs to estimate reduced bed days and deaths avoided.
- Monte Carlo simulations are used to generate range estimates of reduced ADEs, reduced bed days and deaths avoided in response to increased CPOE adoption.

Benefits Model

Model 3: Select Patient Safety Benefits Enabled by SNOMED CT



4. **Model 3 Outputs:**
   - Provides potential patient service outcome and patient health outcome benefits (i.e. deaths avoided, as well as reduced ADEs, reduced bed days).
   - There could also be significant reduction in litigation and punitive damages as a result of the reduction in ADEs. However, we could not identify any studies that we could leverage to quantify the financial benefits.
   - Results are expected to be generalizable (e.g. across nations).
   - Results should be considered directional/indicative of potential benefits.

Benefits Model

Model 3: Addressing Key Limitations of the RAND Study

- **Limitation 1** – The RAND report calculated the reduction in inpatient preventable ADEs, patient bed days, and deaths avoided based on data prior to 2005. Also, the RAND model provided only point estimates for these benefits.
- **Solution 1 –** Model 3 leverages data from more recent studies to estimate inpatient preventable ADEs, reduction in inpatient preventable ADEs from the deployment of CPOE, patient bed days reduced, and deaths avoided. It also leverages Monte Carlo simulations to generate ranges of patient benefits outcomes at varying confidence level intervals.
- **Limitation 2**: In estimating the number of preventable ADEs, the RAND study first estimated the number of serious medical errors (SMEs) per 1000 susceptible patient days. It then assumes that half of the SMEs lead to preventable ADEs.
- **Solution 2:** Model 3 leverages recent data points for inpatient preventable ADEs per 1000 from our literature search. These recent data points are estimated directly by analyzing patient records. Therefore, the inpatient preventable ADEs data used by Model 3 is derived in a more direct way then the indirect approach used by RAND to calculate inpatient preventable ADEs.

Benefits Model

Model 3: Addressing Key Limitations of the RAND Study

- **Limitation 3** – The RAND report implicitly uses 100% CPOE adoption. The report also uses point estimates for the fraction of ADEs that are preventable and the reduction in preventable ADEs with CPOE.
- **Solution 3** – The outpatient section of Model 3 uses client input parameters on CPOE adoption making the estimates more realistic. Also, the model uses data from more recent studies, a number of which were not available to RAND, to estimate outpatient preventable ADEs, reduction in outpatient preventable ADEs from the deployment of CPOE, patient bed days reduced, and deaths avoided. Lastly, the model uses Monte Carlo simulations to generate a range of potential benefits outcomes at varying confidence interval levels.

Benefits Model

Benefits to Costs Multiple (BCM)[1] and Internal Rate of Return (IRR)[2]

- Six studies provided sufficient granularity of both the benefits and costs of clinical information system implementations to conduct both Benefits to Costs Multiple and Internal Rate of Return analysis.
  1. Girosi et al, "*Extrapolating Evidence of Health Information Technology Savings and Costs*", RAND Corp. 2005. The anchor study for most of our analysis. (See Extrapolating Evidence of Health Information Technology Savings and Costs | RAND)
  2. Booz Allen Hamilton, "*Canada Health Infoway's 10-Year Investment Strategy – Pan Canadian Electronic Health Record*" Canada Health Infoway, March 2005. No longer available online.
  3. Walker et al, "The Value Of Health Care Information Exchange And Interoperability". Health Affairs, Vol 24., No. Suppl 1: Web Exclusives, 2005. (See The Value Of Health Care Information Exchange And Interoperability | Health Affairs).
  4. Sprivulis et al., "The Economic Benefits of Health Information Exchange Interoperability for Australia" Australian Health Review, 31(4):531-9 Dec. 2007. (see (PDF) The Economic Benefits of Health Information Exchange Interoperability for Australia (researchgate.net).
  5. Sentara Healthcare, "*Nicholas E. Davies Award, 2010 Program, Organizational Healthcare Full Application*", May 2010. No longer available online.
  6. McKinsey and Company, "*Methodology to Assess the Economic Impact and Potential of Digital Health Solutions on the Canadian Healthcare System*" Canada Health Infoway, October 2015. (See https://www.infoway-inforoute.ca/en/component/edocman/3258-methodology-to-assess-the-economic-impact-and-potential-of-digital-health-solutions-on-the-canadian-health-care-system/view-document?Itemid=101).

1. Benefits to Costs Multiple (BCM) BCM is a simple multiple of gross benefits to costs (total benefits/total costs, both OPEX and CAPEX) there is no discounting of benefits or costs to the present.
2. IRR is the internal rate of return on an investment or project. It is the "annualized effective compounded return rate" or rate of return that sets the net present value of all cash flows (both positive and negative) from the investment equal to zero. The term internal refers to the fact that the calculation excludes external factors, such as the risk-free rate, inflation, the cost of capital, or financial risk. The method may be applied either ex-post or ex-ante. Applied ex-ante, the IRR is an estimate of a future annual rate of return. Applied ex-post, it measures the actual achieved investment return of an historical investment.

Benefits Model

Approach to Calculating BCM and IRR Factors

- Limitations to the approach to calculating BCM and IRR estimates for each study
  - The studies leveraged for the BCM and IRR analysis were conducted at different periods and each study had a somewhat different methodology and analysis timeline to estimate the clinical information system benefits and costs. Therefore, some simplifying assumptions were made to ensure the cross comparability of BCM and IRR estimated factors generated.
  - Some studies provided benefit/cost estimates for multiple scenarios, while others provided information to calculate just the “Most Likely Scenario”.

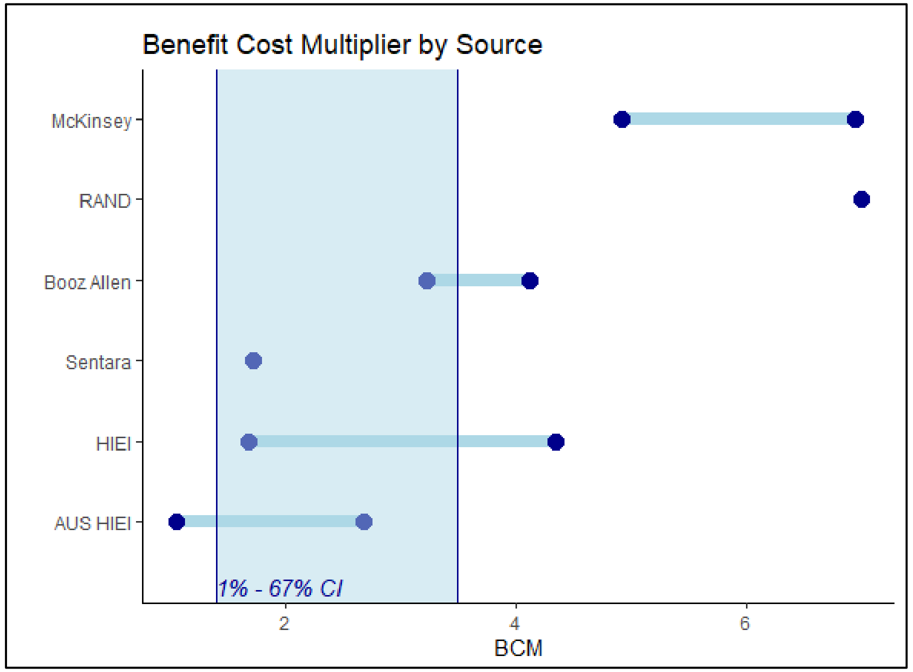
- Simplifying assumptions made:
  1. The timeline of all studies was normalized to 20 years. Annual benefits, OPEX costs and CAPEX were assumed to be for a clinical information system and interoperability solution deployment. Study specific normalizations were made, as necessary.
  2. None (0%) of the annual benefits were recognized in year 1 as the implementation team would be focused on planning, and early-stage implementation activities in year 1. 33% were recognized in year 2, 66% in year 3 and 100% in year 4.
  3. 33% of OPEX (costs) were recognized in year 1 as there would be some OPEX incurred during the planning, and early-stage implementation phases. The OPEX was increased to 66% in year 2 and then to 100% by year 3.
  4. Total implementation CAPEX was spread evenly over years 1 to 3 at the rate of 33% per year.

Benefits Model

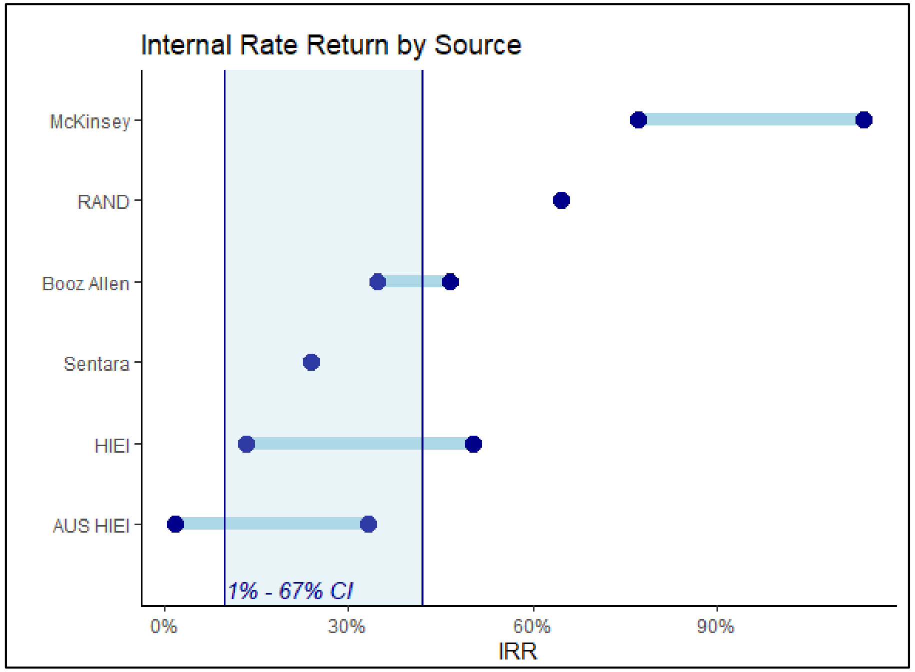
Approach to Calculating BCM and IRR Factors

Range Calculation Methodology

- A 1-67% confidence interval[1] (CI) of the BCM and IRR factors was constructed.



1-67% Confidence Interval: 1.4 – 3.5



1-67% Confidence Interval: 10% - 42%

1. A 1-67% confidence interval was selected to retain the low probability downside scenarios and discards the top third of upside scenarios. This asymmetric confidence interval helps filter out any upward bias that still may be in the model.

Benefits Model

BCM & IRR Estimates by Study for Clinical Information System Deployments

Study	BCM	IRR
1. **RAND** - Extrapolating Evidence of HEALTH Information Technology Savings and Costs.	▪ Most Likely Scenario – 7.0	▪ Most Likely Scenario – 64%
2. **Booz Allen** - Canada Health Infoway's 10-Year Investment Strategy – Pan Canadian EHR.	▪ Low Scenario – 3.2 ▪ High Scenario – 4.1	▪ Low Scenario – 35% ▪ High Scenario – 47%
3. **The Value Of Health Care Information Exchange And Interoperability.**	▪ Low Scenario – 1.7 ▪ Most Likely Scenario – 3.4 ▪ High Scenario – 4.4	▪ Low Scenario – 13% ▪ Most Likely Scenario – 37% ▪ High Scenario – 50%
4. **The Economic Benefits of Health Information Exchange Interoperability for Australia.**	▪ Low Scenario (1) – 1.1 ▪ Low scenario (2) – 1.3 ▪ Most Likely Scenario – 2.0 ▪ High Scenario (1) – 2.6 ▪ High Scenario (2) – 2.7	▪ Low Scenario (1) – 2% ▪ Low scenario (2) – 8% ▪ Most Likely Scenario – 20% ▪ High Scenario (1) – 29% ▪ High Scenario (2) – 33%
5. **Sentara Healthcare eCare System Business Case.**	▪ Most Likely Scenario – 1.7	▪ Most Likely Scenario – 24%
6. **McKinsey** - Canada Health Infoway - Methodology to assess the economic impact and potential of digital health solutions on the Canadian healthcare system.	▪ Low Scenario – 4.9 ▪ High Scenario – 6.9	▪ Low Scenario – 77% ▪ High Scenario – 114%
Range at a 1-67% Confidence Interval (CI) for not normal distributed small sample	▪ **1.4 – 3.5**	▪ **10% - 42%**

Benefits Model

Breakeven Analysis Model

Cost Parameters

Use Recommended Parameters		
☐ Extending SNOMED CT ☐ Language Translation ☐ Mapping Legacy		
1	Membership Costs	
	Licensing cost estimation method:	Manual Entry ($ USD)
	By Country	
	By GNI ($M USD)	
	Manual Entry ($ USD)	5,400,000.00
	CONVERSION: Local currency to USD	1
2	Core Operations	
	Num FTEs	2
	FTE Salary	100,200
	Salary Overhead Load Factor	2
	Travel Allocation	5,000
3	Investment in Tools	
	User's Estimate	5,000,000
4	Reference Set Development	
	Number of Ref Sets	50
	Days per set	5
	Daily Wage	1,000
5	Extending SNOMED CT	
	Number of concepts	1,350
	Avg. modelling productivity	2
	Hourly wage	100
	QA factor	2
6	Language Translation	
	Number of concepts	-
	Translator Hourly Wage	100
	Average Translator Productivity	2
	Deduction? (in local currency units)	
7	Mapping Legacy Terminologies	
	Number of concepts	16,874
	Average mapping productivity	20
	Hourly Wage	100
	QA Factor	2
		Update Model

Total Costs

1	Membership Costs	$ 81,000,000
2	Core Operations	$ 305,600
3	Investment in Tools	$ 5,000,000
4	RefSet Development	$ 250,000
5	Extension Costs	$ 135,000
6	Language Translation	-
7	Mapping Legacy Terminologies	168,740
	Total Costs of Implementation	86,859,340
	Breakeven Percentage of Benefits	**0.010%**

- The breakeven analysis model is a tool designed to compute the percentage of cumulative productivity benefits that must be realized in order to break even on the license and implementation costs of a SNOMED CT.
- The model user can estimate seven different cost estimates associated with a SNOMED CT license[1]:
  1. Membership costs
  1. Core operations
  2. Investment in tools
  3. Reference set development
  4. Extension costs
  5. Language translation
  6. Mapping legacy terminologies
- Costs are estimated in local currency units.
- In this example, we estimate the costs of implementing a SNOMED CT license in the US to be $87M USD, and our Model 1 cumulative benefits to be $875.8B USD giving us a breakeven percentage of 0.01%.

1. Cost categories are taken from the Gevity Study "Building the Business Case for SNOMED CT"

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Benefits Model: Studies Reviewed

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The global language of healthcare

Benefits Model - Studies Reviewed

	Report Title	Author(s)	Link/Source
1	Can Electronic Medical Record Systems Transform Health Care? Potential Health Benefits, Savings, And Costs	Richard Hillestad, James Bigelow, Anthony Bower, Federico Girosi, Robin Meili, Richard Scoville, and Roger Taylor - RAND	https://www.healthaffairs.org/doi/pdf/10.1377/hlthaff.24.5.1103
2	Canada Health Infoway's 10-Year Investment Strategy – Pan Canadian Electronic Health Record (EHR)	Booz Allen	No longer available online
3	The Value From Investments In Health Information Technology At The U.S. Department Of Veterans Affairs	Colene M. Byrne, Lauren M. Mercincavage, Eric C. Pan, Adam G. Vincent, Douglas S. Johnston, and Blackford Middleton	https://www.healthaffairs.org/doi/full/10.1377/hlthaff.2010.0119
4	Canada Health Infoway - Methodology to assess the economic impact and potential of digital health solutions on the Canadian healthcare system	McKinsey & Company	https://www.infoway-inforoute.ca/en/component/edocman/resources/reports/benefits-evaluation/3260-economic-benefit-model-walkthrough-and-detailed-calculations?Itemid=101
5	Effect of Computerized Physician Order Entry and a Team Intervention on Prevention of Serious Medication Errors	D W Bates, L Black ford Leape, D J Cullen, N Laird, L A Petersen, J M Teich, E Burdick, M Hickey, S Kleefield, B Shea, M Vander Vliet, D L Seger	https://pubmed.ncbi.nlm.nih.gov/9794308/
6	Return on Investment for EMR: A Retrospective Analysis of Five Medical Practices	By Kenneth M. Hekman, MBA, FACMPE	http://www.providersedge.com/ehdocs/ehr_articles/ROI_for_EMR-A_Retrospective_Analysis_of_5_Medical_Practices.pdf
7	A Cost-Benefit Analysis of Electronic Medical Records in Primary Care	Samuel J. Wang, MD, PhD, Blackford Middleton, MD, MPH, MSc, Lisa A. Prosser, PhD, Christiana G. Bardon, MD, Cynthia D. Spurr, RN, MBA, Patricia J. Carchidi, RN, MSN, Anne F. Kittler, Robert C. Goldszer, MD, MBA, David G. Fairchild, MD, MPH, Andrew J. Sussman, MD, MBA, Gilad J. Kuperman, MD, PhD, David W. Bates, MD, MSc	https://www.amjmed.com/action/showPdf?pii=S0002-9343%2803%2900057-3

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	Report Title	Author(s)	Link/Source
8	The Value Of Health Care Information Exchange And Interoperability	Jan Walker, Eric Pan, Douglas Johnston, Julia Adler-Milstein, David W. Bates, and Blackford Middleton - Center for IT Leadership	https://www.healthaffairs.org/doi/pdf/10.1377/hlthaff.W5.10
9	The Value of Electronic Health Records in Solo or Small Group Practices	Robert H Miller, Christopher West, Tiffany Martin Brown, Ida Sim, Chris Ganchoff	https://www.healthaffairs.org/doi/10.1377/hlthaff.24.5.1127
10	Reviewing the Benefits and Costs of Electronic Health Records and Associated Patient Safety Technologies	Menachemi, Nir; Brooks, Robert	https://www.deepdyve.com/lp/springer-journals/reviewing-the-benefits-and-costs-of-electronic-health-records-and-9sW0mBMyFm
11	Benefiting from Ambulatory EHR Implementation: Solidarity, Six Sigma, and Willingness to Strive	Michael H. Zaroukian, MD, PhD, FACP; and Arlene Sierra, MPA	https://pdfs.semanticscholar.org/7a1a/c83ab493a90652e6c39321bb0d2880008ad4.pdf
12	Deviation-Based Cost Modeling: A Novel Model to Evaluate the Clinical and Economic Impact of Clinical Pathways	Tsafrir Vanounou MD, MBA, Wande Pratt, BA, Josef E. Fischer, MD, FACS, Charles M. Vollmer Jr, MD, FACS, Mark P. Callery, MD, FACS	https://www.sciencedirect.com/science/article/abs/pii/S1072751507000762
13	The Value of Electronic Health Records with Decision Support	Rainu Kaushal, M.D., M.P.H., and Lisa M. Kern, M.D., Weill - Cornell Medical College	https://books.google.ca/books?hl=en&lr=&id=cZZhAgAAQBAJ&oi=fnd&pg=PT288&dq=estimating+national+benefits+of+EHR&ots=T-6UuyP2qL&sig=OXaw0B9JafeWktJ9VeyYiiiXFMA#v=onepage&q=estimating%20national%20benefits%20of%20EHR&f=false
14	Reducing clinical costs with an EHR: investments in performance management are essential to realizing the full benefits of an EHR system--including reduced costs and improved quality of care	Doug Thompson, Ferdinand Velasco, David Classen and Robert J. Raddemann	https://go.gale.com/ps/anonymous?id=GALE%7CA243277528&sid=googleScholar&v=2.1&it=r&linkaccess=abs&issn=07350732&p=AONE&sw=w
15	Benefits and drawbacks of electronic health record systems	Nir Menachemi and Taleah H Collum	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3270933/

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16	From promise to reality: achieving the value of an EHR: realizing the benefits of an EHR requires specific steps to establish goals, involve physicians and other key stakeholders, improve processes, and manage organizational change	Beverly Bell and Kelly Thornton	https://go.gale.com/ps/anonymous?id=GALE%7CA252005722&sid=googleScholar&v=2.1&it=r&linkaccess=abs&issn=07350732&p=AONE&sw=w
17	Semantic interoperability, data collation (sharing)		https://www.researchgate.net/publication/51616286_Integrating_clinical_research_with_the_Healthcare_Enterprise_From_the_RE-USE_project_to_the_EHR4CR_platform/link/00463532094a90fb90000000/download
18	Using electronic health records to save money	Yosefa Bar-Dayan, Halil Saed, Mona Boaz, Yehudith Misch, Talia Shahar, Ilan Husiascky, and Oren Blumenfeld	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3715342/
19	Cost-Benefit Analysis of Electronic Medical Record System at a Tertiary Care Hospital	Choi, Jong Soo, Woo Baik Lee, and Poong-Lyul Rhee	Cost-Benefit Analysis of Electronic Medical Record System at a Tertiary Care Hospital
20	Benefits Deep Dive into Cerner Millennium Implementation	Author: Sarah Overton (Benefits Lead, HSCIC) Co Author: Patrick Brady (Programme Manager, Barts Health NHS Trust) Co Author: Alison Ellis (Benefits Analyst, HSCIC)	https://confluence.ihtsdotools.org/download/attachments/57808738/Barts_Health_Case_Study.pdf?api=v2
21	Clinical Decision Support Systems (CDSS) for preventive management of COPD patients	Filip Velickovski, Luigi Ceccaroni, Josep Roca, Felip Burgos, Juan B Galdiz, Nuria Marina, and Magí Lluch-Ariet	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4255917/
22	Effect of an electronic medical record alert for severe sepsis among ED patients	Navaneeth Narayanan, Kendall Gross, Megan Pintens, Christopher Fee, Conan MacDougall	https://www.sciencedirect.com/science/article/abs/pii/S0735675715008463
23	Economic and efficiency benefits from OUH Electronic Prescribing and Medicines Administration, after full implementation in March 2015	Clare Cape	https://www.ouh.nhs.uk/patient-guide/documents/epr-case-study.pdf
24	An examination of EHR implementation impacts on patient-flow	Jennifer Bushelle-Edghill, J.Lee Brown Su Dong	https://www.sciencedirect.com/science/article/abs/pii/S2211883716300879?via%3Dihub

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25	Benefits of using an electronic health record	Robin Hoover, MSN-HCI, RN	https://journals.lww.com/nursing/fulltext/2016/07000/Benefits_of_using_an_electronic_health_record.6.aspx
26	Clinical Pathways: Management of Quality and Cost in Oncology Networks in the Metastatic Colorectal Cancer Setting	Peter G. Ellis, Bert H. O’Neil, Martin F. Earle, Stephanie McCutcheon, Hans Benson, Melinda Krebs, Kathy Lokay, and Amanda Barry	https://ascopubs.org/doi/full/10.1200/JOP.2016.019232
27	Clinical Pathways and the Patient Perspective in the Pursuit of Value-Based Oncology Care	Peter G. Ellis, Bert H. O’Neil, Martin F. Earle, Stephanie McCutcheon, Hans Benson, Melinda Krebs, Kathy Lokay, and Amanda Barry	https://ascopubs.org/doi/full/10.1200/EDBK_174794
28	A Multifaceted Intervention to Improve Primary Care Radiology Referral Quality and Value in Canterbury	Kieran Holland, Graham McGeoch, Carolyn Gullery	https://pubmed.ncbi.nlm.nih.gov/28449017/
29	Kings fund - Developing accountable care systems Lessons from Canterbury, New Zealand	Anna Charles	https://www.kingsfund.org.uk/sites/default/files/2017-08/Developing_ACSs_final_digital_0.pdf
30	Clinical Data sharing, standardization of data		https://confluence.ihtsdotools.org/pages/viewpage.action?pageId=45525508&preview=/45525508/50597033/SNOMED_CT_Expo_Poster_201707_BCH.pdf
31	Decreasing triage time: effects of implementing a step-wise ESI algorithm in an HER	Stephen Villa, Ellen J Weber, Steven Polevoi, Christopher Fee, Andrew Maruoka, Tina Quon	https://academic.oup.com/intqhc/article/30/5/375/4985498
32	Novel Application of a Clinical Pathway Embedded in the Electronic Health Record to Improve Quality of Care in Patients Hospitalized With Acute Decompensated Heart Failure	Sunil E Saith, Tony Mathews, David Rhee, Amit Patel, Yu Guo, Jonathan S Austrian, Frank M Volpicelli, and Stuart D Katz	https://www.ahajournals.org/doi/abs/10.1161/circ.138.suppl_1.10718
33	A Vision for a Person-Centered Health Information System (PCHIS) - Discussion Document	Keith Horvath, Patricia Sengstack, Frank Opelka, Andrea Borondy Kitts, Peter Basch, David Hoyt, Alexander Ommaya, Pamela Cipriano, Kensaku Kawamoto, Harold L. Paz, J. Marc Overhage	https://nam.edu/a-vision-for-a-person-centered-health-information-system/

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34	SNOMED CT Generating Cardiology Key Performance Indicators (KPIs)	Md Khadzir Sheikh Ahmad, Ministry of Health Malaysia (MY	https://drive.google.com/file/d/10kF-Wbqfr5eOR-AQoXudN7kMnVULj3QI/view
35	SNOMED CT in an NHS acute hospital - The real deal	Monica Jones – Associate Director of Information Services TRFT & Population Health Management Lead for YHCR	https://drive.google.com/file/d/0B4LR8p2PLplyWWxiRU9OWXVTZnZLLU1IaWszWE84cmZrOFJv/view
36	CAMH - Order sets,	No authors listed	https://www.himss.org/resources/centre-addiction-and-mental-health-himss-davies-enterprise-award
37	The Electronic Medical Records and Genomics (eMERGE) Network: past, present, and future	Omri Gottesman, MD,1,* Helena Kuivaniemi, MD, PhD,2,* Gerard Tromp, PhD,2 W. Andrew Faucett, MS,2 Rongling Li, MD, PhD,3 Teri A. Manolio, MD, PhD,3 Saskia C. Sanderson, PhD,1 Joseph Kannry, MD,1 Randi Zinberg, MS, CGC,1 Melissa A. Basford, MBA,4 Murray Brilliant, PhD,5 David J. Carey, PhD,2 Rex L. Chisholm, PhD,6 Christopher G. Chute, MD, DrPH,7 John J. Connolly, MD,8 David Crosslin, PhD,9 Joshua C. Denny, MD,4 Carlos J. Gallego, MD,9 Jonathan L. Haines, PhD,4 Hakon Hakonarson, MD, PhD,8 John Harley, MD, PhD,10 Gail P. Jarvik, MD, PhD,9 Isaac Kohane, MD, PhD,11 Iftikhar J. Kullo, MD,7 Eric B. Larson, MD, MPH,12 Catherine McCarty, PhD, MPH,13 Marylyn D. Ritchie, PhD,14 Dan M. Roden, MD,4 Maureen E. Smith, MS,6 Erwin P. Böttinger, MD,1 Marc S. Williams, MD,2 and Buttinger The eMERGE Network	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3795928/
38	Can utilization of clinical pathways (CPs) effectively reduce drug spending (DS) within the Oncology Care Model (OCM)?	Andrew Allan Hertler, Rani Khetarpal, James Lloyd Wade, Ed Bassin, Sang Chau, Vijay Kumar Damarla	https://ascopubs.org/doi/abs/10.1200/JCO.2019.37.27_suppl.269

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39	SCT EXPO 2019: James Read Memorial Lecture, Carolyn Gullery, Canterbury District Health Board, NZ (eReferrals/pathways, pt self management, targeted high cost areas)	Carolyn Gullery	https://www.youtube.com/watch?v=L8wAiZDIjdU
40	Clinical Pathways Reduce Cost, Increase Clinical Trial Entry for Patients With NSCLC	James L Weese, MD, Aurora Health Care (Milwaukee, WI), and colleagues	https://www.journalofclinicalpathways.com/news/clinical-pathways-reduce-cost-increase-clinical-trial-entry-patients-nsclc
41	SNOMED CT-Based Standardized e-Clinical Pathways for Enabling Big Data Analytics in Healthcare	AYMAN D. ALAHMAR , (Member, IEEE), AND RACHID BENLAMRI, (Member, IEEE)	https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9093006
42	Patient characteristics associated with venous thromboembolic events: a cohort study using pooled electronic health record data	David C Kaelber, Wendy Foster, Jason Gilder, Thomas E Love, and Anil K Jain	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3534456/
43	HealthPathways: An economic analysis of the impact of primary care pathways in Mackay, Queensland	Robin Blythe, Xing Lee, Sanjeewa Kularatna	http://www.aushsi.org.au/wp-content/uploads/2019/05/Mackay-HealthPathways-Final-Report.pdf
44	SNOMED CT -A Canadian Clinical Perspective	Jeremy Theal, MD FRCPC CMIO, North York General Hospital Physician Lead, Ministry of Health HIS Adoption/Benefits Team	https://confluence.ihtsdotools.org/pages/viewpage.action?pageId=47689896&preview=/47689896/52172469/SNOMED%20International%20James%20Read%20Lecture%20Oct%2020%202017%20FINAL.pdf
45	Building the business case for quality improvement: a framework for evaluating return on investment	Amar Shah, chief quality officer and consultant forensic psychiatrist, Steven Course, chief financial officer and deputy chief executive, East London NHS	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6502557/
46	Oxford University Hospitals NHS Trust Electronic Patient Record (EPR) Benefits realisation case study	Clare Cape,	https://www.ouh.nhs.uk/patient-guide/documents/epr-case-study.pdf

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47	Clinical Terminology and Data Exchange for Clinical Genomics: Australian Case Studies	Michael Lawley	https://drive.google.com/file/d/1iT5qShq79wshZkzWHs-Yh3ltADQg9LHV/view
48	Characterizing the complexity of medication safety using a human factors approach: an observational study in two intensive care units	Pascale Carayon, Tosha B Wetterneck, Randi Cartmill, Mary Ann Blosky, Roger Brown, Robert Kim, Sandeep Kukreja, Mark Johnson, Bonnie Paris, Kenneth E Wood, James Walker	https://pubmed.ncbi.nlm.nih.gov/24050986/
49	The Effect of Computerized Physician Order Entry on Medication Errors and Adverse Drug Events in Pediatric Inpatients	W. James King, Naomi Paice, Jagadish Rangrej, Gregory J. Forestell and Ron Swartz	https://pediatrics.aappublications.org/content/112/3/506.short
50	The Influence that Electronic Prescribing Has on Medication Errors and Preventable Adverse Drug Events: an Interrupted Time-series Study	Jasperien E. van Doormaal, Patricia M.L.A. van den Bemt, PhD, Rianne J. Zaal, Antoine C.G. Egberts, PhD, Bertil W. Lenderink, Jos G.W. Kosterink, PhD, Flora M. Haaijer-Ruskamp, Peter G.M. Mol, PhD	https://academic.oup.com/jamia/article/16/6/816/735777
51	Reducing Medical Errors and Adverse Events	Julius Cuong Pham, Monica S. Aswani, Michael Rosen, HeeWon Lee, Matthew Huddle, Kristina Weeks, and Peter J. Pronovost	https://www.annualreviews.org/doi/full/10.1146/annurev-med-061410-121352#article-denial
52	The Effect of Electronic Prescribing on Medication Errors and Adverse Drug Events: A Systematic Review	Elske Ammenwerth, PhD, Petra Schnell-Inderst, PhD, Christof Machan, MSc, Uwe Siebert, PhD	https://academic.oup.com/jamia/article/15/5/585/732256
53	The costs of adverse drug events in community hospitals	Balthasar L Hug, Carol Keohane, Diane L Seger, Catherine Yoon, David W Bates	https://pubmed.ncbi.nlm.nih.gov/22435229/
54	Adverse Drug Events	Health.gov – no authors listed	https://health.gov/our-work/health-care-quality/adverse-drug-events

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	Report Title	Author(s)	Link/Source
55	Adverse Drug Reactions in Hospitalized Patients: Results of the FORWARD (Facilitation of Reporting in Hospital Ward) Study	Claudia Giardina, Paola M. Cutroneo, Eleonora Mocciaro, Giuseppina T. Russo, Giuseppe Mandraffino, Giorgio Basile, Franco Rapisarda, Rosarita Ferrara, Edoardo Spina and Vincenzo Arcoraci	https://www.frontiersin.org/articles/10.3389/fphar.2018.00350/full
56	Adverse Drug Events in Hospitalized Patients Excess Length of Stay, Extra Costs, and Attributable Mortality	David C. Classen, MD, MS; Stanley L. Pestotnik, MS, RPh; R. Scott Evans, PhD; et al	https://jamanetwork.com/journals/jama/article-abstract/413536
57	National Action Plan for Adverse Drug Event Prevention	U.S. Department of Health and Human Services	https://health.gov/sites/default/files/2019-09/ADE-Action-Plan-508c.pdf
58	Incidence of Adverse Drug Events and Medication Errors in Japan: the JADE Study	Takeshi Morimoto MD, MPH, Mio Sakuma MD, MPH, Kunihiko Matsui MD, MPH, Nobuo Kuramoto MD, Jinichi Toshiro MD, Junji Murakami MD, Tsuguya Fukui MD, MPH, Mayuko Saito MD, MPH, Atsushi Hiraide MD & David W. Bates MD, MSc	https://link.springer.com/article/10.1007%2Fs11606-010-1518-3
59	Adverse Drug Events in Hospitalized Patients Excess Length of Stay, Extra Costs, and Attributable Mortality	David C. Classen, MD, MS; Stanley L. Pestotnik, MS, RPh; R. Scott Evans, PhD; et al	https://jamanetwork.com/journals/jama/article-abstract/413536

Economic Analysis

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SNOMED CT
The global language of healthcare

Economic Analysis

Model 4: National Total Factor Productivity Gains

- In developing an estimate of the SNOMED CT economic benefits consideration was given to the use of an expenditure-based input-output analysis that would show the direct, indirect and induced (multiplier) impacts to GDP [1], employment and income.
- It is recommended that SNOMED International adopt an alternative framework since the expenditure analysis has some significant shortcomings, including:
    - The analysis cannot consider the alternative uses of a given expenditure and will therefore offer a biased impact assessment.
    - The Input-Output framework is not generalizable across economies limiting the usefulness of a general model.
- An alternative approach is proposed by forecasting the productivity gains, derived from the deployment and adoption of an SNOMED CT-enabled clinical information system and interoperability solution, to the broader economy. The increase to Gross National Income (GNI)[2] can then be estimated as a result of the productivity gains including both inpatient and outpatient health care expenditure savings from Model 1: Select Productivity Benefits Enabled by SNOMED CT.

1. GDP is defined as the value of national output produced in a country.
2. GNI is defined as the total income to a nation's households, businesses, and governments. GNI is a commonly used measure of national income.

SNOMED International

Economic Analysis

Model 4: National Total Factor Productivity Gains

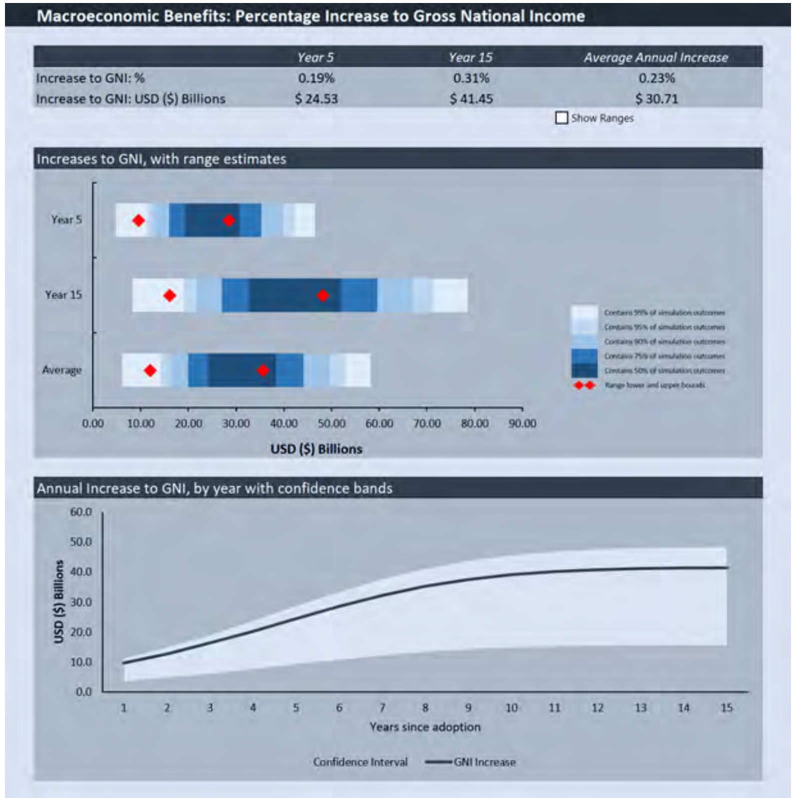
Input Tables

1	Country spend on health care (annual):	2024
	Currency:	US Dollar
	Units:	Billions
2	Country Macroeconomic Variables	
	Country GDP	13040
	Country GNI	13170
3	Confidence Interval	%
	Range low end	1%
	Range high end	67%
		Update Model

1. **Model 4 Purpose:**
   - The model estimates the increase in GNI Gross National Income (GNI) per capita as a result of the productivity gains including both inpatient and outpatient health care expenditure savings from Model 1.
   - An increase in GNI has been empirically correlated with higher living standards, higher real incomes and the ability to devote more resources to areas like health care, education, research and development and capital investment. These measures in turn are correlated to higher literacy, life expectancy and higher technological innovation.
2. **Model 4 Inputs:**
   - The User inputs the national GDP.
   - The model directly picks the total productivity gains (savings) estimate calculated by Model 1.

Economic Analysis

Model 4: National Total Factor Productivity Gains

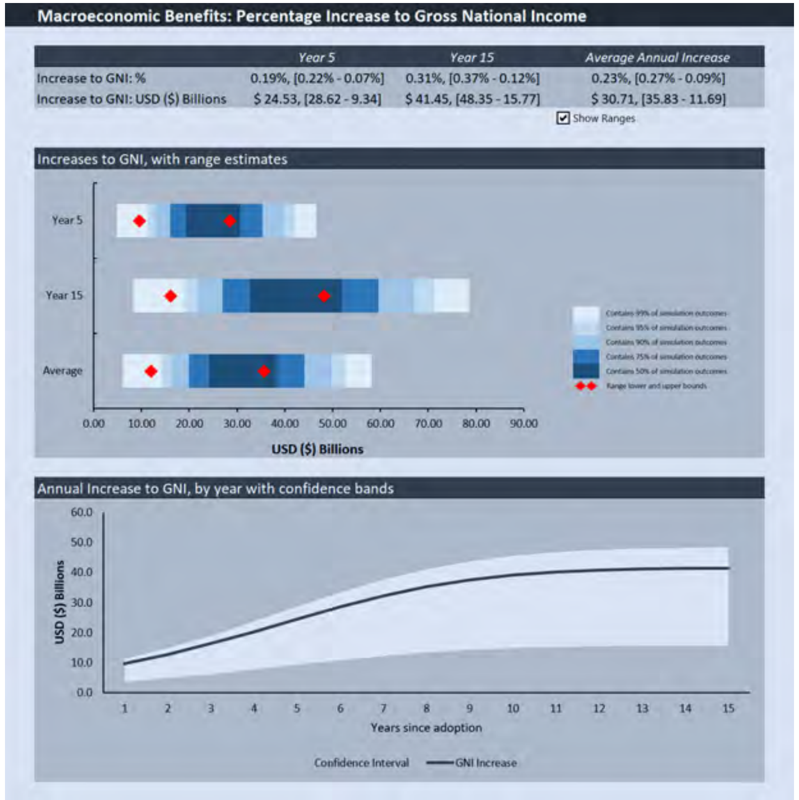


3. **Model 4 Calculation Engine:**
   - The model measures the increase in Multifactor Productivity (MFP)[3] from clinical information systems.
   - The model assumes that both the inpatient and outpatient health care expenditure savings/avoided from Model 1 can support incremental consumption and/or investment in the general economy[4].
   - In order to estimate the increase in GNI, the model measures the increase in MFP for the country’s economy. It achieves this by scaling the growth in MFP by the share of GDP that is made up by the healthcare industry.
   - The model leverages OECD data from 23 countries over the time period of 1996-2019 which shows a positive correlation between the annual increase in MFP and GNI.

3. Multifactor productivity (MFP), also known as total factor productivity (TFP), is a measure of economic performance that compares the amount of goods and services produced (output) to the amount of combined inputs used to produce those goods and services. Inputs can include labor, capital, energy, materials, and purchased services.
4. This is a common neo-classical framework.

Economic Analysis

Model 4: National Total Factor Productivity Gains



3. **Model 4 Calculation Engine con't:**
   - The model runs a series of regressions to quantify the impact of increasing MFP, as a result of a productivity gains from a SNOMED-CT enabled, integrated, clinical information systems. The model then selects the coefficient of determination that best addresses the fixed effects[5] (e.g. noise like the tech – bubble recession of 2000 and the financial crisis of 2007-2008).

4. **Model 4 Output:**
   - The model provides a range of percentage increase in GNI over the 15-year time horizon.
   - The increase to GNI is in the context of all other factors being held constant.

5. Fixed Effects Model - Fixed effects models work to remove omitted variable bias by measuring change within a group. By measuring within a group (across time) you control for a number of potential omitted variables unique to the group. Controlling for unobserved heterogeneity when heterogeneity is constant over time and correlated with independent variables. When there are certain non-random characteristics you don't want ending up in your error term.

Detailed Case Studies

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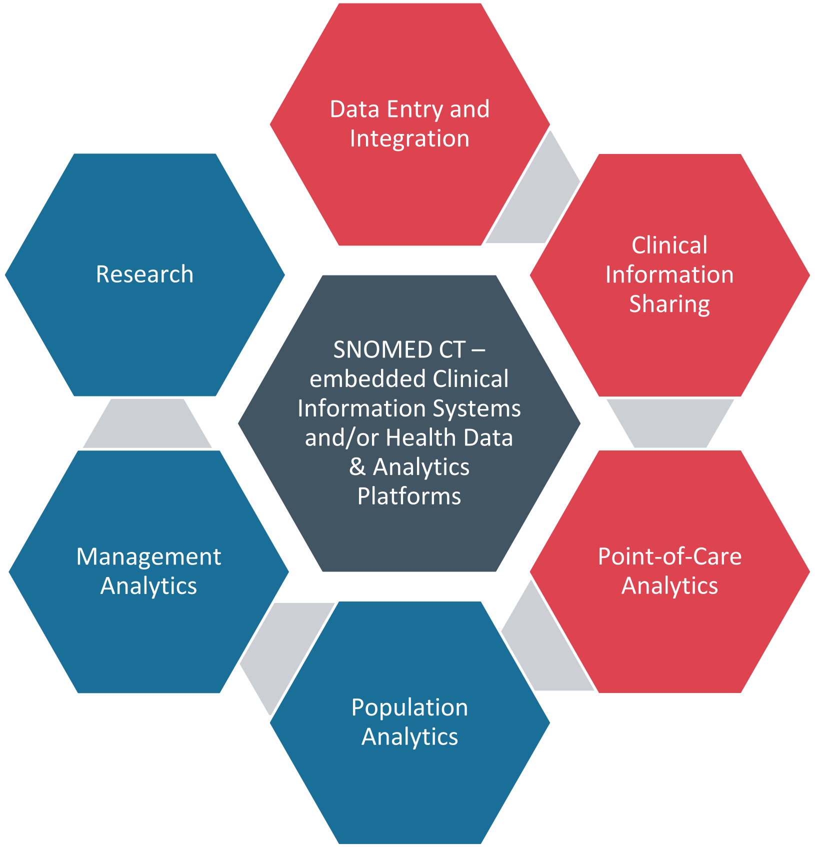
SNOMED CT

The global language of healthcare

SNOMED International

Case Study #1

A Clinical Information System and Health Information Exchange



VA

U.S. Department of Veterans Affairs

Veterans Health Administration

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Case Study #1

VistA: A Clinical Information System

United States – U.S. Department of Veterans Affairs, Veterans Health Administration, Washington DC

- The Veterans Health Administration (VHA), one of three administrations within the Department of Veterans Affairs (VA), is the largest integrated health system in the United States. The VHA is a form of nationalized healthcare service that provides health care benefits and services to military Veterans. As a result all the medical facilities that are part of the VHA are owned by the US Government and all the doctors and workers at the facilities are paid by the government.
- In 2020 the VHA employed approximately 350,000 people including over 150,000 medical professionals who provide or support care at 1,255 health care facilities, including 170 medical centers and 1,074 outpatient clinics, serving 9 million enrolled Veterans each year. The 2020 VHA budget is USD$85 billion.
- In 1996, the Veterans Health Care Eligibility Reform Act enabled the VHA to be restructured "from a hospital system to a health care system," as directed by then Under Secretary for Health, Kenneth W.Kizer, MD. Dr. Kizer changed the organization from the previously independent and often competing large hospital medical centers to 22 integrated service networks providing patient-centred care[1].
- Change in Care Settings - the transformation facilitated shifting care from the hospital to ambulatory-care facilities and the home environment, allowing a reduction of authorized hospital and long-term care beds from approximately 92,000 to 53,000, with a concomitant decrease in hospitalizations and an increase in ambulatory-care visits and home care services.
- Increase in Patient Throughput - From 1996 to 2003, the number of veterans treated annually increased by 75% from approximately 2.8 to 4.9 million, but only with a ~5% annual increase in budget over the same period.

1. Kizer, K., "Journey of Change" Washington, DC: Department of Veterans, 1997.

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U.S. Department of Veterans Affairs
Veterans Health Administration

SNOMED International

Case Study #1

VistA: A Clinical Information System

United States – U.S. Department of Veterans Affairs, Veterans Health Administration, Washington DC

- As part of this major transformative effort Kizer and the VHA made significant enhancements to its existing **SNOMED CT**-embedded **(e.g. problem list, anatomic pathology, health summary)** system called VistA**.** VistA is very comprehensive and supports all clinical, administrative, and financial functions across the VHA for over 450,000 users.
- Clinically, VistA provides a single patient record across all VHA health care facilities and with new CPOE and clinical decision support capabilities implemented in the late 1990's, 94% of all pharmacy orders throughout the VHA were electronically entered directly by the prescriber. In addition, the VHA in the early 2000s introduced My *HealtheVet* that allows veterans to access and update their personal health record, refill prescriptions, schedule appointments, as well as port their health records to institutions outside the VHA health system or keep a personal copy of their health records.
- VistA is a custom built solution that consists of 180 clinical, financial, and administrative applications integrated within a single transactional database. Over 65% of all physicians trained in the U.S. rotate through the VHA and use VISTA, making VistA the most familiar EHR in the U.S. It has continually won awards and in 2014, and again in 2016, national surveys of over 15,000 physician users of EHRs rated VistA with the highest overall satisfaction rating in the U.S[2].
- The VistA applications have been placed in the public domain and as an open-source system has been used by other US health care organizations (e.g. Department of Defense Military Health System, Indian Health Service and other non-government hospitals), as well as internationally in at least 15 countries. In 2018 the VHA contracted Cerner to replace VistA as part of a 10-year, $16 billion implementation project with rollout expected to start in 2021 (COVID delayed).

2. Peckham C, Kane L, Rosensteel S (August 25, 2016). "Medscape EHR Report 2016: Physicians Rate Top EHRs". Medscape. Retrieved August 27, 2017. See https://www.medscape.com/features/slideshow/public/ehr2016

U.S. Department of Veterans Affairs
Veterans Health Administration

Case Study #1

VistA: A Clinical Information System

United States – U.S. Department of Veterans Affairs, Veterans Health Administration, Washington DC

VistA Cost-Benefit Analysis

- Byrne et al[3] compared health information technology in the VHA to norms in the US private health care sector, plus estimated the costs and benefits of selected VistA applications for the period 2004 to 2007.
- Health IT Spending: On average, the VHA has higher ratios of health IT total spending and IT operations and maintenance costs than the private health care sector. For capital expenses, the VHA is at or below the industry averages.
- Adoption of Health IT: The VA achieved close to 100 percent adoption of selected VistA components (e.g. CPRS or the Computerized Patient Record System) since 2004. In contrast, the private health care sector had not reached significant adoption of any of these applications. In 2007, adoption in the private health care sector of inpatient electronic health records stood at 61 percent; use of inpatient bar-code medication administration was 22 percent; computerized physician order entry adoption was 16 percent; and outpatient electronic medical record adoption 12 percent.
- IT-Related Quality Measure Performance: For preventive care process measures such as cancer screenings, the VHA had higher performance during 2004–2007 relative to the private health care sector. VHA patients with diabetes had better glucose testing compliance (15% higher), more controlled cholesterol (17% higher), and more timely retinal exams when compared to the Medicare health maintenance organization (HMO) private-sector benchmark (see the details on the chart overleaf).

3. Bryne et al., "The Value From Investments In Health Information Technology At The U.S. Department Of Veterans Affairs", Health Affairs 29, No. 4., 2010. See https://www.healthaffairs.org/doi/pdf/10.1377/hlthaff.2010.0119

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U.S. Department of Veterans Affairs
Veterans Health Administration

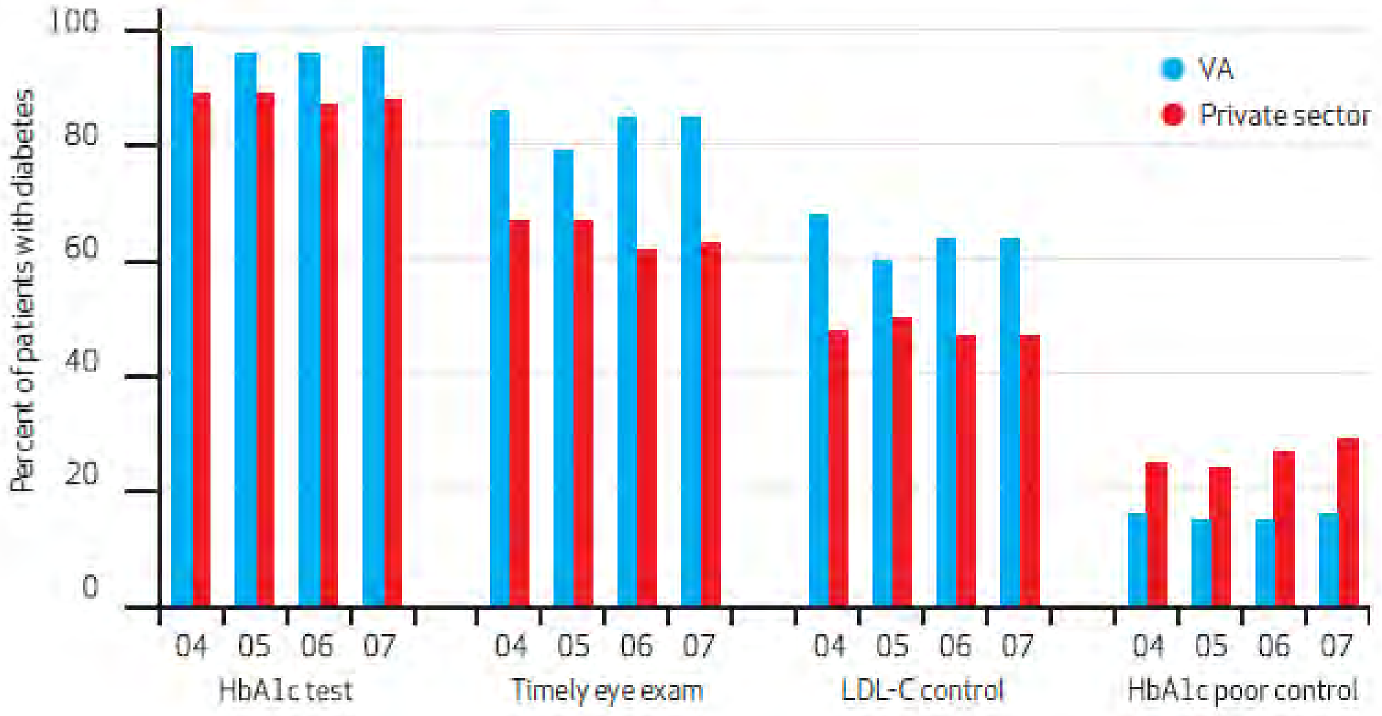
SNOMED International

Case Study #1

VistA: A Clinical Information System

United States – U.S. Department of Veterans Affairs, Veterans Health Administration, Washington DC

Selected Outpatient Health Information Technology (IT)-Related Quality Measures For Patients With Diabetes, Department Of Veterans Affairs (VA) And Private Sector, 2004-2007



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VistA Cost-Benefit Analysis con't

- Net Value: The total net value of the VHA's investments in the VistA components modeled exceeds $3.09 billion. By 2003, the benefit projections equaled the costs, with the VHA potentially accruing a net positive value from 2004 through 2007. In 2007, the annual net value was estimated to exceed $687 million, with annual benefits projected to be threefold greater than annual costs.
- Benefits: The gross value of the VHA's investments in VistA applications was projected to be $7.16 billion. Cumulative reductions in unnecessary care attributable to prevention of adverse drug event–related hospitalizations and outpatient visits as a result of VistA was the largest source of benefit in the projections, with an estimated value of $4.64 billion, or 65 percent of total estimated value. The cumulative value of eliminated redundancies (e.g. duplicate laboratory tests) accounted for $1.92 billion, or 27 percent of projected value. (see more detail in the chart overleaf)
- Costs: The total cost to develop, implement, and maintain the VistA applications, including the Computerized Patient Record System, was estimated at $4.07 billion. The Computerized Patient Record System entailed the largest investment of the VistA applications analyzed, with projected costs of $3.60 billion (which includes $1.56 billion for the earlier Decentralized Hospital Computer Program). The bar-code medication administration, picture archiving and communication systems, and Laboratory Electronic Data Interoperability application were comparatively smaller investments, collectively equaling $470 million.

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Cost Benefit Analysis - VistA Applications and Sources of Value			
VistA Component	**System Feature**	**Source of Value**	**Benefit Category**
Computerized Patient Record System (CPRS; 1997–2007; inpatient, outpatient)	• Electronic capture and reporting of allergies/adverse reactions, problem lists, inpatient and outpatient medications, test results, discharge summaries, provider notes, notifications/patient record flags • Orders for medications, laboratory tests, radiology tests, event delay, diets, consult/request tracking • Clinical decision support through clinical reminders, order checking.	• Reduced inpatient costs for preventable adverse drug events caused by inpatient medications • Reduced inpatient costs for avoided influenza and pneumonia • Reduced inpatient costs for preventable adverse drug events caused by outpatient medications • Reduced outpatient visit costs for preventable adverse drug events caused by outpatient medications • Reduced laboratory and radiology costs for redundant and unnecessary tests • Reduced time spent on chart pulls by file clerks in the inpatient setting • Reduced time spent on chart pulls by file clerks in the outpatient setting	• Avoided utilization • Avoided utilization • Avoided utilization • Avoided utilization • Eliminated redundancy • Reduced workload • Reduced workload
Picture archiving and communication system (2002–2007; inpatient)	• Exam lists, exam locks, specialized display tools, results-routing capabilities, color imaging, 3D imaging	• Reduced radiological film supply costs • Reduced film processor maintenance costs • Reduced time spent on film processing by radiology department clerks • Reduced floor-space costs for film library	• Decreased expenses • Decreased expenses • Reduced workload • Reduced expenses
Bar-code medication administration (1998–2007; inpatient)	• Real-time, point-of-care validation for administration of unit dose and IV medications	• Reduced inpatient costs for preventable adverse drug events caused by inpatient medication administration errors	• Avoided utilization
Laboratory Electronic Data Interoperability (2001–2007; inpatient and outpatient)	• Laboratory order sending and tracking, results transmission and integration into CPRS, standardized electronic communication with non-VistA laboratories	• Reduced time spent on order processing by VA laboratory technicians	• Reduced workload

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Veterans Health Information Exchange

- Because the majority of Veterans receive care at both VHA and private health care facilities, the VHA set up a Veterans Health Information Exchange (VHIE)[4] to support interoperability between the VHA, other federal agencies and the private health care sector to better manage the coordination of care.
- Currently the VHA and over 220 participating providers can electronically share a variety of health information including: prescriptions and medications, allergies, Illnesses, laboratory and radiology results, immunizations, procedures and clinical notes, and other relevant medical information. The health information, including SNOMED CT encoded information from VistA, is extracted to a Continuity of Care document and exchanged securely with the participating providers.
- The participating providers include federal agencies (e.g. Department of Defense, Social Security Administration), health care organizations (e.g. Kaiser Permanente, Johns Hopkins Medicine), state and regional HIEs (e.g. Indiana Health Information Exchange, Maine HealthInfoNet) and the private sector (e.g. Walgreens Pharmacies, CVS MinuteClinic).
- All VHIE participating providers have to be part of the national HIE, eHealth Exchange, which operates in all 50 states. VHIE can exchange information at both at an organizational level (i.e. Continuity of Care documents via eHealth Exchange) and at the personal provider level (i.e. direct messaging via DirectTrust)[5]. The eHealth Exchange network is the largest HIE in the US and is connected to 75 percent of all US hospitals, to 61 regional or state health information exchanges, and more than 30 EHR technologies (e.g. Epic, Cerner).

4. See https://www.va.gov/VHIE/index.asp
5. See https://ehealthexchange.org/ and https://www.directtrust.org/

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VHIE: A Health Information Exchange

United States – U.S. Department of Veterans Affairs, Veterans Health Administration, Washington DC

Veterans Health Information Exchange

Benefits Achieved

- **Allergy Documentation Rate** - Review of all inbound VHIE transactions in FY14 showed that VHIE use was associated with a nearly eight-fold increase in the allergy documentation rate (7.5% vs. 0.84%)[6].
- **Access to Immunization Services** - The VHIE Retail Immunization Coordination Project established a partnership between the VHA and Walgreens so Veterans could receive their immunizations at a local Walgreens located closer to their home than their nearest VHA facility. Analysis of Veterans immunized at Walgreens between September 2014 and January 2015 showed that 64% of study Veterans now traveled <5 miles to receive their immunization, 12% of study Veterans traveled between 5 to 10 miles, and 24% of study Veterans traveled more than 10 miles. In addition, it was noted that 93% of Veterans traveled less than 54 miles, the average distance rural Veterans traveled to the nearest VHA facility.
- **Laboratory Test an Imaging Ordering** - Participation in the VHIE reduced the ordering of laboratory and imaging tests at inappropriately short intervals in the ambulatory care setting. CBC & Renal profile ordering was reduced by 1.98%; Lipid and Liver tests by 3.19%; and imaging orders by 1.3%. The effect upon potential overuse was realized early, within the first year of implementation of the VHIE.

6. Pan et al., "Assessments of the Veteran Medication Allergy Knowledge Gap and Potential Safety Improvements with the Veteran Health Information Exchange", AMIA Annual Symposium Proceedings 2012. See https://www.ncbi.nlm.nih.gov/pmc/journals/362/
7. Botts et al., "Improved Veteran Access to Care through the Veteran Health Information Exchange (VHIE) Retail Immunization Coordination Project", AMIA Annual Symposium Proceedings 2016. See https://www.ncbi.nlm.nih.gov/pmc/journals/362/
8. Haggstrom et al., "Impact of VA Health Information Exchange upon the Overuse of Laboratory and Imaging Tests", AMIA Annual Symposium Proceedings 2017. See https://www.ncbi.nlm.nih.gov/pmc/journals/362/

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VHIE: A Health Information Exchange

United States – U.S. Department of Veterans Affairs, Veterans Health Administration, Washington DC

Veterans Health Information Exchange

Benefits Achieved con't

- **Diabetes Care** - Providers of Veteran patients enrolled in the VHIE had improved access to diabetes data residing in non-VHA health care systems. About 1 in 5 Veteran patients had data identifying diabetes diagnoses in non-VHA clinical systems. However, the VHIE program had no measurable effect upon the quality of diabetes care[9].
- **Prevalence of Medication Data in Non-VHA health Care Systems** – A study was conducted to describe the prevalence of medication dispensing across VHA and non-VHA health care systems among a cohort of Veteran patient population. The data demonstrated that 17.4% of Veterans had medication use identified from non-VHA sources, including prescriptions for antibiotics, antineoplastics, and anticoagulants. These data support the need for the VHIE to improve sharing and coordination of information, with the potential to reduce adverse medication interactions and improve medication safety[10].

9. Haggstrom et al., "Impact of VA Health Information Exchange upon the Quality of Diabetes Care", J Gen Intern Med. 2014 Apr; 29 (Suppl 1).
10. Nguyen et al., "Medication Use among Veterans across Health Care Systems", Appl Clin Inform. 2017 Mar 8; 8(1):235-249

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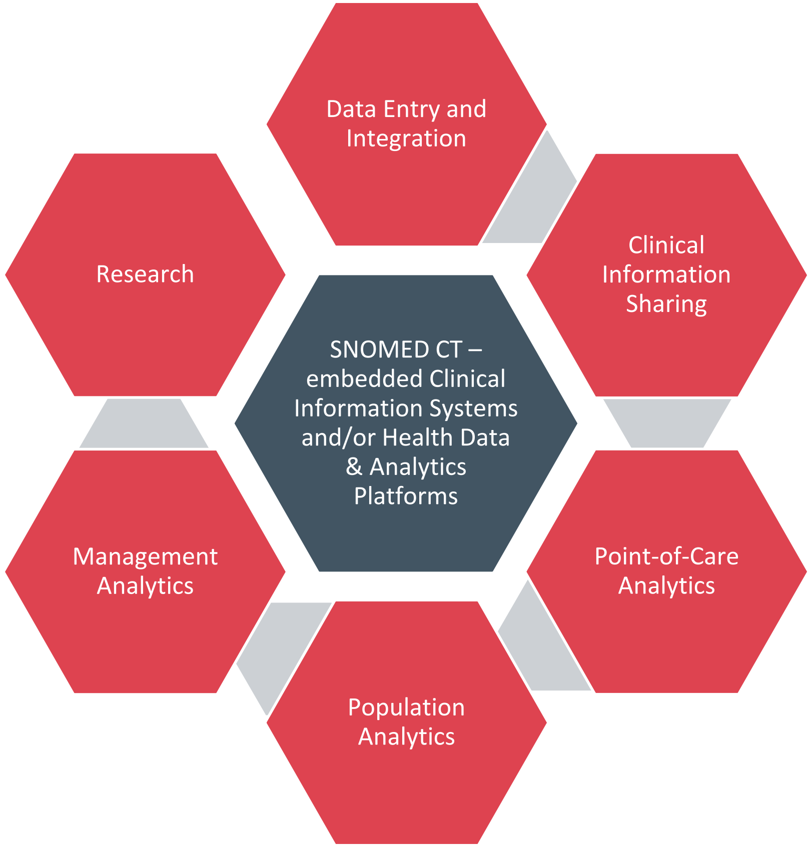
Case Study #2

Health Connect: Enabling the Transformation of Care Delivery



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Case Study #2

HealthConnect: Enabling the Transformation of Care Delivery

United States – Kaiser Permanente, Oakland, California

- Kaiser Permanente (KP) is was founded in 1945 and is made up of three distinct but interdependent groups of entities: the Kaiser Foundation Health Plan, Inc. and its regional operating subsidiaries; Kaiser Foundation Hospitals; and the regional Permanente Medical Groups. KP operates in eight US states (Hawaii, Washington, Oregon, California, Colorado, Maryland, Virginia, and Georgia) and the District of Columbia, and is the largest managed care organizations in the United States.
- Kaiser Permanente is the largest nonprofit healthcare plan in the United States, with over 12 million members. It operates 39 hospitals and more than 700 medical offices, with approximately 300,000 personnel, including more than 85,000 physicians and nurses. In 2019 it had operating revenue of USD$84.5 billion.
- As one of the nation's earliest adopters of electronic health records (EHRs), KP has achieved organization-wide use and integration of health information technology. HealthConnect, the organization's clinical information system project using the Epic Care EHR was started in 2004, and fully deployed in 2010, for a total cost of around USD$4 billion.
- The story of the KP HealthConnect implementation is detailed in the book "*Connected for Health, Using Electronic Health Records to Transform Care Delivery*"[1], the contents of which has been used to create much of this case study.
- KP had a history of digital health excellence that reached back to the 1960's. However, in 2002 KP hired George Halvorson as its CEO with the urgent need to integrate care across the entire KP organization by leveraging health information technology, and provide KP with a competitive advantage in healthcare delivery.

1. Liang L et al, "Connected for Health, Using Electronic Health Records to Transform Care Delivery" a Jossey-Bass Publication, 2010, ISBN 978-1-118-01835-4

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HealthConnect: Enabling the Transformation of Care Delivery

United States – Kaiser Permanente, Oakland, California

- In 2003 Halvorson, among other actions, started the transformation effort with the completion of the Board-approved IT business case[2]. To support the HealthConnect investment KP anticipated that use of the EHR system would result in increased efficiencies, improved clinical decision making, better care coordination, reduced medication errors, and new levels of patient engagement. The business case quantifies 36 financial benefits, which fall under the broad categories of reduced operating costs, increased revenues, and reduced capital expenditure. A positive cumulative net cash flow was calculated and a cost-benefit analysis identified a break-even point 8.5 years after the 2004 project initiation.
- The next step was to "start with the end in mind", in this case, value realization by improving the quality of care through the power of evidence. A Blue Sky vision was created that had four themes: Home as a Hub; integration of medical and wellness activities; secure and seamless transitions of care; and care that is customized to the patient. Next came the complete re-design and transformation of the health care delivery processes at KP.
- KP also developed 5 principles for its HealthConnect implementation: business-led; common platforms, processes and services; a preference to buy vs build; a single vendor integrated system; a system that can meet 80% of the KP needs.
- KP selected Epic Systems to deploy HealthConnect in emergency, inpatient, outpatient, laboratories, pharmacy, imaging, public health, membership and financials/benefits areas in all KP locations. It also provided bedside documentation, electronic ordering with clinical decision support, a patient portal (My Health Manager aka MyChart) and a suite of population management tools. KP also became a leader in developing interoperability among US healthcare organizations.

2. Garrido T. et al., "Making the Business Case for Hospital Information Systems – A Kaiser Permanente Investment Decision", Journal of Healthcare Finance, February 2004. https://www.researchgate.net/publication/7896965_Making_the_Business_Case_for_Hospital_Information_Systems-A_Kaiser_Permanente_Investment_Decision

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HealthConnect: Enabling the Transformation of Care Delivery

United States – Kaiser Permanente, Oakland, California

- KP HealthConnect uses an array of international standards, chief among those is **SNOMED CT**. Others include LOINC (lab), DICOM (imaging), RxNorm (drug) and NIC,NOC,NANDA (nursing)[3]. **SNOMED CT** was chosen over ICD and CPT because it provided a richer, more granular expression of the data that is more familiar to clinicians. Further, coding patient care data using **SNOMED CT** could then be easily leveraged for clinical decision support, clinical and population analytics, as well as public health interventions. Starting in 2010, KP has generously donated its **SNOMED-CT** embedded Convergent Medical Terminology to SNOMED International to benefit all health care providers in the US and globally.
- A key component of the KP HealthConnect deployment was the meaningful involvement of clinicians (e.g. physicians and nurses) from the visioning, vendor selection, clinical process re-design, as well as to the system build, go-live, use and the on-going transformation. It was recognized early that the deployment of KP HealthConnect won't make clinicians necessarily faster in all situations, but they should be better.
- The use of HealthConnect to support the transformation of care delivery at Kaiser Permanente is still viewed by the health care industry as a landmark clinical information system deployment for a large integrated health care system, not just in the U.S., but also globally. Today, a decade later, Kaiser Permanente is recognized as an employer of choice (e.g. a best place to work in IT for the past 10 years), excellence in care (e.g. top scores for quality and service), as well as for its innovative leaders.

3. Wiesenthal A., "Kaiser Permanente HealthConnect" – A Large Scale EHR Deployment Using SNOMED CT" HINZ Conference presentation, 2007. See https://www.slideshare.net/HINZ/kaiser-permanente-healthconnect-ehr-and-snomed

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United States – Kaiser Permanente, Oakland, California

KP took an immediate, medium-term and long-term perspective on realizing the benefits from HealthConnect

1. Day 1 Benefits of HealthConnect (immediate)

The clinical use of HealthConnect provides immediate benefits to clinicians and patients.

- Improved patient safety with comprehensive, legible patient health records.
- More efficient inpatient and outpatient care with 24/7 access to complete patient health records.
- Eliminate duplicate tests (e.g. laboratory, radiology) through availability of orders and results.
- Improve patient engagement by KP clinicians demonstrating that "we know you". Patients don't have to repeat the same information about allergies, medications, and other elements of their medical history.

2. Harvested Value from HealthConnect (medium term)

Many of the benefits of KP HealthConnect have required deliberate policy changes, workflow re-design, committed leadership, and an openness to innovations by knowledgeable clinicians. For example:

- Improved patient safety due to the implementation of level 1 drug-drug interactions.
- Reduced cost of medical records operations.
- Re-engineered workflows to improve quality outcomes while reducing waste and costs (see two examples overleaf)
- Reduced cost of regulatory compliance and other reporting activities.
- Savings from legacy system retirements.

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HealthConnect: Enabling the Transformation of Care Delivery

United States – Kaiser Permanente, Oakland, California

EXAMPLE I: Re-Engineered Clinical Workflows - KP Hawaii Quality Improvement for Patients with Chronic Kidney Disease

- Specialist nephrologists, such as Dr. Brian Lee at KP Hawaii[4], were used to managing individual patients that had been referred to them by a GP. Specialists had never been involved in driving improvements in care for, in this case, the entire patient population of 10,000 people with chronic kidney disease.
- Dr. Lee and his colleagues used laboratory results to identify and rank by risk all patients diagnosed with chronic kidney disease.
- Using the **SNOMED CT**-embedded KP HealthConnect Lee then monitored the primary care delivered by primary care clinicians to the most high-risk patients to ensure that it was in line with evidence-based treatment recommendations, and when appropriate, he provided unsolicited e-consults to the patient's GP.
- In effect Dr. Lee inverted the traditional referral process. This required access to patients' electronic records, but also dramatic changes in the relationship between specialists and GPs, including the support of the clinical leadership.
- Results of Lee's initiative showed that it increased early intervention for high-risk patients and reduced by two-thirds the number of late specialist referrals – those occurring within the four months of the onset of end-stage renal disease. Early referral is essential to make the changes that will slow the progression of the disease.

4. Lee and Forbes., "The Role of Specialists in Managing the Health of Populations with Chronic Illness: The Example of Chronic Kidney Disease" The British Medical Journal, 2009. See https://www.bmj.com/content/339/bmj.b2395.full

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United States – Kaiser Permanente, Oakland, California

EXAMPLE II: Re-Engineered Workflows – Population and Management Analytics

- During 2003-2004 the KP Board and senior executives began to look at performance oversight in the areas of quality, service and patent safety. The accountability shift from a position of “we believe we deliver the highest quality care” to “the numbers tell the real story” took time to develop and evolve.
- Three-year, system-wide goals were introduced at KP including the commitment to reach the 90th percentile on all the NCQA HEDIS (Healthcare Effectiveness Data and Information Set)[5] quality measures and the Joint Commission’s National Hospital Inpatient Quality Measures[6]. These objectives were tied to staff compensation and pay-for-performance structures.
- As a result of this focus KP created “Big Q” a organizational dashboard, using management analytics, that reported on quality, service, safety, risk management and resource stewardship in both inpatient and outpatient care settings. The resulting transparency was a catalyst for change.
- The result was a significant drop in patient harm, an improvement in HEDIS and cost of care rates, as well as improvements in hospital and outpatient service performance.
- By the end of 2008 KP was above the 90th HEDIS percentile for breast and colorectal cancer screening; controlling high blood pressure; cardiovascular LDL control; and diabetes LDL control, as well as above the 75th percentile for cervical cancer screening.

5. See https://www.ncqa.org/hedis/
6. See https://www.jointcommission.org/

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HealthConnect: Enabling the Transformation of Care Delivery

United States – Kaiser Permanente, Oakland, California

EXAMPLE II: Re-Engineered Workflows – Population and Management Analytics con't

- Following advice from the Institute for Healthcare Improvement the next step for KP in improving transparency was to move beyond the traditional clinical quality perspective and add information on lives saved.

Translating Clinical Metrics to Lives Saved (2004-2008 Q4)

Metric	Increase	Savings per Decade
Cholesterol Control	16.8%	1,350 lives
Blood Pressure Control	36.6%	4,890 lives
HbA1C < 9.0	7.8%	738 lives
Smoking Cessation	14%	787 lives
Breast Cancer Screening	11.3%	565 lives 4,349 Stage 4 cases prevented
Cervical Cancer Screening	5.8%	38 lives
Colon Cancer Screening	24.2%	3.838 lives
TOTAL		**12,206 lives saved**

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EXAMPLE II: Re-Engineered Workflows – Population and Management Analytics con't

- … and further, information was translated into cost savings or resource stewardship.

Linking Quality Improvements with Financial Outcomes

Potential Savings from Reducing Harm	Amount
Estimated Savings from reducing LOS cost for Methicillin-resistant staphylococcus aureus (MRSA), *C. Difficile*, and urinary tract infections	$34,000,000
Estimated savings based on extrapolated CMS costs for coded harm from falls and coded pressure ulcers	$17,000,000
Potential savings from medication reconciliation on admission	$9,000,000
Annualized savings estimate by reducing costs associated with BSI, VAP and surgical site infections	$8,000,000
Conservative savings estimate (10% of admission savings) above from medication reconciliation at admission, discharge and other indirect savings	$900,000
Total (projected savings may be incremental because some processes were in place and achieving some impact)	**$68,900,000**

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3. Transformation of Care enabled by HealthConnect (long term)

The third area of Value Realization was the longer term Transformation of Care supported by HealthConnect.

- Improved capability to identify, support and disseminate health care innovations.
- Increased opportunity for collaboration and cultural transformation.
- Identification and dissemination of best practices and clinical guidelines.
- The ability to conduct better manage population health.
- Expanded and more responsive research capabilities.

EXAMPLE III: Healthcare Innovations – Managing the Panel

- In the early 2000's, the primary care physicians at KP, like elsewhere, were caught in the daily grind of providing reactive care to increasingly sick patients. While HealthConnect allowed them to focus more completely on each individual patient, very few had the time or energy to think about the health care needs of the population of patients that they cared for – their patient panel. Many of their patients never came to their clinic, making them effectively invisible.

- Two primary care physicians at the Hawaii Permanente Medical Group felt there had to be a better way – what they called Total Panel Ownership (TPO). TPO focused on the primary care team's (e.g. physicians, nurses, medical assistants) relationship with the entire patient population. The team needs to "own and manage the panel", rather than the appointment schedule. This change in focus required a redesign of primary care processes.

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EXAMPLE III: Healthcare Innovations – Managing the Panel con't.

- To roll-out the TPO approach KP deployed innovation teams and a change package (e.g. data driven workflows, relationship-based care so the team "knows" the patient, more convenient ways to interact with patients including less face-to-face visits and more telephone visits, and collaborative care planning and decision making with the patient).
- KP HealthConnect functionality supported the new TPO workflows. For example: the generation of health maintenance alerts (e.g. vaccinations, disease screening) and appointments scheduled; unlike pre-EHR telephone visits, all relevant patient information is available to the clinician; real time processing of lab and medication orders; completion of clinical notes is completed during the call; and an immediate "After Visit Summary" immediately sent to the patient.
- The net result of TPO was a decrease in office visits – a 9% reduction per 1,000 members. Correspondingly there was an increase in telephone visits (e.g. in 2010 in Hawaii 30% of same day primary care visits were provided by telephone),as well as secure messaging communications and the patient portal interactions. Over a 3-year period physicians saw on average 6% more of their panel of patients, thereby increasing capacity or throughput.
- Almost all primary care innovation teams improved their quality performance, with 50% out-performing their regions. Quality measures also improved for the innovation teams faster than their regional counterparts.
- Finally, physician work satisfaction increased significantly, and the patient-physician "relationship" measure improved by up to 64%.

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HealthConnect: Enabling the Transformation of Care Delivery

United States – Kaiser Permanente, Oakland, California

EXAMPLE IV: Collaboration and Cultural Transformation – The *My Health Manager* Patient Portal

- Kaiser Permanente started interacting with patients online (e.g. health advice, discussion groups) in the mid-1990's in its Northern California region. These innovations were expanded and by 1999 KP Online had 117,000 users. In 2003 with the adoption of HealthConnect new opportunities arose with the Epic MyChart module to provide KP members with secure access to their medical records. KP branded it My Health Manager and made it available to all 8.6 million members.
- My Health Manager features included provision of test results, allergies, diagnoses, immunizations, prescriptions, summaries of past office visits, with the medical data sourced from KP HealthConnect. In addition, appointment booking, health assessment tools and encyclopedias, plus secure messaging services were provided to patients. To assist KP put in place a patient advisory group that by 2010 had expanded to a 30,000 person virtual advisory group.
- As was expected, many clinicians initially felt that patients were not ready to see their health data without the physician acting as an interpreter. Having patients access their records at the click of a mouse was unsettling to many clinicians. A cultural change was needed. This was achieved through required clinician leadership, communication and collaboration.
- By 2010, My Health Manager had 3.3 million users or 63% of KP membership over 13 years of age, with around 80,000 new registrations per month. The most visited features were test results, "email your doctor" and online medication refills with around 72,000 patient visits per day to the portal in 2010.
- In 2020, My Health Manager and the underlying product Epic MyChart remain leaders in the patient portal space, globally.

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EXAMPLE V: Population Health – Coronary Artery Disease

- Coronary Artery Disease (CAD) is one of the top five chronic conditions that account for the majority of health care costs. In 2010 it was the leading cause of mortality in the U.S. contributing to 40% of all deaths. Kaiser Permanente of Colorado developed the Collaborative Cardiac Care Service (CCCS) to improve the health of patients with CAD[7].
- Within 24 hours of hospital discharge all patients hospitalized with a cardiac event are enrolled in a 3-6 month educational and case management program with a nursing team and a pharmacy team. CCCS works collaboratively with patients, primary care physicians, cardiologists, and other health care professionals to coordinate proven cardiac risk reduction strategies for CAD patients. Activities include lifestyle modification, medication management, patient education, laboratory monitoring, and management of adverse events, The CCCS team uses HealthConnect and HealthTrac to document all interactions with patients, track patient appointments, and collect data for evaluation of both short and long-term patient outcomes.
- By 2010 CCCS was following over 12,000 patients with CAD. CCCS demonstrated improvements in cholesterol screening (55% to 96.3%) and reduction in low-density lipoprotein cholesterol (LDL-c) <100 mg/dL (22% to 76.9%). Approximately 85% of these patients were receiving statin monotherapy The CCCS has shown a 76% reduction in all-cause mortality associated with CAD in the patients followed by the service. Patient and physician satisfaction has been high with CCCS.
- The program received the Care Continuum Alliance's Leadership Award in 2009 for the best use of technology to improve patient health outcomes.

7. Sandhoff et al., Collaborative Cardiac Care Service" Permanente Journal, 2008 Vol 12 No. 3. See https://www.thepermanentejournal.org/files/Summer2008/cardiac-care.pdf

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EXAMPLE VI: Population Health – Mammography Screening

- In the early 2000’s studies showed that early mammography screening, detection, diagnosis and treatment can reduce the breast cancer death rate by 20 to 50 percent, since 96% of all early stage, localized breast cancers are curable.
- IN 2003 KP set up “Operation Innovation” to identify and contact all women who met the age recommendations for mammograms, but had not been screened in the last 18 months.
- The program included use of the KP HealthConnect clinical information system to create the population cohort, track the mammography screening status of each target member, and record the results and procedures of each women.
- In addition, a wide range of methods were used to contact members, as well as conveniently and rapidly provide their mammograms (e.g. mobile mammography units) and results (e.g. a specialized team of clinicians was used to reduce the time for mammogram result-to-biopsy-to-diagnosis-to-surgical consultation).
- The program achieved a dramatic increase from 79.5% to 92% of eligible women receiving regular mammograms between 2004-2007. In addition there was a reduction in the time from the initial suspicion to the diagnosis of breast cancer from a median of 19 days to 9 days, with 79% of patients diagnosed within the target of 14 days.
- By 2008, Kaiser Permanente achieved the best breast cancer screening rates in the United States[8].

8. National Committee on Health Assurance., “NCQA 2008 Quality Compass” Healthcare Effectiveness Data and Information Set (HEDIS).

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United States – Kaiser Permanente, Oakland, California

EXAMPLE VII: Best Practices and Clinical Guidelines – Patient Safety

- The Institute of Medicine's seminal report "*To Err Is Human*" published in 2000 was a wake-up call to the health care industry, and a call-to-action for Kaiser Permanente. CEO George Halvorson recognized the opportunity to use KP HealthConnect to reduce preventable harm/injury to patients, improve the delivery of evidence-based care, and assist clinicians through the timely provision of information and decision support.
- With the focus on patient safety KP HealthConnect provided immediate benefits: legible, detailed longitudinal patient data, including the problem list, available 24/7; alerts (e.g. drug-drug interactions) and dose restrictions; and evidence-based order sets. KP then accelerated patient safety performance by: closing the loop of diagnostic test results; enhancing CPOE and decision support; creating drug surveillance features, as well as new ways to detect harm.
- **Reducing Ventilator-Associated Pneumonia (VAP)** – VAP is the 2nd most common hospital-associated infection, and is preventable. In 2006, the Institute for Health Improvement's (IHI) ventilator bundle of five best practices were embedded into the KP HealthConnect ICU order sets. As a result the average VAP incidence rate reduced 60% in the first year and has a sustained reduction of 36% below the pre-intervention rate.
- **Automated Harm Detection** – KP deployed the IHI Global Trigger Tool directly into HealthConnect as a way to identify adverse events, quantify the risk, degree and severity of harm. This adverse event surveillance capability allows KP to search all hospital inpatient records in real time and quickly identify and alert any quality/safety issues, as well as improve patient safety across the entire organization.

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EXAMPLE VIII: Research

- KP has been conducting health care research since 1943. By 2010 it had eight research centres across the U.S. conducting epidemiological and health service research, making it one of the largest research programs in the country. Most of the research is published in the peer-reviewed "*Permanente Journal*"[9] or other leading health care publications.
- With HealthConnect KP is able to easily access longitudinal, standardized clinical data on all its members. This "super-charged" KP's research efforts. By way of example, a few early EHR-enabled research papers are highlighted below.
  - **Population Research** – A landmark study on gestational diabetes mellitus (Hillier)[10].
  - **Patient Safety** – Utility of alerts in laboratory and prescription ordering (Raebel)[11], and effects of EHR alerts for contraindicated prescriptions among elderly patients (Smith)[12].
  - **Care Quality** – the effectiveness of diabetes management (Schmittdiel)[13].
  - **Effectiveness** – comparing outcomes for 40,000 patients taking Celebrex versus Vioxx (Graham)[14].

9. See http://www.thepermanentejournal.org/
10. Hillier et al., "Childhood Obesity and Metabolic Imprinting: the Ongoing Effects of Maternal Hyperglycemia". Diabetes Care, September 2007. See https://care.diabetesjournals.org/content/diacare/30/9/2287.full.pdf
11. Raebel et al., "Randomized Trial to Improve Laboratory Safety Monitoring of Ongoing Drug Therapy in Ambulatory Patients". Pharmacotherapy, May 2006. See https://accpjournals.onlinelibrary.wiley.com/doi/abs/10.1592/phco.26.5.619
12. Smith et al., "The Impact of Prescribing Safety Alerts for Elderly Persons in an EMR". Archives of Internal Medicine, May 2006. See https://jamanetwork.com/journals/jamainternalmedicine/article-abstract/410337
13. Schmittdiel et al., "The Effectiveness of Diabetes Care Management in Managed Care". American Journal of Managed Care, May 2009. See https://europepmc.org/article/med/19435397
14. Graham et al,. "Risk of Acute Myocardial Infarction and Sudden Cardiac Death in Patients Treated with Cyclo-oxygenase 2 Selective and Non-selective Non-Steroidal Anti-Inflammatory Drugs". Lancet. Feb 2005. See https://www.sciencedirect.com/science/article/abs/pii/S0140673605178647

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Case Study #3

eCare: A Clinical Decision Support System

NORTH YORK GENERAL

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NORTH YORK GENERAL

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Case Study #3

eCare: A Clinical Decision Support System

Canada – North York General Hospital Clinical Decision Support System, Toronto, Ontario

- North York General Hospital (NYGH) is a community academic hospital affiliated with the University of Toronto providing inpatient, ambulatory and long term care services. It was a HIMSS Davies Award of Excellence winner in 2016.
- NYGH commenced the deployment of their *eCare* project in 2007, using the Cerner clinical information system[1,2]. In 2010 Phase II of the project was initiated for Computerized Provider Order Entry (CPOE), clinical decision support, and electronic medication management (i.e. eMAR, bar coding, medication reconciliation and eRx on discharge).
- The introduction of CPOE and **SNOMED CT**- enabled evidence-based order sets at NYGH was an opportunity to shift the organization to evidence-based practice. However, similar to other CPOE and evidence-based order set implementations the *eCare* project met with significant resistance, particularly from physicians.
- NYGH initially tried to introduce **SNOMED CT**- encoded problem lists through drop-down lists, but achieved less than 1% physician adoption because there were too many terms and it took too long (i.e. ~12 seconds) per diagnosis to complete.
- NYGH then changed tack and introduced **SNOMED CT** using a "stealth approach" by building diagnoses and comorbidities into ordering workflow (increased to 15% adoption), adding diagnoses into documentation workflow for endoscopy, diabetes care, and urology (increased to 30% adoption), and finally into physician in-patient documentation when the vendor upgraded this functionality (100% adoption in the pilot group) which has been rolled out specialty-by-specialty.

1. Theal et al., "CPOE with Evidence-Based Clinical Decision Support Improves Patient Outcomes", Healthcare Quarterly Vol 17 No 1, Longwoods, 2014
2. Theal et al., "CPOE with Evidence-Based Clinical Decision Support Improves Patient Outcomes – Part 2", Healthcare Quarterly Vol 17 No 4, Longwoods, 2014

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Case Study #3

eCare: A Clinical Decision Support System

Canada – North York General Hospital Clinical Decision Support System, Toronto, Ontario (continued)

- During this process the NYGH clinicians were invited to develop their own library of evidence-based order sets as a way to both standardize (i.e. use of evidence) and personalize (i.e. patient care plan) care. Once created, the 850 plus NYGH order sets were then made available to other health organizations across Canada.

Significant Patient Outcome Benefits Achieved[3]

- Achieved 100% user adoption of the CPOE system; 92% of physician orders and 86% of medication orders entered by MDs.
- Approximately 50% of physician order volume was generated from evidence-based order sets.
- Increased use of evidence-based admission order sets from 36.5% pre-CPOE to 97.4% post-CPOE.
- Medication turnaround time for STAT antibiotics improved by 83% (291 to 50 mins) which is important for diagnoses like pneumonia, where getting the antibiotic faster vastly improves patient health outcomes.
- In a review of CPOE and evidence-based order sets North York researchers found that inpatient preventable mortality from pneumonia and COPD exacerbation was reduced by 45% using CPOE vs paper orders, and by 56% using CPOE with a correctly matched evidence based order set (even after adjustment for comorbidities, age, sex, diagnosis, length of stay and critical care unit admission). Over 5 years this amounted to over 120 lives saved, a positive patient health outcome.

3. Theal J., "SNOMED CT – A Canadian Clinical Perspective", James Read Memorial Lecture, SNOMED International EXPO, Bratislava, 2017. See https://confluence.ihtsdotools.org/display/FT/SNOMED+CT+Expo+2017#:~:text=Thursday%2C%2019th%20October%202017%20%20%20%20,Expo%202017%20Drinks%20Reception%20-%20O%20...%20

Case Study #3

eCare: A Clinical Decision Support System

Canada – North York General Hospital Clinical Decision Support System, Toronto, Ontario (continued)

Significant Patient Outcome Benefits Achieved con't

- Appropriate prophylaxis against venous thromboembolism (VTE) – a blood clot in a deep vein - increased from 50% of inpatients to >97% of inpatients, with a corresponding 39% reduction in VTE, a positive patient health outcome.

Economic Benefits Achieved

- The eCare ROI was determined by applying the Economics of Patient Safety[4] findings for 4 adverse events to the NYGH experience. The four adverse events included: reduction in medication errors, reduction in nosocomial adverse drug events, VTE prevention and prevented recurrences of *C. difficile.*
- The total cost avoidance from improvements in the occurrence of the four adverse events was determined to be CAD$38.1M over 5 years, or CAD$7.6M per year.
- When the total cost of acquiring and implementing the *eCare* clinical information system was also taken into account a net savings over the 5-year period of CAD$1.2 million was achieved.

4. Etchells, Mittmann et al., "The Economics of Patient Safety in Acute Care – A Technical Report", Canadian Patient Safety Institute, 2012. See https://www.patientsafetyinstitute.ca/en/toolsResources/Research/commissionedResearch/EconomicsofPatientSafety/Documents/Economics%20of%20Patient%20Safety%20-%20Acute%20Care%20-%20Final%20Report.pdf

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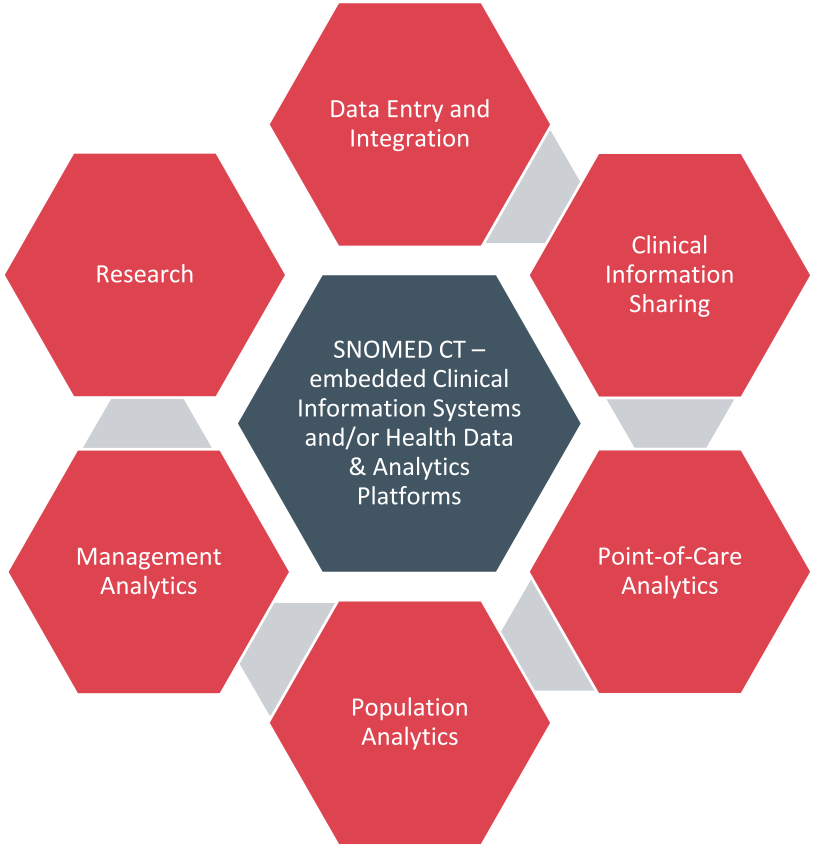

NHS Barts Health NHS Trust

East London Health & Care Partnership

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Case Study #4

A Regional Digital Health Initiative

United Kingdom – BARTS NHS Trust and the East London Health and Care Partnership, London, England

BARTS NHS TRUST

- Established in 2012, BARTS NHS Trust (BARTS) runs five hospitals throughout the City of London and East London. The trust provides community, acute care and specialist services to a population of over 2.6 million people, in an area characterized by significant diversity and health inequalities. The health profile and health needs vary significantly between, and within, individual boroughs, with a distinct difference between the Inner and Outer London boroughs. It is one of the largest NHS trusts in England, and accounts for 1.5% of all hospital activity in the country. It runs the largest cardiovascular centre in the United Kingdom, the second largest cancer centre in London, as well as the leading stroke and renal units.
- While BARTS uses a single instance of its **SNOMED CT**-embedded Cerner Millennium clinical information system across its five hospitals it is also a key player in the broader East London and London digital health initiatives. This case study will highlight the use of **SNOMED CT** across the six use domains for:
  - The BARTS clinical information system implementation,
  - The East London Patient Record (EHR) implementation,
  - The East London Discovery program, and
  - The OneLondon program.

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A Regional Digital Health Initiative

United Kingdom – BARTS NHS Trust and the East London Health and Care Partnership, London, England

BARTS CLINICAL INFORMATION SYSTEM IMPLEMENTATION AND USE

- The BARTS SNOMED CT-embedded Cerner Millennium clinical information system (locally known as the Care Record System or CRS) was introduced in 2008, and subsequently expanded and enhanced, with a focus on
  1. **Single System** - where all BARTS patient data is recorded in a consistent and coherent format, that is easily shareable among clinicians and is open to analysis,
  2. **Connectedness** - where the Trust's Electronic Health Record (EHR) data is available in real-time to primary care, community care and mental health clinical professionals thereby enabling coordinated health care, and
  3. **Big Data**, the sharing of data enables the creation of central data repositories from which structured analysis is possible across a wide spectrum of circumstances, e.g. patient outcomes, satisfaction, performance monitoring, genomics and research.
- A "Benefits Deep Dive"[1] of the CRS implementation was conducted in 2013. It identified many of the same benefits that we have seen in the other clinical information system implementation case studies such as:

  Emergency Department: More effective record storage and retrieval; less duplicate data entry; reduction in 4-hour breaches; improvements in ED efficiency and workflow from using an electronic whiteboard.

  Outpatient Clinics: More effective record storage and retrieval; reduction in paper referrals due to a centralized e-referral service; improved appointment booking; more effective patient communications by providing letters at the end of the consultation; and an increase in revenues due to improved coding the finished consultant episodes (FCE).

1. Overton et al., "Benefits Deep Dive into Cerner Millennium Implementation July 2013 to January 2014", Health and Social Care Information Centre (now NHS Digital), 2014 https://confluence.ihtsdotools.org/display/CP/Clinical+Use+Cases?preview=%2F57808738%2F96810424%2FBarts_Health_Case_Study.pdf

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United Kingdom – BARTS NHS Trust and the East London Health and Care Partnership, London, England

BARTS CLINICAL INFORMATION SYSTEM IMPLEMENTATION AND USE

Infection Control Problem[2,3]

- in 2016 BARTS was not compliant with national legislative requirement to isolate infectious patients appropriately. Clinicians were unable to obtain daily aggregate data for current inpatients showing: infections, infection status (active vs. inactive), and location (open bay vs. side room).
- A manual data collection process meant scrolling through bed boards and individual patient records. For a trust with 2,100 beds across 110 wards at five different sites, this process was both time-consuming and prone to human error.
- BARTS now has an automated system of infection control reporting using **SNOMED CT** terms, which pulls in data directly from every patient's laboratory results. As a result, clinical decisions are now better guided and supported by reliable, up-to-date information. It also allows nurses on the ward and the infection control team to instantly spot patients who should be moved to isolation, and it assists with contact tracing when needed.
- Patient Safety Benefits Achieved – A 30% reduction in number of patients inappropriately located in open bays; reduced risk of exposure to infections; reduced risk of infection transmission; and reduction in time spent by the Infection Control team to locate and isolate infectious patients.

2. Gutteridge C., "Speaking a common language: driving interoperability using SNOMED CT", September 2019. See https://www.cerner.com/gb/en/blog/speaking-a-common-language-driving-interoperability-using-snomed-ct
3. Gutteridge C.,"Practical use of SNOMED CT- Real World Examples from BARTS Health" Presentation at SNOMED International Conference. Helsinki March 28th 2019

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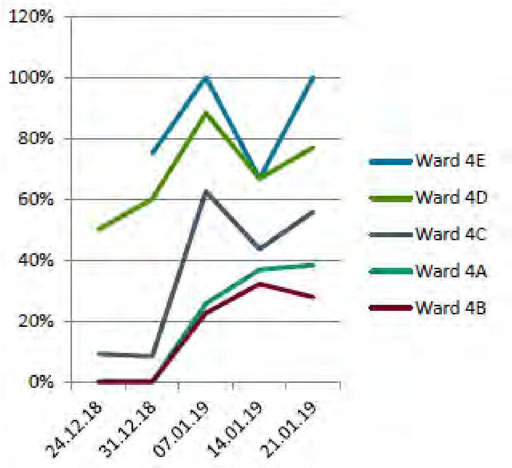
BARTS CLINICAL INFORMATION SYSTEM IMPLEMENTATION AND USE

Smoking Cessation[4]

- Compared to national benchmarks, there are higher numbers of smokers in east London – this in turn, results in higher rates for smoking-related disease admissions to hospital and higher mortality rates for cancer and respiratory disease.
- East London, also has a large South Asian Community. Tobacco chewing is common because tobacco is often added to paan (betel nut, herbs & spices wrapped in betel leaf and chewed). In the local Bangladeshi community, 60% of men and 50% of women use chewing tobacco. Tobacco +/- paan is a public health issue because it increases the risk of oral cancer, cardiovascular disease and adverse pregnancy outcomes.
- BARTS uses **SNOMED CT** to record patients who smoke and/or chew tobacco on their problem list. They are immediately referred to a smoking cessation program, which is a requirement for payment under NHS commissioning arrangements.
- BARTS also does data extraction from the Cerner clinical information system using **SNOMED CT** to determine the number of inpatients on each ward who smoke and/or chew tobacco and have cancer (i.e. 30% to 100%). In the first 8 months the recording of smoking status by clinicians increased from 5% to 50% of patients.



4. Gutteridge C.,"Practical use of SNOMED CT- Real World Examples from BARTS Health" Presentation at SNOMED International Conference. Helsinki March 28th 2019

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BARTS CLINICAL INFORMATION SYSTEM IMPLEMENTATION AND USE

Chronic Obstructive Pulmonary Disease (COPD) Clinical Audit[5]

- An estimated 3 million people in the UK have COPD, and it is the second most common cause of emergency hospital admission. Further, about a third of those admitted to hospital as a result of their COPD are readmitted within a month of discharge. The total annual cost of COPD to the NHS is over £800 million.
- BARTS is required to collect clinical audit data on COPD patients. It had an opportunity to gain £1.8 million and improve its reputation with funders by bringing COPD emergency spending in line with the best 5 hospitals in its NHS peer group.
- BART's respiratory clinicians and the ICT team moved from a paper-based system, to continuous data collection using a hybrid of paper-based and **SNOMED CT** encoded electronic methods, including clinical documentation.
- The next stage is a move to a fully integrated system that will pull data from respiratory teams in all of the Trust's hospital and community sites, based on **SNOMED CT** terminology agreed with clinicians. Collaboration with other departments, including acute medicine and mental health, is also vital.

5. Gutteridge C.,"Practical use of SNOMED CT- Real World Examples from BARTS Health" Presentation at SNOMED International Conference. Helsinki March 28th 2019

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EAST LONDON HEALTH AND CARE PARTNERSHIP

- BARTS (see the purple and orange boroughs) is also part of the East London Health and Care Partnership (ELHCP).

The ELHCP region has:

- The highest population growth in London.
- A changing population with increasing diversity.
- A high percentage of the population relying on benefits, experiencing unemployment, plus living in poor housing and environment.
- Poor health outcomes for its population including obesity, cancer, mental health, and dementia.
- Service quality issues including a high reliance on emergency services, late diagnoses and treatment and access to services issues, particularly primary care.
- Further, there is significant variation between each borough/place in health and care outcomes, available services, and resources.

We are:
- **7 CCGs**
- **8 London Councils**
- **5 NHS Trusts – 3 acute and 2 community**
- **286 GP Practices**

Waltham Forest
Population: 276,000
Deprivation (IMD rank): 15
Life Expectancy at birth: 82.4
GP Practices: 40
Major Hospitals:
Whipps Cross [5]

Redbridge
Population: 300,600
Deprivation (IMD rank): 119
Life Expectancy at birth: 82.7
GP Practices: 42
Major Hospitals:
King George Hospital [6]

City and Hackney
Population: 277,000
Deprivation (IMD rank): 2 (Hackney) & 226 (City of London)
Life Expectancy at birth: 80.9 (Hackney)
GP Practices: 42
Major Hospitals:
Homerton[3]
St Bartholomew's [7]

Havering
Population: 250,500
Deprivation (IMD rank): 166
Life Expectancy at birth: 81.9
GP Practices: 43
Major Hospitals:
Queen's Hospital [2]

Tower Hamlets
Population: 296,300
Deprivation (IMD rank): 6
Life Expectancy at birth: 81.0
GP Practices: 35
Major Hospitals:
Royal London [1]

Newham
Population: 338,600
Deprivation (IMD rank): 8
Life Expectancy at birth: 81.3
GP Practices: 49
Major Hospitals:
Newham University Hospital [4]

Barking and Dagenham
Population: 206,700
Deprivation (IMD rank): 3
Life Expectancy at birth: 80.0
GP Practices: 35

Case Study #4

A Regional Digital Health Initiative

United Kingdom – BARTS NHS Trust and the East London Health and Care Partnership, London, England

ELHCP EAST LONDON PATIENT RECORD[6]

- The ELHCP East London Patient Record (eLPR) has been in place since 2014. It is a consolidated, read only view of a patients' health record, and has more detailed clinical data than the national Summary Care Record. The record is sourced from 4 Clinical Commissioning Groups (CCGs), 5 BARTS acute hospital sites, 2 mental health trusts, three sets of community services and almost 200 GP practices, covering a population of about 1.5 million.
- The eLPR is created and shared among clinicians via two independent Cerner health information exchanges (HIEs), with over 150,000 eLPR views occurring per month in late 2020. Interoperability is achieved within East London by standardizing data entry and coding care, pathway by care pathway, using **SNOMED CT** standards.
- In 2017 an eLPR Benefits Study Evaluation[7] was conducted, where clinician users of the eLPR in both primary and secondary care settings were surveyed and interviewed.

Key Benefits Identified

- **Efficiency** - 48% of clinicians felt the amount of paperwork had been reduced, 63% felt there had been a reduction in records notes going missing and 42% recorded a reduction in the number of investigations ordered. Similarly, 78% of hospital clinicians state that they could better handle the speed and quality of treatment in their department. About 80% of the clinicians stated that the number of phone calls answered or made were reduced because the information is available in eLPR thereby reducing the need to call a colleague for further information.

6. See http://www.cityandhackneyccg.nhs.uk/about-us/elpr.htm
7. Readman et al, "East London Patient Record Benefits Study Evaluation", 2018. See https://www.eastlondonhcp.nhs.uk/downloads/ourplans/digital/East%20London%20Patient%20Record%20Benefits%20Report%20DIGITAL%20FINAL.pdf

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A Regional Digital Health Initiative

United Kingdom – BARTS NHS Trust and the East London Health and Care Partnership, London, England

EAST LONDON PATIENT RECORD con't

Key Benefits Identified con't

- **Referrals** - Based on the responses to the survey it was concluded that 1,233 referrals are avoided across Waltham Forest, East London and City (WELC) each year. Taking the cost of first referral, single professional for the lowest cost treatment function (Anesthetics) and a market forces factor of 1.2 (just under both Homerton and Barts Health's figure), i.e. £111, this equates to an annual saving of £133k.
- **System Consolidation** - In 2017 the Newham Hospital Urgent Care Centre was able to consolidate its use of systems through the eLPR. This brought a number of notable benefits including: elimination of dual-entry and associated training costs and time wasted entering data into multiple systems leading to savings in licensing and support costs. This will save Newham CCG approximately £500k per year.
- **Patient Engagement** - 62% of clinicians felt that the patient engagement and relationship was improved with eLPR.
- **Clinician Satisfaction** - Overall, 81% of clinicians felt eLPR had a positive effect on their working day.

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THE ELHCP DISCOVERY PROGRAM[8]

- Discovery East London was first established in 2016 to create a linked dataset of real-time clinical data from a myriad of care settings, including BARTS, across five boroughs: City of London, Hackney, Newham, Tower Hamlets and Waltham Forest. The service has now been scaled across London, with a potential opportunity to scale it nationally, as part of the NHS Data Discovery Service[9].
- The ELHCP Discovery program objective has been to publish primary care, secondary care (e.g. BARTS), mental health and other care data in a common health data platform so that it can be used for clinical analytics, population analytics, management analytics and research purposes. By implementing strict data governance and controlled technical access approved users of the data can subscribe to the service and use it for their approved purpose (e.g. research).
- The data in the Discovery data platform is all encoded in **SNOMED CT**. The data from the source systems either comes as **SNOMED CT**-encoded (e.g. data from GP systems and the BARTS secondary care system) or is transformed to **SNOMED CT** as part of the ETL process, if the source system does not use **SNOMED CT**.
- At this time there are over 25 projects that are either live or in progress. By way of example eight of these twenty-five projects are sourced from the BARTS NHS Trust. Examples of live projects are shown overleaf.

8. See https://www.eastlondonhcp.nhs.uk/downloads/ourplans/digital/Discovery_Programme-Annual_Report_Jan_2019.pdf
9. See https://www.discoverydataservice.org/Content/Overview.htm

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THE ELHCP DISCOVERY PROGRAM

Examples of Live Projects

1. **Serious Mental Illness (SMI),** East London Foundation Trust (ELFT): The SMI query reconciles ELFT secondary care mental health data with primary care serious mental health datasets.
2. **BARTS Pancreas Tissue Bank**, BARTS: The Barts Pancreas Tissue Bank (BPTB) is a unique and vital resource for researchers to provide a multitude of **specimen types from pancreas disease and cancer patients** as well as healthy controls. The samples are mainly collected from the Royal London Hospital and curated at Barts Cancer Institute.
3. **NHS 111 Discovery Frailty Flagging**, Multiple Boroughs: The Discovery Data Service helps to **identify potentially frail patients** using a frailty algorithm and the results are provided to the NHS 111 London Ambulance Service clinician upon request.
4. **Childhood Immunizations and 6-Week Check**, NE London Child Health Immunization Service: The daily extract provides an **update on changes in all immunizations over the past 24 hours,** so the data platform and GP systems are in sync.
5. **East London Genes and Health**, Multiple Boroughs: The East London Genes and Health (ELG&H) study aims to **improve the health of people of Pakistani and Bangladeshi heritage** by **analyzing the genes and health of 100,000 local people**. A more detailed description of this project is outlined starting on the next page.

Case Study #4

A Regional Digital Health Initiative

United Kingdom – BARTS NHS Trust and the East London Health and Care Partnership, London, England

ELHCP DISCOVERY: POPULATION HEALTH ANALYTICS and RESEARCH – East London Genes and Health Study[10]

- Recent genomic advances offer the potential to better understand the genetic causation of disease, and to direct pharmacotherapy to rare loss-of-function gene variants.
- East London Genes & Health (ELGH) is a community based, long-term study of health and disease in British-Bangladeshi and British-Pakistani people in east London. ELGH has a population-based design incorporating cutting-edge genomics with **SNOMED CT**-embedded electronic health record (EHR) data linkage and targeted recall-by-genotype (RbG) studies. ELGH has >34,000 volunteers with funding to expand to 100,000 volunteers by 2023.
- Almost a quarter of the world's population, and 5% of the UK population, are of South Asian origin. The risk of coronary heart disease is 3-4 times higher, and type 2 diabetes (T2D) 2-4 times higher in UK South Asians compared with Europeans. East London incorporates one of the UK's largest South Asian communities (29% of 1.95 million people), of which 70% are British-Bangladeshi and British-Pakistani, and its population live in high levels of deprivation (Tower Hamlets, Hackney, Barking and Dagenham are the 9th, 10th and 11th most deprived local authorities in England).
- Compared to White Europeans, South Asians living in east London have a two-fold greater risk of developing T2D, nearly double the risk of non-alcoholic liver disease, and over double the risk of multimorbidity, with the onset of cardiovascular disease occurring 8 years earlier in men. Determinants of poor cardiometabolic health start early in the life course, with higher rates of overweight and obese children in east London compared to the UK average.

10. Finer et al., "East London Genes & Health (ELGH), a community based population genomics and health study of British-Bangladeshi and British-Pakistani people.", bioRxiv preprint, February 2019. See https://www.biorxiv.org/content/10.1101/426163v2.full.pdf

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United Kingdom – BARTS NHS Trust and the East London Health and Care Partnership, London, England

ELHCP DISCOVERY: POPULATION HEALTH ANALYTICS and RESEARCH – East London Genes and Health Study con't

- ELGH[11] combines health data science using linked NHS **SNOMED CT**-embedded EHR data, BARTS **SNOMED CT**-embedded EHR data as well as local GP systems data (now with **SNOMED CT**-embedded data) with exome sequencing and SNP array genotyping to elucidate the genetic influence on health and disease, including the contribution from high rates of parental relatedness on rare genetic variation and homozygosity (autozygosity), in the two understudied ethnic groups. Linkage to longitudinal health record data enables both retrospective and prospective analyses.
- **Stage 1** entailed the development of the study cohort**.** ELGH invited voluntary participation of all British-Bangladeshi and British-Pakistani individuals aged 16 and over, living in, working in, or within reach of, east London. Recruitment is largely undertaken by bilingual health researchers, and takes place in: (a) community settings, e.g. mosques, markets and libraries, supported by a third-sector partner organization (Social Action for Health), and (b) healthcare settings, e.g. GP surgeries, outpatient clinics. Stage 1 volunteers complete a brief questionnaire, give consent to lifelong EHR linkage, and donate a saliva sample for DNA extraction and genetic tests. Between April 2015 and January 2019, ELGH has recruited 34,482 volunteers to Stage 1 (currently ELGH has ~50,000 volunteer recruits).
- Through **Stage 2** studies, ELGH now offers researchers the opportunity to undertake recall-bygenotype and/or recall-by-phenotype studies on volunteers. Sub-cohort, trial-within-cohort, and other study designs are possible. ELGH is a fully collaborative, open access resource, open to academic and life sciences industry scientific research partners. Eight approved Stage 2 research studies using the ELGH Stage 1 cohort data have been published and sixteen are underway.

11. See http://www.genesandhealth.org/

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ELHCP DISCOVERY: POPULATION HEALTH ANALYTICS and RESEARCH – East London Genes and Health Study con't

By way of example, the ELGH Stage 2 Studies Published to Date[12] include:

1. Trans-ethnic and ancestry-specific blood-cell genetics in 746,667 individuals from 5 global populations. Cell 2020 Sept 3. DOI https://doi.org/10.1016/j.cell.2020.06.045
2. Genomewide Association Study of Severe Covid-19 with Respiratory Failure. New England Journal of Medicine 2020 Jun 17. DOI https://doi.org/10.1056/NEJMoa2020283
3. Evaluating potential drug targets through human loss-of-function genetic variation. Nature 2020 May;581(7809):459-464. DOI https://doi.org/10.1101/530881
4. Characterizing a healthy adult with a rare HAO1 knockout to support a therapeutic strategy for primary hyperoxaluria. eLife 2020;9:e54363. DOI https://doi.org/10.7554/eLife.54363
5. Effects of autozygosity on a broad range of human phenotypes. Nature Communications 2019 Oct 31;10(1):4957. DOI https://doi.org/10.1038/s41467-019-12283-6
6. Formalising recall by genotype as an efficient approach to detailed phenotyping and causal inference. Nature Communications 2018 Feb 19;9(1):711. DOI https://doi.org/10.1038/s41467-018-03109-y
7. Estimating the human mutation rate from autozygous segments reveals population differences in human mutational processes. Nature Communications 2017 Aug 21;8(1):303. DOI https://doi.org/10.1038/s41467-017-00323-y
8. Health and population effects of rare gene knockouts in adult humans with related parents. Science 2016 Apr 22;352(6284):474-7. DOI https://doi.org/10.1126/science.aac8624

12. See http://www.genesandhealth.org/about-study/scientific-publications

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ELHCP DISCOVERY: POPULATION HEALTH ANALYTICS – COVID-19 in Ethnic Minority Populations[13]

- The first wave of the London COVID-19 epidemic peaked in April 2020. Attention initially focused on severe presentations, intensive care capacity, and the timely supply of equipment. While general practice saw a rapid uptake of technology to allow for virtual consultations, little was known about the pattern of suspected COVID-19 presentations in primary care.
- A cross-sectional study was undertaken using ELHCP Discovery. Utilizing anonymized data from the **SNOMED CT-**encoded primary care records of approximately 1.2 million adults registered with 157 practices in four adjacent east London clinical commissioning groups (note: all GP EMRs use **SNOMED CT** in the UK). The study population includes 55% of people from ethnic minorities and is in the top decile of social deprivation in England.
- General Practitioners recorded 8,985 suspected COVID-19 cases between 10 February and 30 April 2020. Univariate analysis showed a two-fold increase in the odds of suspected COVID-19 for South Asian and black adults compared with white adults.
- Using data from GP primary care records, black and South Asian ethnicity is a predictor of suspected COVID-19, with levels of risk similar to hospital admission reports.

13. Hull et al., "Prevalence of Suspected COVID-19 Infection in Patients from Ethnic Minority Populations: a Cross-Sectional Study in Primary Care.", British Journal of General Practice, Online First 2020. See https://bjgp.org/content/early/2020/09/07/bjgp20X712601

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United Kingdom – BARTS NHS Truѕt and the East London Health and Care Partnership, London, England

ONELONDON PROGRAM[14]

- OneLondon is one of the country's first Local Health and Care Record Exemplars (LHCRE), designated by NHS England. The OneLondon LHCRE is a partnership of NHS organizations and local government across all of London, working together with citizens to transform London's health and care services by integrating information to support patient care.
- Both BARTS and the East London Health and Care Partnership are part of the OneLondon program. In short, the OneLondon program will take the digital health successes from the likes of BARTS and the East London Health and Care Partnership and extend that across the entire the City of London and the 32 boroughs with its combined population of over 9 million people.
- For example the OneLondon Patient Record (similar to eLPR), as well as a OneLondon data platform similar to the East London Health and Care Partnership Discovery platform is being deployed. Currently, the OneLondon Patient Record provides clinician access to the health records of 6 million patients in 3 of the 5 zones in London.
- The first step in the OneLondon program has been citizen engagement which occurred over the 12 month period starting in June 2019. This process resulted in the recent publication of the "*Public Deliberation in the Use of Health and Care Data*"[15].

14. See https://www.onelondon.online/
15. See https://www.onelondon.online/wp-content/uploads/2020/07/Public-deliberation-in-the-use-of-health-and-care-data.pdf

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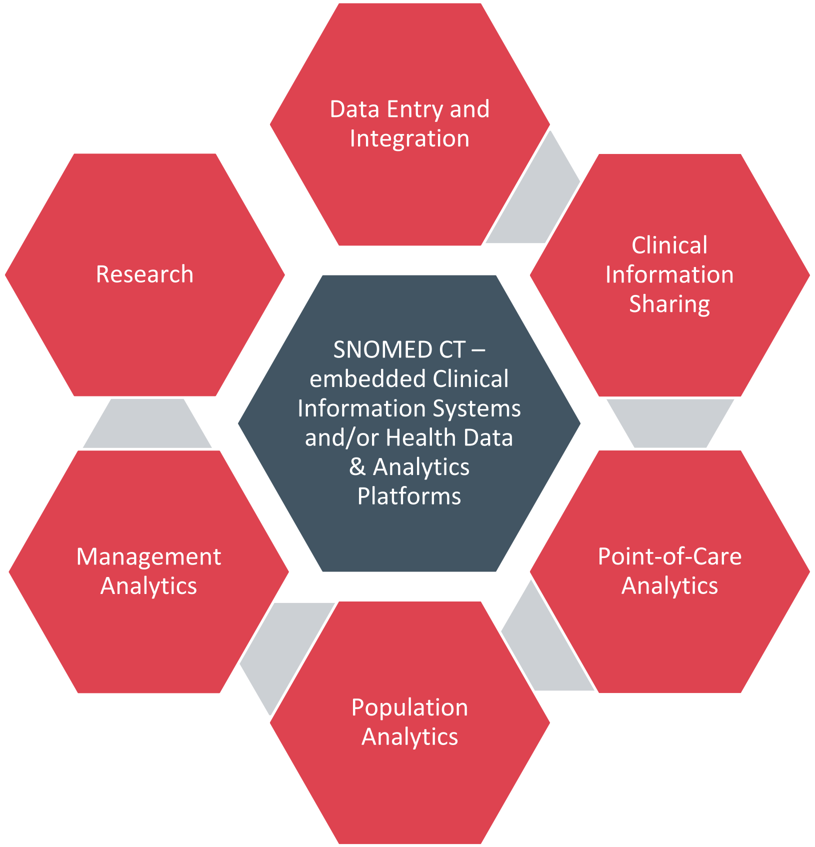
Case Study #5

eHospital: A Clinical Information System



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Cambridge University Hospitals' current digital maturity is the highest of any of the trusts visited.

National Advisory Group report on Health Information Technology in England, chaired by Professor Robert Wachter (September 2016)

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Case Study #5

eHospital: A Clinical Information System

United Kingdom – Cambridge University Hospitals NHS Foundation Trust, Cambridge, England

- Cambridge University Hospitals (CUH) is one of the largest healthcare trusts in England, caring for patients through its two hospitals – Addenbrooke's and The Rosie. Located on the 142 acre Cambridge Biomedical Campus, it is also a leading national centre for specialist treatment, a comprehensive biomedical research centre, one of only six academic health science centres in the UK, and a university teaching hospital with a worldwide reputation for clinical excellence.
- CUH deployed its £200 million *eHospital* clinical information system from Epic, for both inpatient and outpatient services, across the entire Trust in October 2014 – one patient, one record for all CUH patients[1]. In June 2017 CUH launched the MyChart patient portal. Through 2018 CUH deployed interoperability between *eHospital* and primary care, diagnostic services and acute care organizations in the UK and internationally. CUH is a HIMSS level 6 EMRAM organization, has won many national and international awards, and is recognized is a NHS Global Digital Exemplar organization.
- *eHospital* has enabled CUH to transform clinical processes from paper-based to fully digital ways of recording care and accessing information; supported by medical device integration, as well as handheld/mobile device integration to enable care to be recorded in real-time at the bedside. *eHospital* is connected to national systems such as the NHS Spine (national personal demographics service) and e-Referral Service from primary care to secondary care.
- CUH used **SNOMED CT** for coding diagnoses, symptoms and problems in their *eHospital* system, key data that is used for many inpatient and outpatient clinical processes. In addition, this data is used for advanced analytics and research[2].

1. Cambridge University Hospitals NHS Foundation Trust., "eHospital – Patients at the Heart of Our Digital Hospital", See a 28 page summary of the project at https://www.cuh.nhs.uk/sites/default/files/misc/Brochure_eHospital_Website%20Version_September%202019.pdf
2. Drumright, O'Neill, Chaudhry "Changing What We Do". A presentation about the Cambridge University Hospitals eHospital project and the links to the Cambridge Biomedical Research Centre. See https://community.jisc.ac.uk/system/files/515/cambridge%20implementation%20nhs%20he%20forum%20june%202015%20FINAL.pdf

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Case Study #5

eHospital: A Clinical Information System

United Kingdom – Cambridge University Hospitals NHS Foundation Trust, Cambridge, England

The CUH eHospital implementation has resulted in both a significant number of **patient service outcomes** (e.g. access and productivity gains) and **patient health outcomes** (e.g. reduction in adverse events, morbidity and mortality) benefits.

Key Quantitative Benefits Achieved[3]

- **Chart Pulls** - £460,000 saved annually in staff time as paper patient records no longer require retrieval from medical records.
- **Nursing Productivity** - £1.1m saved annually in nursing time as observations and medication administration are recorded directly into patient records at the bedside, using handheld devices connected to our EHR.
- **Adverse Drug Events** - 850 significant adverse reactions prevented each year with electronic allergy-related prescribing alerts in our EHR triggering a change in medication prescriptions - saving 2,450 bed days a year, equivalent to £0.98 million/year.
- **Medication Management** - 100% recording of the indication for antibiotic prescribing leading to more meaningful antibiotic stewardship – antibiotics are only prescribed if they are truly needed.
- **Patient Health Outcomes** - 42% reduction in sepsis mortality with electronic sepsis alerts built into the EHR by the eHospital team.

3. The CUH benefits detailed on this and subsequent pages are those that would use SNOMED CT encoded data as part of the clinical business process. CUH has also quantified other benefits (e.g. from medical devices) where SNOMED CT would not be used. These types of benefits have not been included in this case study.

Case Study #5

eHospital: A Clinical Information System

United Kingdom – Cambridge University Hospitals NHS Foundation Trust, Cambridge, England

Out-Patient Clinics

Using fully digital out-patient clinics has enabled CUH to improve patient care, safety and experience; and to make the running of the busy clinics much more effective and efficient.

- **Elimination of Paper**: 100% reduction in paper first referrals from GPs to the consultant-led clinics/services because the EHR is integrated with the NHS e-Referral service.
- **Appointment Efficiency Gains**: 4,500 clinic appointment slots per year were freed up in orthopedics for patients who absolutely need to come to hospital for treatment, because clinicians were able to view clinical notes and x-rays virtually (i.e. virtual fracture clinic) in the EHR to determine whether a patient needs an appointment, or not.
- **Effective Patient Communications**: 80% of clinic letters in pediatric gastroenterology are given to the parents at the end of clinic because data from the EHR is automatically combined into a structured letter.
- **Improved Clinic Throughput**: 20% more patients are being seen (i.e. capacity creation) in the surgical pre-assessment clinic as patients are able to complete their own initial documentation on a digital tablet, with the information then saved automatically to their health record within the EHR.

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United Kingdom – Cambridge University Hospitals NHS Foundation Trust, Cambridge, England

Emergency

Addenbrooke's Hospital is one of the busiest emergency (A&E) departments in the UK and is a Major Trauma Centre for the region. Quick and easy access to information is essential for all staff working in Emergency due to the high volume of patients being treated, twenty-four hours a day, seven days a week.

- **Elimination of Paper: the a**dministrative burden of urgently sourcing paper records for patients arriving in the emergency department has been completely eliminated.
- **Emergency Department Management Efficiency Gains**: a digital emergency department allows rapid access to the patients information in the EHR. Staff can see, at a glance, colour-coded information about: each patient; waiting time; which area and bed they are in; acuity level; early warning score with alerts; status of their emergency care pathway; when they were last reviewed by a clinician; and when assessments were completed.
- **Appointment Efficiency Gains**: Elimination of waiting for paper notes to be released from the emergency department before follow-up appointments can be booked.
- **Improved Coordination of Care**: Letters are automatically sent from the EHR to the patients' GP when the patient is admitted to an inpatient area from the emergency department.
- **Improved Coordination of Care:** Discharge summary letters are sent electronically from the EHR to the patient's GP within 24 hours of discharge from the emergency department.

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eHospital: A Clinical Information System

United Kingdom – Cambridge University Hospitals NHS Foundation Trust, Cambridge, England

Digital Theatres and Critical Care

In high dependency areas, like operating theatres and intensive care, a huge amount of data is created about severely unwell patients who are hooked up to ventilators, monitors, and other medical devices. Prior to having the EHR CHU clinical teams had to manually assimilate data from multiple sources and devices. Now, all of the physiological monitors and ventilators, in all 40 theatres,148 high-dependency areas and critical care beds, are connected to the EHR.

- **Staff Efficiency Gains**: data generated from medical devices is being automatically and continuously recorded directly into the EHR removing the need for manual transcription and associated errors - a staff time saving equivalent to £2.6 million a year.
- **Theatre Throughput:** 18% increase in main theatre case volume (i.e. capacity creation) through faster theatre turnaround and analytics in the EHR.
- **Clinical Efficiency Gains:** a 30 minute reduction in our Rapid Response Team getting to patients across our hospitals that need them the most.
- **Improved Patient Outcomes:** 2-3 avoidable deaths prevented each year with electronic routine review of best practice for ventilator tidal volumes in the EHR.

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Case Study #5

eHospital: A Clinical Information System

United Kingdom – Cambridge University Hospitals NHS Foundation Trust, Cambridge, England

Sepis "the Silent Killer"

Sepsis is a life-threatening condition that arises when the body responds to an infection by attacking its own tissues and organs. Every year in the UK approximately 250,000 people are affected by sepsis and it accounts for around 50,000 deaths, more than bowel, breast and prostate cancer combined. Research shows that for every hour delay in receiving antibiotics the risk of sepsis mortality increases by 8% - this is the sepsis risk.

- **Improved Patient Care**: 100% sepsis screening now occurs in the Emergency department.
- **Improved Patient Care**: 70% increase in patients receiving antibiotics for sepsis within 1 hour of arrival in Emergency with electronic sepsis alerts in our EHR.
- **Improved Patient Care:** 80% increase in patients receiving antibiotics for sepsis within 90 minutes of arrival in Emergency.
- **Improved Patient Care**: a 50% increase in adult inpatients receiving antibiotics for sepsis within both 60 and 90 minutes of the sepsis alert being triggered in the EHR.
- **Improved Patient Health Outcomes**: 42% reduction in sepsis mortality across the Trust. At least 64 lives saved in 2018 with sepsis alerts created in the EHR.

Case Study #5

eHospital: A Clinical Information System

United Kingdom – Cambridge University Hospitals NHS Foundation Trust, Cambridge, England

Clinical Data Sharing Requiring Interoperability of Clinical Information Systems

- **Sharing the EHR beyond CUH** - Located 35 miles apart, approximately 30 per cent of patients attending CUH (i.e. Addenbrooke's and The Rosie) also present at the West Suffolk Hospital for care and treatment. In 2018 the CUH eHospital EHR (Epic) was connected to West Suffolk Hospital's Cerner Millennium EHR. At the push of a button, CUH clinicians are able to easily and securely access clinical information (i.e. conditions, treatments, and test results) about a patient that is held within West Suffolk Hospital EHR and vice-versa, enabling real-time information and data sharing to save time and reduce delays to care and unnecessary repeats of tests and procedures.
- This digital link also connects Cambridge University Hospitals with all hospitals across the world that use an Epic EHR to advance the care of their internationally shared patients.
- Finally CUH has integrated eHospital to Royal Papworth Hospital's Lorenzo system to enable the real-time sharing of test results as soon as they have been verified in CUH laboratories.
- Separately, CUH has been working with NHS Digital[4] to develop and test a new FHIR medication specific message that will be used to share medication information between GPs and hospitals. This has meant testing the functionality and all possible varieties of medication prescriptions to ensure that the structure of the medication data can meaningfully and safely convey the clinical message. Some elements of the message are human readable text, but there is also coded data using **SNOMED CT** and dm+d codes.

4. Interview with Dr. Afzal Chaudhry, CCIO, CUH NHS FT., See https://www.thehtn.co.uk/2019/11/17/interview-series-dr-afzal-chaudhry-ccio-cambridge-university-hospitals-nhs-ft/

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Case Study #5

eHospital: A Clinical Information System

United Kingdom – Cambridge University Hospitals NHS Foundation Trust, Cambridge, England

Patient Portal – clinical information sharing that allows CUH patients digital access to their health information

- **Electronic Record** - A patient's eHospital information is available to them electronically via Epic MyChart instead of being posted to them: appointment letters /past appointment details; current health problems/conditions; clinic letters/clinical correspondence; vital signs (weight, height, blood pressure, temperature, pulse, respiratory rate); test results; medications; known allergies.
- **Access 24x7** - Patients can access their information in MyChart anytime and anywhere. In the comfort of their own home they can access it on a desktop computer or laptop, or when on the move, at CUH hospitals or abroad via the 'MyChart' app for tablet and Smartphone devices. MyChart is also compatible with screen readers for visually impaired patients.
- **Effective Appointments** - CUH patients can also complete pre-appointment questionnaires electronically within MyChart, with the results then being discussed during their next clinic appointment. This makes appointments much more effective as our patients and clinicians spend more time discussing care and treatment plans together.
- **Reduce Patient Visits** - Empowering CUH patients to contribute to their health record, MyChart encourages our patients to contribute to their health information without having to make unnecessary visits to CUH hospitals. For example, if patients have been prescribed new medication by their GP, they can add the medication name, dose and frequency to their record via MyChart for discussion with their clinical team during their next hospital appointment.
- As of December 2019 23,000+ patients are using CUH MyChart. See CUH patient Allan Craig's experience on the next page.

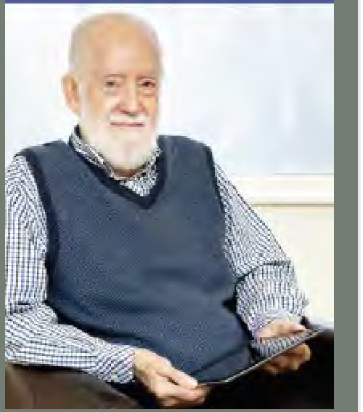
Case Study #5

eHospital: A Clinical Information System

United Kingdom – Cambridge University Hospitals NHS Foundation Trust, Cambridge, England

I have always played an active role in my own treatment and like to understand my conditions. I have a range of medical problems, which started in 1969 when I was diagnosed with polycystic kidney disease. My blood pressure was controlled for a long time to help delay the need for dialysis treatment before I eventually had a successful kidney transplant in 1989. I was diagnosed with a serious heart condition and underwent a quadruple bypass and aortic valve replacement in 1999. As a result of the drugs I have to take following my transplant, I've also suffered with osteoporosis, abdominal hernias, basal cell carcinomas and several hematomas. I like to work with my clinicians in the management of my health conditions, which was why the MyChart patient portal particularly appealed to me. MyChart allows me to view my upcoming hospital appointments, details of past appointments and hospital visits, clinical letters from my doctors and my test results. I like how I can also access a health summary page, either on my computer at home or on my smartphone, which includes a full list of my medications, as well as links to further information to help me to manage my conditions and learn more about the medications that I have been prescribed. More and more people are living with a range of complex health conditions. Having all the information available in one place, explained in plain English, is really useful for patients like me, especially when I am regularly in and out of hospital and using other healthcare services. I can access MyChart from anywhere in the world with an internet connection, which gives me peace of mind when I want to travel because if I were to need medical help in another part of the UK or abroad, I can log in using my smartphone and show my information to those clinicians caring for me. Having my health information to hand has helped me to better manage my conditions and I believe that patient awareness and involvement contributes to a more joined-up health care system.

Transplant patient and user of MyChart, *Alan Craig* talks about his experiences



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SNOMED International

Case Study #6

Care Pathways Economic Analysis

phn NORTHERN QUEENSLAND

Queensland Government

Mackay Hospital and Health Service

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Case Study #6

Care Pathways Economic Analysis

Australia – HealthPathways Economic Analysis in Mackay, Queensland

- HealthPathways is an evidence-based clinical pathway that enables general practitioners (GPs) to better manage the interface between primary care, community services, and hospital services. It was originally developed in 2008 by the Canterbury Initiative (New Zealand) and now has 40 deployments in 3 countries (i.e. New Zealand, Australia and UK).
- The pathways (i.e. over 600 clinical pathways have been developed to date) are developed collaboratively by general practitioners, specialists, nurses, and allied health professionals across all sectors and are tailored to the local context. The HealthPathways search function uses **SNOMED CT** concepts, synonyms and hierarchies.
- HealthPathways is designed to improve GP confidence in managing complex conditions, improve referral appropriateness, and reduce unnecessary care – all patient service outcomes.
- HealthPathways is widely used in Australia due to the popularity among general practitioners and its ease of use. The Mackay (Queensland) HealthPathways went live in June 2015, a joint implementation by the Northern Queensland Primary Health Network and the Mackay Hospital and Health Service. An economic evaluation of the Mackay HealthPathways implementation was conducted by the Australian Centre for Health Services Innovation in 2018[1].
- The researchers analyzed every outpatient specialist appointment referred from primary care between January and March in 2015 (pre-Pathways) and 2017 (post-Pathways) for diabetes (full implementation), cardiology (partial implementation), respiratory (partial implementation) and urology (no implementation: the control group).

1. Blythe et al., "HealthPathways: An Economic Analysis of the Impact of Primary Care Pathways in Mackay, Queensland", 2019. See https://www.healthpathwayscommunity.org/News/Latest-Community-News/ArticleID/1356/Information-systems-supporting-integrated-care

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Case Study #6

Care Pathways Economic Analysis

Australia – HealthPathways Economic Analysis in MacKay, Queensland (continued)

Referral Findings

- The analysis found that following implementation there had been reductions in diabetes and cardiology referrals from both primary care and specialist referral sources. Further, the analysis found that the percentage of appropriate referrals for diabetes had increased significantly following the introduction of HealthPathways. For the other disease groups the change in appropriate referrals was not significant.

Economic Impact

- The report concluded that given the difference in patterns between diabetes (full implementation) and urology (the control group), there was early evidence for the long term effectiveness of HealthPathways in Mackay through reduced demand for specialist services. The short-term impact is the reduction in waiting lists by up to 67% for fully and successfully implemented pathways such as Diabetes.
- The report speculates that if the Diabetes gold-standard implementation was replicated across other disease groups an average annual systemic cost saving of approximately $110,500 per pathway is potentially possible. Further, it was estimated that a gold-standard implementation is required for just 4 Pathways before the program is cost-saving, and 6 gold-standard Pathways will pay off its initial investment within a year in system-wide savings.
- As of November 2018, there was 36 different disease groups supported by HealthPathways, and a long-term change to practice involving comprehensive use of HealthPathways could potentially save upwards of $3,600,000 annually in Mackay alone after deducting the costs of maintaining the program. HealthPathways has now been deployed across Queensland.

Case Study #6

Care Pathways Economic Analysis

HealthPathways – Other Selected Studies

1. Canterbury District Health Board (New Zealand), "Case Study-Improving Patient Flow from Gynecology Services to the Whole of System". See study URL at https://researchbibliography.streamliners.co.nz/bibliography/NYP4IDP6
2. Holland et al, "A multifaceted intervention to improve primary care radiology referral quality and value in Canterbury, NZ", New Zealand Medical Journal, 2017. See https://www.nzma.org.nz/journal-articles/a-multifaceted-intervention-to-improve-primary-care-radiology-referral-quality-and-value-in-canterbury
3. Andrews et al, "Evaluation of 3D HealthPathways", Synergia, 2018. See https://www.ccdhb.org.nz/about-us/integrated-care-collaborative-alliance/3dhb-health-pathways/healthpathways-report-final-26-june-2018.pdf
4. McGeoch et al., "Is HealthPathways Effective – An Online Survey of Hospital Clinicians, General Practitioners and Practice Nurses" New Zealand Medical Journal, 2015. See https://www.nzma.org.nz/journal-articles/is-healthpathways-effective-an-online-survey-of-hospital-clinicians-general-practitioners-and-practice-nurses
5. Norid et al, University of Sydney, "HealthPathways Sydney Evaluation" March 2019. See study URL at https://researchbibliography.streamliners.co.nz/bibliography/?topic=HealthPathways+Evaluation&type=report&page=1&page-len=1&sort=date_desc

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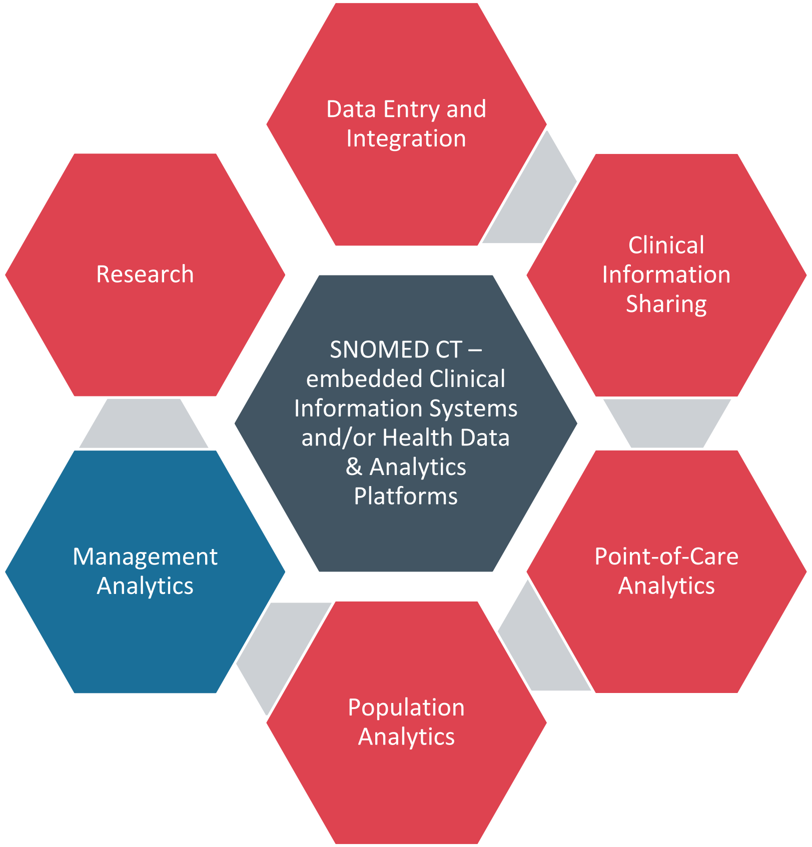
SNOMED International

Case Study #7

Clinical and Translational Research



University of Nebraska Medical Center

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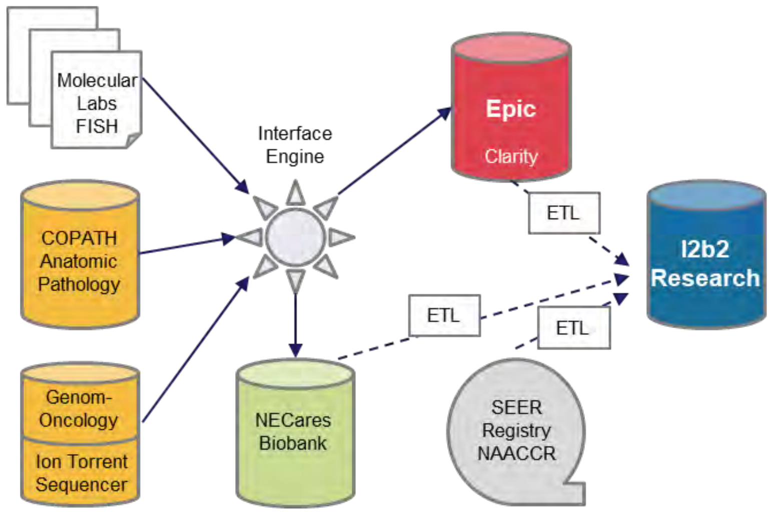
Case Study #7

Clinical and Translational Research

United States – University of Nebraska Medical Center, Nebraska, USA.

- Founded in 1869 and chartered as the Omaha Medical College in 1881, the college became part of the University of Nebraska in 1902. The University of Nebraska Medical Center (UNMC)[1] is now one of four campuses of the University of Nebraska and is located on Omaha, Nebraska. UNMC has over 4,200 students in a variety of healthcare disciplines (e.g. medicine, nursing, pharmacy, dentistry, public health and allied health).
- UNMC has a clinical partnership with Nebraska Medicine[2] which covers metro Omaha and region providing access to more than 1,000 doctors and nearly 40 specialty and primary care health centers. Two hospitals, Nebraska Medical Center and Bellevue Medical Center have more than 800 licensed beds. Nebraska Medical Center is regularly ranked in the top 50 Hospitals in the U.S.
- Nebraska Medicine implemented the Epic clinical information system (called One Chart), including a patient portal in 2013. Clinical data is entered directly or integrated from other sources (e.g. Sunquest COPATH Anatomic Pathology laboratory system). See the architecture example for Structured Pathology Reporting in the diagram to the right.
- The data from Epic and other sources (e.g. Biobank, Cancer Registry) are extracted and loaded into the i2b2 data warehouse and analytics platform at UNMC and then made available for clinical and translational research.

Nebraska Structured Pathology Reporting



1. University of Nebraska Medical Center. See https://www.unmc.edu/
2. Nebraska Medicine. See https://www.nebraskamed.com/

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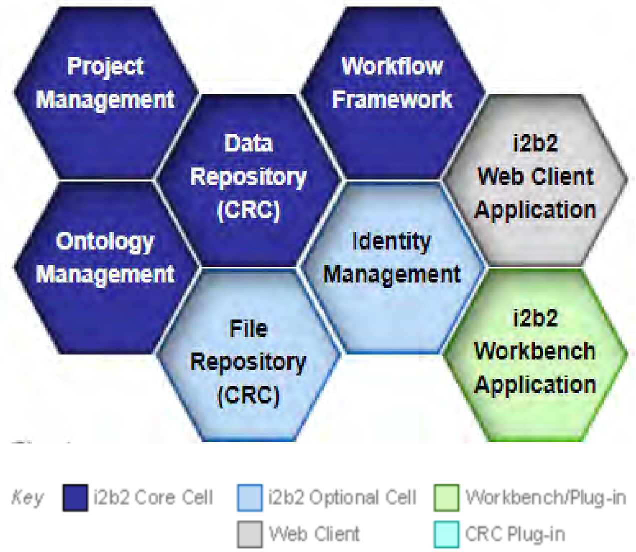
Case Study #7

Clinical and Translational Research

United States – University of Nebraska Medical Center, Nebraska, USA.

- i2b2 (*Informatics for Integrating Biology and the Bedside*)[3] is an open-source health research data warehouse and analytics platform, originally funded by the National Institutes of Health and developed at the Harvard Medical School. It is now used at over 200 healthcare locations worldwide.
- The i2b2 data warehouse and analytics platform consists of a core cell and a number of optional plug-ins (i.e. file repository, identity management, web client application and the workbench application). Ontology management is part of the core cell and is where SNOMED CT is deployed.
- i2b2's data model is a "star-schema", but does not use a standardized data model (e.g. as with OMOP[3] and PCORnet[4]). Local implementations develop concept hierarchies (called "ontologies") that provide a window into the imported data.



- Data in i2b2 can be queried by a cohort query tool with analytics plugins. For example, the query tool is used by Nebraska Medicine investigators to rapidly assess the feasibility of a research project, as well as prototype data management strategies.

3. I2b2 Informatics for Integrating Biology & the Bedside. See https://www.i2b2.org/
4. Nebraska Medicine. See https://www.nebraskamed.com/
5. The Observational Medical Outcomes Partnership (OMOP). See https://fnih.org/what-we-do/major-completed-programs/omop
6. Patient-Centered Clinical Research Network (PCORnet). See https://pcornet.org/

University of Nebraska Medical Center

SNOMED International

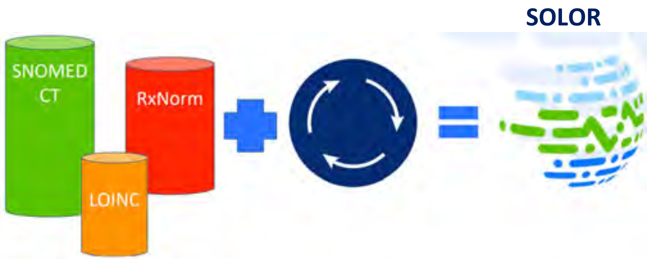
Case Study #7

Clinical and Translational Research

United States – University of Nebraska Medical Center, Nebraska, USA.

- The challenge with i2b2 is that it very difficult to render poly-hierarchical terminologies such as SNOMED CT in the platform. Each concept in a path in i2b2 metadata can only have a single parent, whereas the SNOMED CT concept model concepts can have multiple parent concepts. UNMC has had to develop a work-around so that SNOMED CT can be reliably represented as a single hierarchy and used in i2b2 for research purposes.
- UNMC has created SNOMED CT terminology extensions (i.e. the Nebraska Lexicon) for
  - genomics data sets supporting care,
  - detailed coding of Cancer Synoptic data, thereby expanding the UNMC cancer registry,
  - expanded SNOMED CT coverage of the organisms hierarchy that is integrated with laboratory coding for microbiology. This feature supports 13 healthcare centers across Nebraska with decision support capabilities for antimicrobial stewardship.
  - extended analytics capabilities of SNOMED CT observables for laboratory medicine. This feature supports advanced querying of the laboratory database for research and quality improvement.

- UNMC is collaborating with the Veterans Health Administration and their SOLOR[7] initiative to integrate the "Big Three" terminologies in the U.S. (i.e. SNOMED CT, LOINC and RxNorm) into a common ontology for use in the i2b2 platform. In addition, UNMC has invested significant resources in collaborations with the National Library of Medicine, Regenstrief Institute and SNOMED International to support the integration of these three terminologies and are a leader in this field.



7. SOLOR. See http://solor.io/

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Case Study #7

Clinical and Translational Research

United States – University of Nebraska Medical Center, Nebraska, USA.

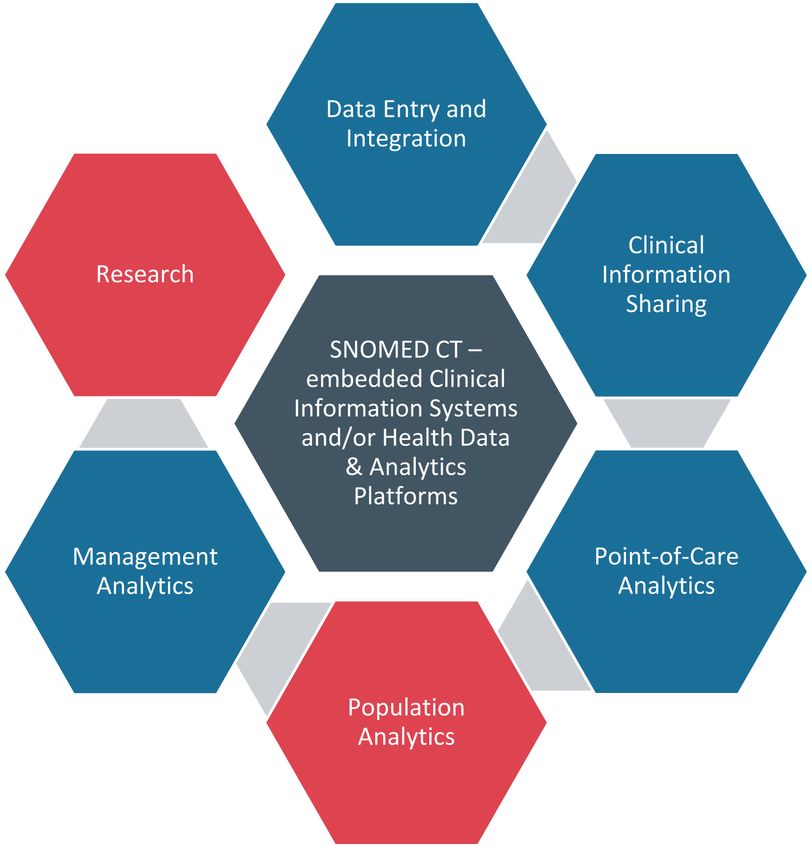
- **Research Activities Supported** – UNMC and its i2b2 platform supports three streams of research:
  1. **National PCORnet** (see call-out box) **sponsored research** – UNMC provides query response and datasets for approximately 100-125 research projects annually. (see https://pcornet.org/)
  2. **National COVID Cohort Collaborative** - UNMC sends data extracts for national COVID-19 research to a central research repository about 25-30 times a year, since June 2020. (see https://ncats.nih.gov/n3c)
  3. **Nebraska Medicine** – UNMC supports approximately active 25-35 investigator-initiated research projects annually.

PCORnet or the *Patient-Centered Clinical Research Network* is a research "networks of networks" across the United States. It includes 8 large Clinical Research Networks, 2 Health Plan Research Networks, and a Coordinating Center. For example, UNMC is part of the Greater Plains Collaborative (GPC), one of the eight clinical research networks. GPC includes 12 leading medical centers in 8 states, for example, University of Kansas Medical Center, Allina Health, Indiana University, Intermountain Healthcare, and the University of Iowa Healthcare.

SNOMED International

Case Study #8

Observational Data Research



OHDSI
OBSERVATIONAL HEALTH DATA SCIENCES AND INFORMATICS

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Case Study #8

Observational Data Research

Observational Health Data Sciences and Informatics (OHDSI), Columbia University, New York, USA.

- OHDSI[1] is an international network of researchers and observational health databases with a central coordinating centre housed at Columbia University in New York. Currently, OHDSI strives to develop reliable real world, health care evidence through methodological research, open-source analytics development, and clinical evidence generation.
- OHDSI provides access to over 100 different databases, with half a billion patient records from 19 different countries, with more than 200 million patient records from outside the U.S. All its solutions are open source. Observational research using OHDSI solutions starts with observational data, gathered through various populations, care settings, data capture processes, and health systems. By converting that data through the OMOP Common Data Model (CDM), the research can create three types of evidence: clinical characterization; population-level effect estimation, and patient-level prediction.
- OHDSI developed the OMOP CDM, as a global standard for observational research. As part of the CDM, the OMOP Standardized Vocabularies are available for two main purposes: common repository of all vocabularies used in the health care community; as well as standardization and mapping for use in research.
- Similar to **SNOMED CT** all clinical events in the OMOP CDM are expressed as concepts, which represent the semantic notion of each event. **SNOMED CT** is used as a standard concept in five of the seven data domains – condition, procedure, measurement, device and observation. Like **SNOMED CT**, the OMOP CDM represents relationships in a hierarchy through 'is a" statements, as well as attribute relationships among concept hierarchies, so the OHDSI OMOP CDM is at level 4/5 on the **SNOMED CT** maturity model.

1. Observational Health Data Sciences and Informatics (OHDSI). See https://www.ohdsi.org/

Case Study #8

Observational Data Research

OHDSI Hydroxychloroquine Safety Study[2] Completed in Four Days

- In the face of rapid spread and escalation of the coronavirus, many decisions are being made quickly and a number of therapies are being trialed for its treatment. One of these is the use of hydroxychloroquine, a drug approved in 1950s. The drug has been used for malaria, lupus and rheumatoid arthritis. However, physicians have been using it off label for COVID-19 and in the past weeks the FDA has approved the use of the drug for compassionate use in the treatment of COVID-19. Despite the lack of evidence of its clinical effectiveness, U.S. President Donald Trump says the drug has shown “very encouraging results” in treating COVID-19. More research needed to be done based on these claims.
- Over 4 days in March 2020, Professor Dani Prieto-Alhambra, Professor of Pharmaco-and Device Epidemiology at the Centre for Statistics in Medicine at Oxford University in England and a team of researchers from around the world set out to analyze the safety profile of hydroxychloroquine. The team used data from fourteen datasets to analyze the medical history of over 950,000 patients who have previously taken hydroxychloroquine. Patient data came from six countries: Germany, Japan, the Netherlands, Spain, the UK and the USA.
- First, they found it to be a safe medication for short-term use. When administered at the doses used for current indications like rheumatoid arthritis, they did not detect any worrying side effects. However, when prescribed in combination with azithromycin, it may induce heart failure and cardiovascular mortality and they urged caution in using the two together. It was noted that there is a lack of sufficient data at higher doses, and hence it is too early to understand the clinical effectiveness in treating COVID-19. Formal clinical trials in this regard are ongoing.

2. Lane et al., “Safety of hydroxychloroquine, alone and in combination with azithromycin, in light of rapid wide-spread use for COVID-19: a multinational, network cohort and self-controlled case series study”. Medrxiv, May 31, 2020. See preprint at https://www.medrxiv.org/content/10.1101/2020.04.08.20054551v2.full.pdf

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Case Study #8

Observational Data Research

OHDSI Hypertension Study - Recommended Diuretic Causes More Side Effects than a Similar Hypertension Drug

- The 2017 American College of Cardiology/American Heart Association hypertension guideline recommends thiazide and thiazidelike diuretics as one of the first-line treatment classes for hypertension. Hydrochlorothiazide is the most commonly prescribed member of the class, but the guideline states that chlorthalidone is preferred on the basis of longer half-life and proven trial reduction of cardiovascular disease. However, there are no large, completed randomized clinical trials comparing these medications, although one is in progress.
- A recent OHDSI study[3] compared chlorthalidone and hydrochlorothiazide on 55 outcomes in 3 large observational databases of patients from the United States. The findings contrast with current treatment guidelines recommending chlorthalidone over hydrochlorothiazide. Chlorthalidone, the guideline-recommended diuretic for lowering blood pressure, causes more serious side effects than hydrochlorothiazide, a similarly effective diuretic, according to the OHDSI study.
- The researchers found that patients taking chlorthalidone had nearly three times the risk of developing dangerously low levels of potassium and a greater risk of other electrolyte imbalances and kidney problems compared with those taking hydrochlorothiazide. Information from the largest individual database studied by the team revealed that 6.3% of patients treated with chlorthalidone experienced hypokalemia (low blood potassium), compared with 1.9% of patients who were treated with hydrochlorothiazide.

3. Hripcsak et al., "Comparison of Cardiovascular and Safety Outcomes of Chlorthalidone vs Hydrochlorothiazide to Treat Hypertension". JAMA Internal Medicine, August 10, 2020. See https://jamanetwork.com/journals/jamainternalmedicine/fullarticle/2760777?resultClick=1

Case Study #8

Observational Data Research

EHDEN-OHDSI Knee Replacement Study

- The IMI European Health Data & Evidence Network (EHDEN) project and OHSDI recently published the results of its first 'study-a-thon' in Lancet Rheumatology on the effectiveness and safety associated with uni-compartmental versus total knee replacement[4]. This was the largest study to date with data on more than 250,000 individuals who underwent either procedure in five databases from the US and the UK.
- The choice of which type of knee replacement to recommend remains difficult for surgeons, and there remains insufficient information to inform them and patients of the best approach, dependent on the patient's personal context.
- The study emulated to the extent possible, the design of the five year Total or Partial Knee Arthroplasty Trial (TOPKAT). The study-a-thon assessed whether the efficacy results seen in the trial translated into effectiveness in real-world settings and provided further consideration of safety outcomes that were too uncommon to assess in TOPKAT.
- Uni-compartmental knee replacement was associated with a reduced risk of complications, in particular venous thromboembolism, and persistent opioid use, possibly indicating a reduced risk of persistent pain after surgery. Total knee replacement was, however, associated with a lower risk of revision procedures, and the need to repair or replace the original replacement.

4. Burn E, et al; "Complications and adverse events of uni-compartmental versus total knee replacement" Lancet Rheumatology, published online November, 2019 . See https://www.thelancet.com/journals/lanrhe/article/PIIS2665-9913(19)30075-X/fulltext

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Case Study #8

Observational Data Research

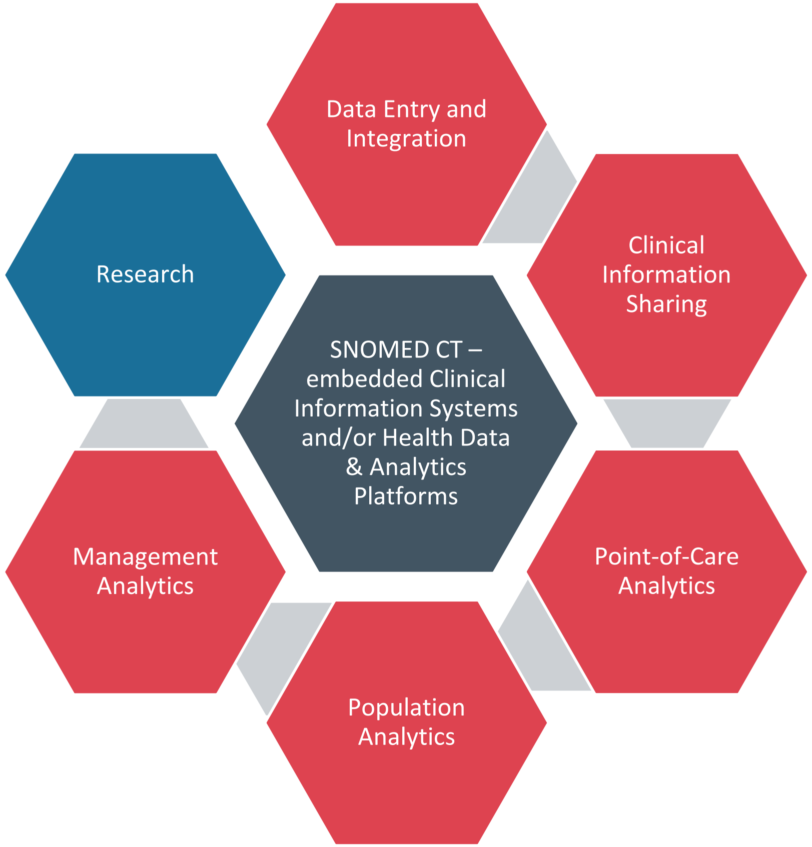
OHDSI Cervical Cancer Risk Study - Cervical Cancer Risk Decreases In Users Of Copper IUDs vs. Hormonal IUDs -

- Studies from the 1980s suggested a reduced risk of cervical cancer among women who used an intrauterine contraceptive, though those studies did not differentiate between the varying types of IUDs. Furthermore, much of the data from those studies was collected prior to the availability of most hormonal IUDs.
- By standardizing four decades' worth of data from the Columbia University Irving Medical Center database through the OMOP Common Data Model and using high-level analytics developed within the OHDSI collaboration, the research team ran a retrospective cohort analysis of more than 10,000 patients who received IUDs.
- Overall, IUD use has become more popular over the past 20 years. Copper IUD use has remained constant whereas hormonal IUD use has increased. The rising popularity of hormonal IUDs may be related to the fact that they decrease the pain and bleeding of menses.
- The study[5] found that the diagnosis of high-grade cervical neoplasia was 0.7% in the copper IUD (Cu IUD) cohort and 1.8% in the hormonal IUD (LNG-IUS) cohort.
- In conclusion, patients who used copper intrauterine devices (Cu IUD) were found to have a lower risk of high-grade cervical neoplasms (cervical cancer) compared to users of the levonorgestrel-releasing intrauterine system (LNG-IUS).

5. Spotnitz al., "Relative Risk of Cervical Neoplasms Among Copper and Levonorgestrel-Releasing Intrauterine System Users". Obstetrics and Gynecology, February, 2020. See https://journals.lww.com/greenjournal/Fulltext/2020/02000/Relative_Risk_of_Cervical_Neoplasms_Among_Copper.11.aspx

Case Study #9

Public Health Surveillance



Southern Medical University

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Southern Medical University

Case Study #9

Public Health Surveillance

China – Public Health (COVID-19) Surveillance in Honghu, Hubei.

- The outbreak of the coronavirus disease (COVID-19) in China and many other countries has put huge pressure on the health care system. One method of controlling the communicable diseases is the use of a surveillance system to track the exposed and infected individuals, as well as clinical outcomes. However, traditional surveillance systems have limitations in terms of timeliness, spatial resolution, and scalability. Meanwhile, reporting from these systems tends to be national or regional with insufficient information about diseases at the community or city level, which caused low efficiency for the social distancing and quarantine measures.
- In response to this significant challenge the Honghu Hybrid System (HHS) was developed at a cost of USD$430,000 as a pilot for COVID-19 surveillance and control. It was successfully deployed within 72 hours in Honghu in the Hubei province, a city 145 kilometers (90 miles) away from Wuhan (the capital city of the Hubei province) with a population of over 900,000 people.
- This system (see schematic overleaf) collected daily structured electronic medical record data from nine hospitals; real time information about symptoms and personal contact history from the WeChat platform (one of the largest mobile social network apps in China with more than 1 billion monthly active users); and daily reported case diagnosis information from one third-party polymerase chain reaction lab, one third-party antibody lab, and one public health information system. A novel mini program using the WeChat platform software development kit was created for symptom reporting and spatial data collection.

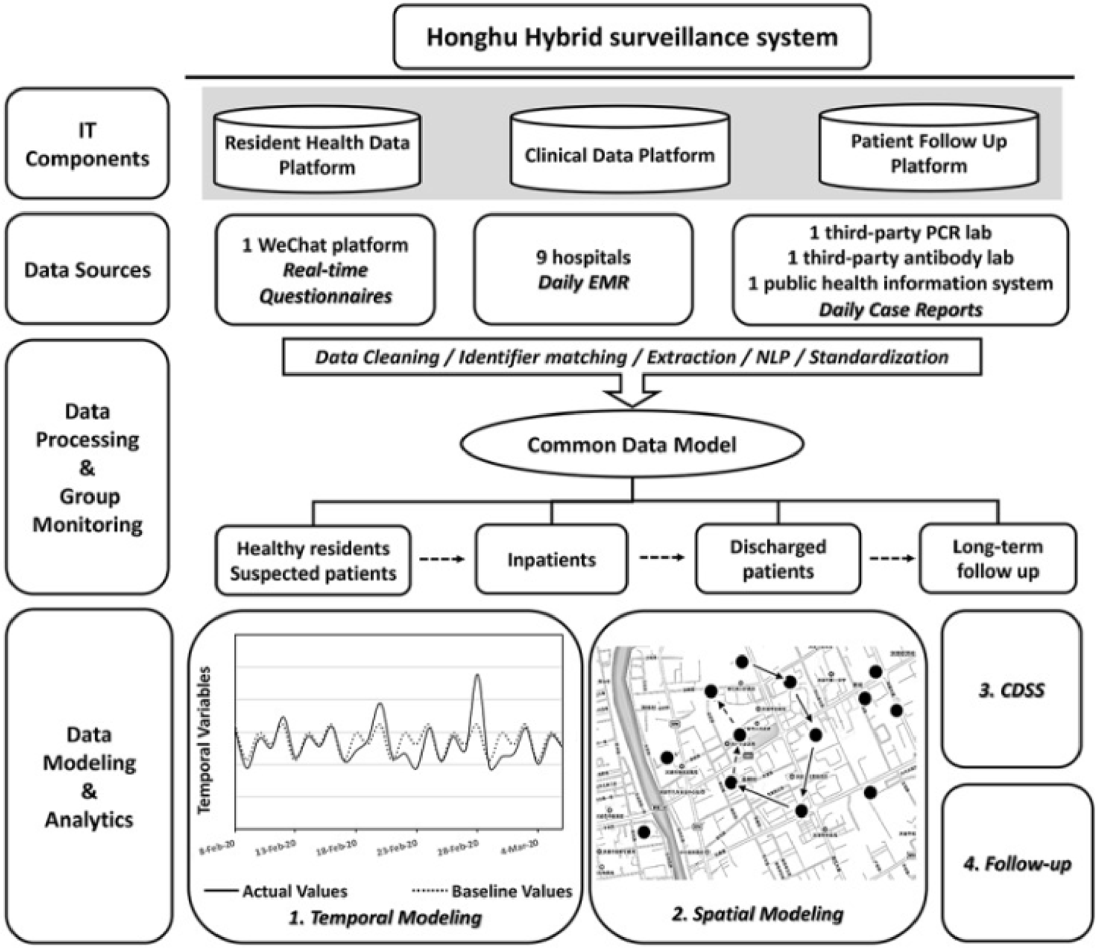
1. Gong et al., "Cloud Based System for Effective for Surveillance and Control of COVID-19: Useful Experiences from Hubei, China", Journal of Medical Internet Research, 2020. See https://europepmc.org/article/MED/32287040

Case Study #9

Public Health Surveillance

China – Public Health Surveillance in Honghu, Hubei.

- The data feeds were normalized temporally and spatially and then loaded into a common data model that had been built for the storage, management, and analysis of the integrated COVID-19 data.
- Vocabulary control was implemented based on the **SNOMED CT** synonyms in Chinese for symptoms and the disease itself. LOINC was used to code-related tests and ICD-10 CM codes for the diseases based on the coding standards released by the National Health Commission of China.
- Syndromic surveillance was implemented on a mobile phone–based social media platform targeting different groups of individuals (e.g. I am experiencing a cough today). This included the general population, in hospital and discharged patients, people with higher risk of infection (i.e. those with travel history to Wuhan, contact history with confirmed cases, or under medical observation in isolation sites), and health care professionals (i.e., doctors, nurses, public health experts, and social workers).



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Case Study #9

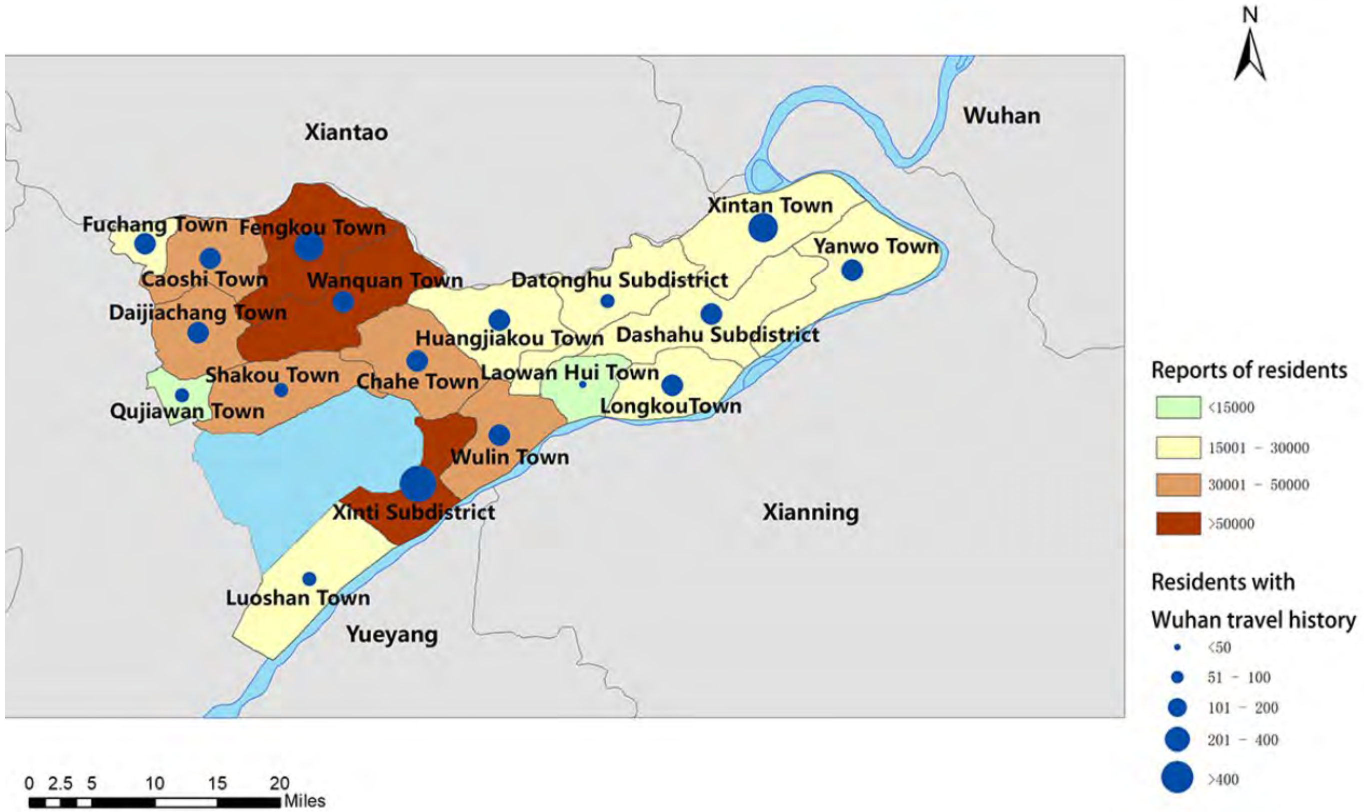
Public Health Surveillance

China – Public Health (COVID-19) Surveillance in Honghu, Hubei.

- The high coverage (over 95% of the residents) and daily active reports (up to 900,000 person-times) demonstrated the feasibility of intense monitoring during the COVID-19 epidemic.

Policy Making Decision Support

- Monitoring the fluctuation and trends analysis of the syndromic surveillance data supported policy-related decision making. The large population size, plus the stability and fluctuation of the trends provided strong evidence for local authorities to evaluate the effectiveness of disease management and make timely adjustments accordingly. Spatial analyses also played a critical role as clustering of exposed residents indicated by the concentration of patients in a part of the city further illustrated high risk for local outbreaks and would then trigger home visits by social workers.



Case Study #9

Public Health Surveillance

China – Public Health (COVID-19) Surveillance in Honghu, Hubei.

Clinical Decision Support and Resource Management

- A clinical decision support system based on an in-hospital mortality prediction system was built for patients with COVID-19 to improve the clinical care, decrease death risk, and prioritize limited medical resources. Based on the Multilobular Infiltration, Hypo-Lymphocytosis, Bacterial Coinfection, Smoking History, Hyper-Tension and Age (MuLBSTA) scoring system, which is a partially validated prediction system for the in-hospital mortality of patients with COVID-19. About 10% of patients were classified as high-risk (MuLBSTA score ≥12). They were either relocated to the single hospital in the area that had an intensive care unit or screened with important biochemical markers more frequently.

Follow-up of Discharged Patients

- We used the social media platform to register the discharged patients and required the patients to report their symptoms daily in the 2 months after discharge. After the follow-up system was initiated, 100% coverage was achieved within 3 days. The reported recurrence of symptoms such as high fever was linked with home visits by social workers inside communities and readmission to hospital.

Conclusion

- Based on the field study in Honghu city, the Honghu Hybrid System has been observed to be effective and feasible for COVID-19 surveillance and control. It helped strengthen the checkpoints on the full chain of COVID-19 control, including "early test, early report, early isolation, and early treatment" during the outbreak.

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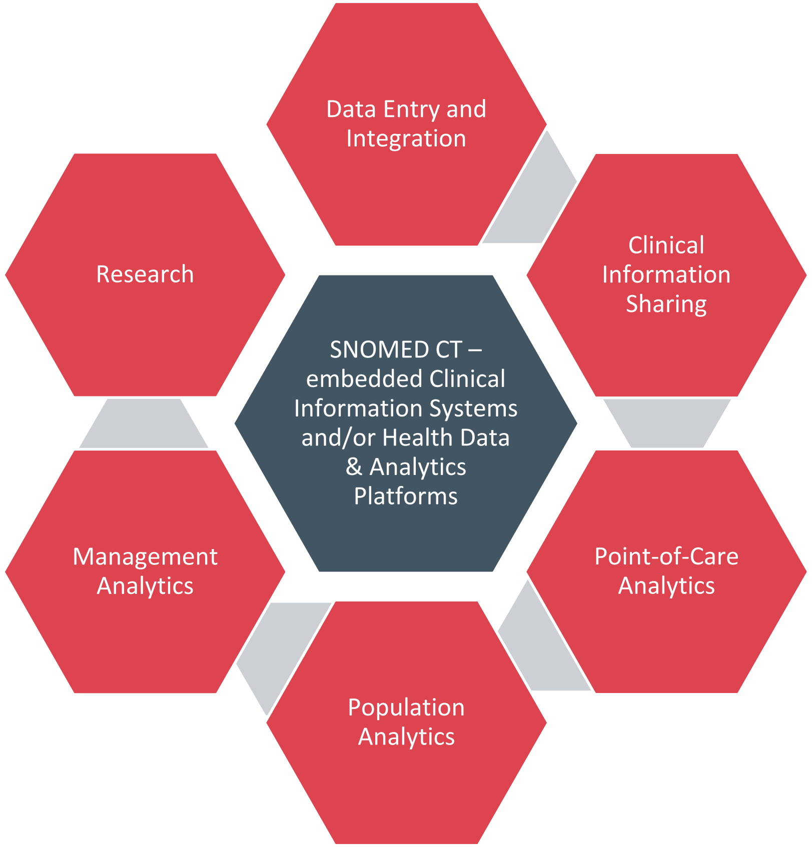
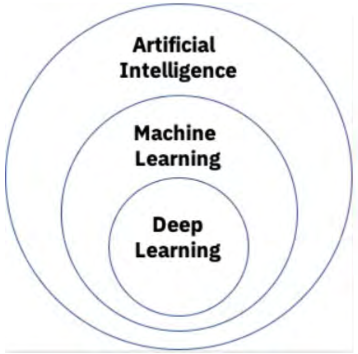
Case Study #10

Artificial Intelligence: A Look into Now and a Peek into the Future





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Case Study #10

Artificial Intelligence: A Look into Now and a Peek into the Future

Artificial Intelligence in Healthcare Globally

- Artificial Intelligence (AI) is simply defined by Merriam-Webster online as "*1: a branch of computer science dealing with the simulation of intelligent behavior in computers, 2: the capability of a machine to imitate intelligent human behavior*".
- Many nations and regions around the world (e.g. US, Europe, UK, China) have been actively looking at the future role of artificial intelligence generally, as well as its use in healthcare specifically[1,2,3,4,5,6,7].
- As part of these reviews the impact on society (see table on right), organizations and the nations' workforce have also been considered.

AI and AI-mediated technologies	Specific implementations.	TAL	Social Impact
Algorithms for computer-aided diagnosis.	SW for decision support in (most) clinical areas.	8, 9	Positive
Structured reports, eHealth.	SW for improved workflow, efficiency.	8, 9	
AR/VR, advanced imaging tools.	Tools for information visualization and navigation.	6, 7, 9	
	Image-guided surgery. Teleoperation.	4, 6, 9	
Digital pathology, 'virtopsy'.	SW for automated, extensive analysis.	4-9	
Personalized, precision medicine.	Tailored treatments. Prediction of response.	4-9	
	'in-silico' modeling and testing. The 'digital twin'.	4-6	
	Drug design.	4, 8	
Apps, chatbots, dashboards, online platforms.	The 'digital doctor' (assistance for professionals and for patients).	8, 9	
Companion and social robots.	For hospitalized persons, children & the elderly.	4-9	
Big Data collection and analyses.	Epidemiology, prevention and monitoring of disease outbreaks.	2-9	
	Fraud detection. Quality control, monitoring of physicians and treatments.	4-9	
IoT, wearables, mHealth.	Automated clinical/health surveillance in any environment/institution.	7, 8	
	Monitoring, automated drug delivery.	7-9	
Gene editing.	Disease treatment, prevention.	7, 8	
Merging of medical and social data. 'Social' engineering.	Prevention of episodes with clinical relevance (e.g. suicide attempts).	6, 8	Controversial
	Tailored marketing (e.g. related to female cycles).	6, 8	
Reading and decoding brain signals. Interaction with neural processes.	Treatment of diseases. Restoring damaged functions.	3-8	
	Brain-machine interfaces.	5-8	
	Control of prostheses, exoskeletons. 'Cyborgs'.	2-7	
	Neurostimulation. Neuromodulation.	4-8	
	Neuroprostheses (for the central nervous system).	2-5	
	Mind 'reading' and 'manipulation'.	1-3	
Genetic tests. Population screening.	Disease tests. Direct-to-consumer tests.	4-9	
Personalized, precision medicine.	Individual profiling. Personalized molecules (for treatment) at 'impossible' prices.	3-6	
Gene editing.	'Engineered' humans.	2, 6	
	Gene-enhanced 'superhumans'.	2	
	Self-experimentation medicine. Biohacking.	2, 6	
Fully autonomous AI systems.	The 'digital doctor'.	2-5	
	'Robotic surgeon'.	2, 4	
Human-animal embryos.	Organs for transplants.	2, 4, 5	
	Hybrid beings ('chimera').	2, 4	
The quest for immortality.	Whole-brain emulation / 'transglom'.	1, 2	
The search for artificial life forms.	'Living machines' ('biological robots', 'biobots')	4, 6	
	Military.	2, 3	
Evil biohacking.	Targeting specific individuals or groups.	1, 2	
Weaponization.	From 'small labs' to military labs.	1, 2	
Bioterrorism.	From 'small labs'.	1, 2	Negative

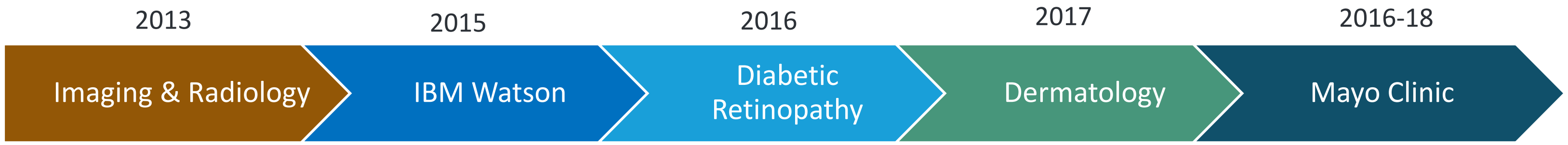
1. Matheny, M. et al., "Artificial Intelligence in Health Care: The Hope, the Hype, the Promise, the Peril". Washington, DC: National Academy of Medicine, 2019. See https://nam.edu/wp-content/uploads/2019/12/AI-in-Health-Care-PREPUB-FINAL.pdf
2. U.S. Government Accountability Office and the National Academy of Medicine, "Artificial Intelligence in Healthcare: Benefits and Challenges of Machine Learning in Drug Development" GAO-20-215SP, 2019. See https://www.gao.gov/products/gao-20-215sp
3. Gómez-González, E. and Gómez, E., "Artificial Intelligence in Medicine and Healthcare: applications, availability and societal impact", EUR 30197 EN, Publications Office of the European Union, Luxembourg, 2020. See https://publications.jrc.ec.europa.eu/repository/bitstream/JRC120214/jrc120214_ai_in_medicine_and_healthcare_report-aiwatch_v50.pdf
4. McKinsey & Company and EIT Health "Transforming Healthcare with AI: the Impacts on Workforce and Organizations" McKinsey, 2019. See https://www.mckinsey.com/industries/healthcare-systems-and-services/our-insights/transforming-healthcare-with-ai
5. Harwich E, Laycock K., "Thinking on its Own: AI in the NHS", the Reform Research Trust, 2018. See https://reform.uk/research/thinking-its-own-ai-nhs
6. Topol E., "The Topol Review: Preparing the healthcare workforce to deliver the digital future". The National Health Service (NHS), 2019 See https://topol.hee.nhs.uk/
7. China State Council "New Generation of Artificial Intelligence Development Plan", Document 2017, no 35, in Foundation for Law and International Affairs, https://flia.org/notice-state-council-issuing-new-generation-artificialintelligence-development-plan/.

Case Study #10

Artificial Intelligence: A Look into Now and a Peek into the Future

Artificial Intelligence in Healthcare Globally

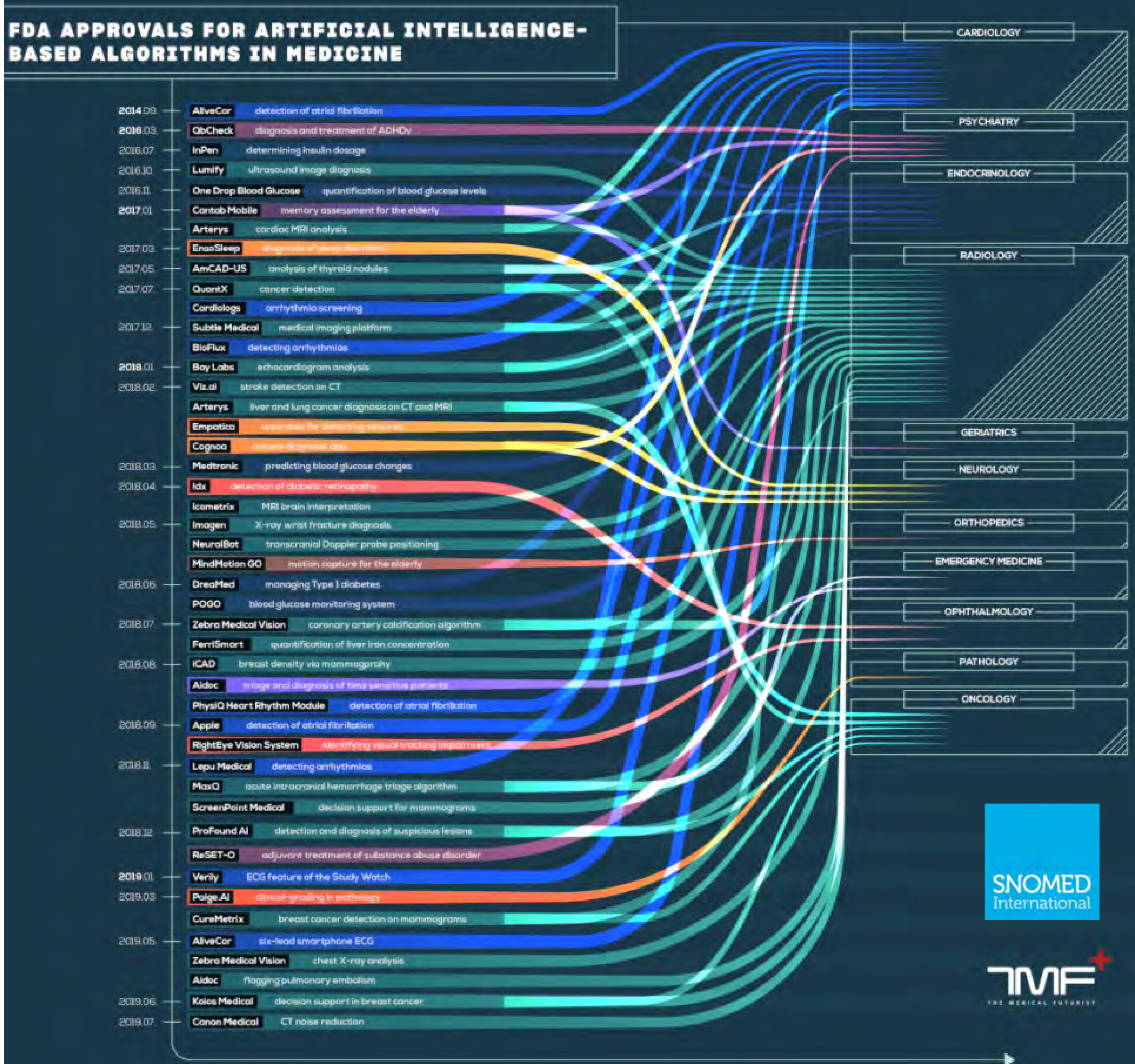
- The use of AI in healthcare is not new – it has been used for decades. However, the increasing capture of data electronically in clinical information systems, the increase in personal data captured through devices, sensors, imaging or genomics and the increase in computing power available – either through cloud-based computing platforms or on the phones in our pockets – is enabling a new generation of applications of AI through-out the healthcare system.



- Medical imaging/radiology were recent early adopters of AI given the substantial amount of imaging data available and the fact that early algorithm and model development was focused on images in general (e.g. LUNIT in South Korea).
- IBM Watson Health was an early entrant that initially focused on oncology via massive amounts of medical literature data and through acquisition of Truven Health Analytics and its 100 million patient records.
- In 2016 AI solutions focused on the diagnosis of diabetic retinopathy from a database of 128,000 retinal images. In neurology, AI was used in man/machine interfaces for spinal injury prostheses. In dermatology, a use of current models included an analysis of 129,000 dermatological lesions to distinguish two different skin cancers from serborrheic keratosis.
- In 2016, Mayo Clinic and AliveCor conducted a study utilizing EHR records from 2.8 million 12-lead ECGs from over 20 years of patient records and EKG readings for insights on potassium levels and correlations with T waves in ECGs.

Artificial Intelligence in Healthcare Globally

- Arterys was one of the first companies to receive U.S. FDA clearance for a cardiology application, Cardio DL, which provides automated, editable ventricle segmentations from MRI images of the heart.
- Since then there has been over 40 FDA approvals for artificial intelligence-based algorithms in medicine (as of 07/2019). The majority of the approvals have been in radiology, cardiology, oncology, and endocrinology.
- Not surprisingly, the venturee capital investment in AI solutions has exploded during the past 5 years with the locus of development activity being in the U.S. (e.g. Recursion Pharmaceuticals), China (e.g. Ping) and Israel (e.g. OrCam) and the UK (e.g. Babylon).
- China leads the world in the number of health care AI research studies (41), followed by the US and Europe (28 each).

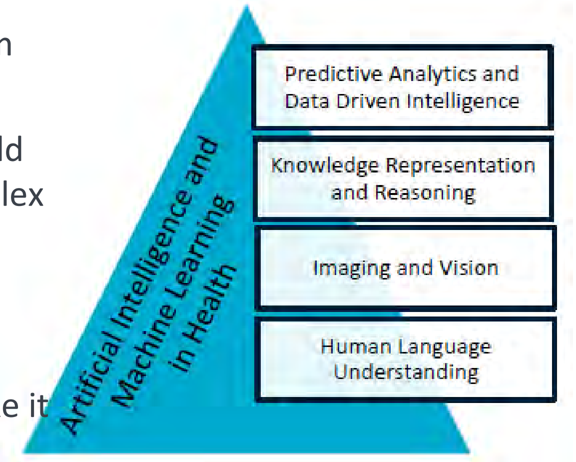


Case Study #10

Artificial Intelligence: A Look into Now and a Peek into the Future

Australia – One Nation's View Into Artificial Intelligence in Healthcare

- For most nations, the introduction of AI into healthcare is seen as providing a wide range of access, quality and productivity benefits during a time when healthcare costs continue to steadily increase. However, for many, the use of AI is also daunting, given the potential workforce impacts and the potential for negative unintended consequences.
- In July 2020 CSIRO and the Australian eHealth Research Centre published "*Exemplars of Artificial Intelligence and Machine Learning in Healthcare*"[8]. It provides, an overview of artificial intelligence (AI) and machine learning (ML), where **SNOMED CT** fits in the AI/ML space, and thirty-four case studies showcasing the use of AI/ML in healthcare in Australia.
- CSIRO divides the use of AL/ML in healthcare into four domains:
    1. **Predictive Analytics and Data-Driven Intelligence** is concerned with extracting insights from existing data (e.g. **SNOMED-CT** coded clinical data).
    2. **Knowledge Representation and Reasoning** is how we represent information about the world (e.g. as in **SNOMED CT** semantic network) so a computer system can utilize it to solve complex tasks and enabling us to infer(new) knowledge.
    3. **Imaging and Vision** involves analyzing images or videos to derive insight into the cause and impact of medical conditions.
    4. **Human Language Understanding** uses AI methods to understand natural language and make it machine-readable.



8. Koopman, B., Bradford, D., Hansen, D. (Eds) (2020) Exemplars of Artificial Intelligence and Machine Learning in Healthcare: Improving the safety, quality, efficiency and accessibility of Australia's healthcare system. Report Ep203543. CSIRO, Australia. Version 1.0 dated July 2020 is available at aehrc.com/ai

Case Study #10

Artificial Intelligence: A Look into Now and a Peek into the Future

Australia – One Nation's View Into Artificial Intelligence in Healthcare

- **Artificial Intelligence** depends on high quality data to either train AI models or for AI based analysis. This includes **clinical data**, genomics data, imaging, administrative data, as well as sensor and wearables data.
- In AI, there have traditionally been two schools with contrasting approaches – symbolic AI and statistical AI.
  - **Symbolic AI** methods make use of curated medical domain knowledge (i.e. facts or rules), such as **SNOMED CT**.
  - **Statistical AI** takes the opposite approach; rather than predefining the knowledge and rules, it 'learns' these from the data itself by extracting patterns and insights.
  - While **SNOMED CT** encoded healthcare data can support both approaches, the full value of **SNOMED CT** (i.e. its semantic network capabilities) is realized when symbolic AI is used.
- **Machine Learning (ML)** gives computers the ability to learn without being explicitly programmed. There are two main ML tasks: classification and regression.
  - Classification uses a ML model to 'classify' data into categories; for example, classifying the type of cancer found in a pathology report into breast cancer, lung cancer and so on.
  - Regression, in contrast, uses a ML model to predict a value rather than a category. For example, predicting the length of stay for a patient given their condition. ML models learn from data, in either a supervised (i.e. answer choices are provided) or an unsupervised manner (i.e. answer choices are not provided).
- **Deep Learning** uses artificial neural networks for either classification or regression, both supervised and unsupervised.

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Case Study #10

Artificial Intelligence: A Look into Now and a Peek into the Future

Australia – One Nation's View Into Artificial Intelligence in Healthcare

Predictive Analytics and Data-Driven Intelligence Case Studies (12)

- **Data Driven Insights from Clinical Information Systems** – In Case Study 1 ML uses clinical data to predict the risk of patient hospitalization or readmission. Case Study 2 optimized elective surgery by modelling all the inter-connected departments requiring access to share surgery resources. Case Study 3 demonstrates how real time analytics is made possible through interoperable data efforts such **SNOMED CT** and FHIR. Case Study 4 demonstrates how analytics can be used to predict future demand for services and patient flow. Case Study 5 showed how deteriorating patients can be identified and with an earlier intervention, prevent their condition worsening.

- **Insights from the Human Genome** – Case Study 6 uses random forest models to identify the underlying genetic causes of neurodegenerative diseases, thereby opening up new treatment avenues. Case Study 7 uses ML to help with the laborious curation task that pathologists must perform with genetic data. Case Study 8 uses ML to guide effective gene editing. Case Study 9 presents a cloud architecture with ML to visualize and track the genomic fingerprint of the COVID-19 virus.

- **Insights from Sensors** - Sensors have become ubiquitous in the home environment. Sensors in the home can aid elderly people to live independently in their homes for longer, which has health and economic benefits. Case Study 10 used passive (non-wearable and non-intrusive) sensors to accurately measure how someone is coping at home and identify when they might need assistance. Where multiple people live together, Case Study 11 used ML to identify the different individual people, from the elderly to infants. Case Study 12 used miniature wearable sensors for early identification of infants at risk of Cerebral Palsy.

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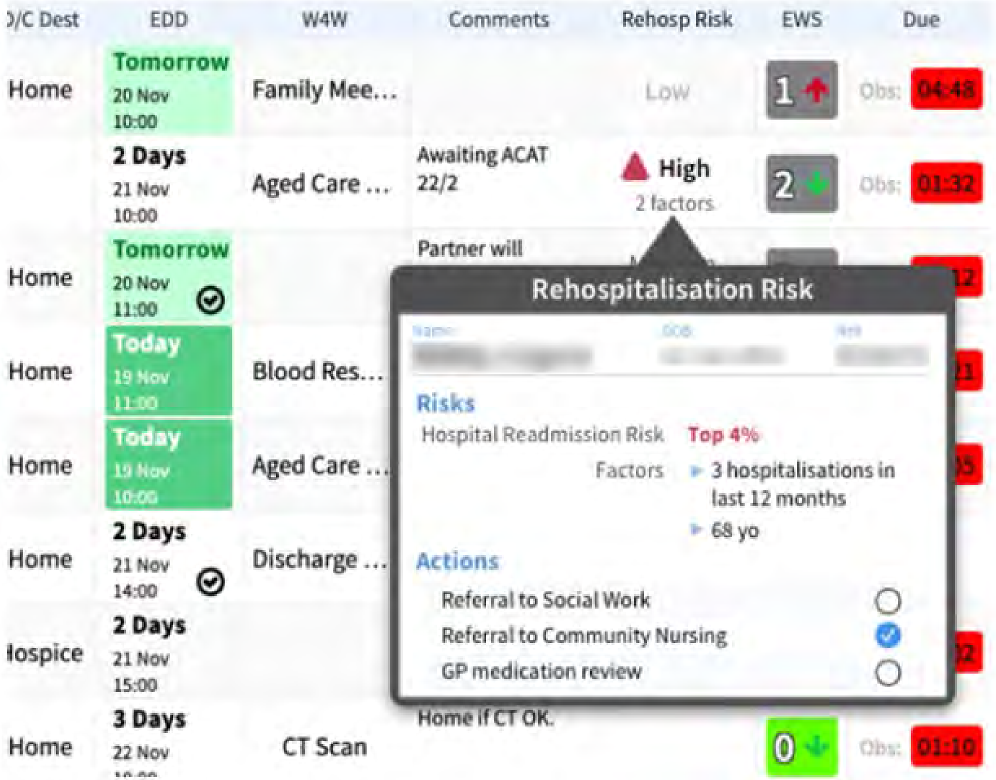
Artificial Intelligence: A Look into Now and a Peek into the Future

Australia – One Nation's View Into Artificial Intelligence in Healthcare

Predictive Analytics and Data-Driven Intelligence Case Studies

CASE STUDY 3 HIGHLIGHTED: RE-HOSPITALIZATION RISK STRATIFICATION

- New South Wales (NSW) Health uses the **SNOMED CT**-embedded Cerner clinical information system. The use of the HL7 FHIR data model and the **SNOMED CT** terminology has improved the interoperability of these systems, as well as for use by AI algorithms. Leveraging these standards has facilitated the deployment and scalability of real time clinical analytics and decision support applications.
- A predictive risk stratification algorithm developed by CSIRO was added to vendor Alcidion's Miya Platform. **SNOMED CT** data from the NSW Cerner system was sent as FHIR resources to the Alcidion Miya platform whenever certain trigger conditions were met, e.g. a new pathology report was received (see diagram on the right of this page).
- The CSIRO algorithm then calculated a risk score based on the **SNOMED CT** clinical data received and was displayed in the Miya platform on dashboards to support real-time decision making. This work demonstrates the potential for improved detection and management of patients at risk of readmission.



Case Study #10

Artificial Intelligence: A Look into Now and a Peek into the Future

Australia – One Nation's View Into Artificial Intelligence in Healthcare

Knowledge Representation and Reasoning Case Studies (6)

- **Knowledge Representation using Ontologies** - Case Study 13 describes the "Snorocket" reasoner, software that uses the Dresden algorithm, to rapidly draws inferences and create new knowledge using the **SNOMED CT** medical ontology.
- **Extending Medical Ontologies** - One key advantage of the formal logic of ontologies like **SNOMED CT** and reasoners like Snorocket is that it can be extended to support new domains (e.g. medications). Case Study 14, shows how the Australian Medicines Terminology (AMT) and reasoners can be extended to provide support for medications, including numeric values such as dosages. AMT is included in the Australian edition of **SNOMED CT**. Case Study 15 solves the problem of keeping medication ontologies up-to-date by analyzing medication lists and automatically generating the appropriate medications knowledge in the AMT medical ontology. Case Study 16, shows how new medical knowledge can be added through 'post-coordination', whereby new concepts can easily be defined using the existing formal logic of **SNOMED CT**.
- **How Knowledge Representation Supports Analytics** - Knowledge about how to use the **SNOMED CT** ontology, including its rules and properties, supports the use of the ontology in many applications – including data analytics, search engines and NLP. The representation of knowledge in this way is a core part of AI. Case Study 17 demonstrates Pathling, an advanced analytics service that exploits standardized **SNOMED CT** medical data to provide APIs that enable data visualization, dashboard analytics, patient cohort selection and data preparation services.
- **Integrating AI into Clinical Workflow** - Case Study 18 presents FORTE, a FHIR-based Workflow Platform for integrating AI into a Radiology Clinic. This provides a means of integrating automated methods into an existing clinical workflow.

Case Study #10

Artificial Intelligence: A Look into Now and a Peek into the Future

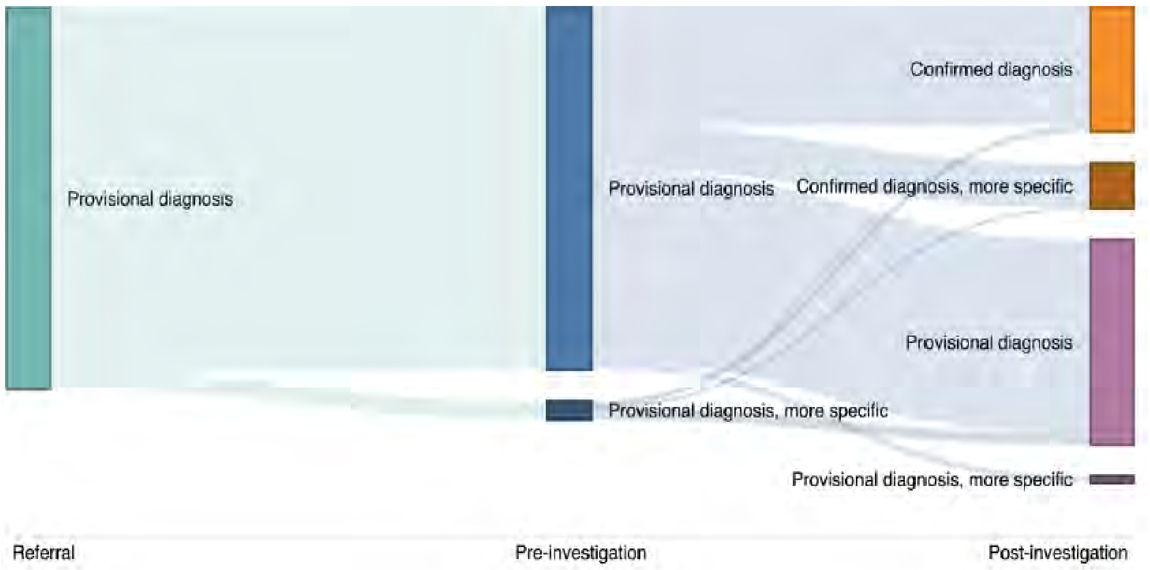
Australia – One Nation's View Into Artificial Intelligence in Healthcare

Knowledge Representation and Reasoning Case Studies

CASE STUDY 17 HIGHLIGHTED: ADVANCED ANALYTICS OF GENOMIC PHENOTYPE DATA

- Increasingly more data is being collected using SNOMED CT and shared using FHIR. This provides an opportunity to use these two standards to build advanced analytics tools on top of this data. Pathling, is an advanced analytics service that exploits this standardized health data to provide APIs that enable data visualization, analytics dashboards, patient cohort selection and data preparation services.

- Pathling understands the FHIR data model and it can integrate with a FHIR terminology server to enable the use of the description logic underpinning SNOMED CT.
- Pathling was recently used to perform an advanced analysis of genomic phenotype data which was collected using FHIR and SNOMED CT. In this set of data, differential diagnoses were collected at stages through the patient journey using SNOMED CT. As more testing was undertaken (including whole genome sequencing) Pathling was able to use the SNOMED CT semantics to understand the change in diagnosis – from a general diagnosis to a more specific diagnosis, or potentially to a completely unrelated diagnosis (e.g. see the Sankey diagram generated from the data to the right).



Case Study #10

Artificial Intelligence: A Look into Now and a Peek into the Future

Australia – One Nation's View Into Artificial Intelligence in Healthcare

Human Language Understanding Case Studies (6)

- **Natural Language Processing** - There are two main automated approaches to Natural Language Processing (NLP): rule-based and ML based. Case Study 19 is an example of how rule and deep learning approaches can be combined to extract valuable **SNOMED CT**-encoded information on cancer from a range of free text medical documents. Case Studies 20 and 21 show how machine-learning based NLP and **SNOMED CT** can be integrated into hospital workflow to detect missed limb fractures and to identify patients with antibiotic resistant infections. Case Study 23 shows how NLP can be used to automatically quantify the semantic similarity between sentences in medical literature for evidence-based medicine.

- **Information Retrieval** - Case Study 22 demonstrates how a range of machine-learning based information retrieval methods can be used to help produce better systematic reviews of the literature.

- **Conversational Agents** - With the rise of social and communication technologies, conversational agents, or chatbots, provide a means for users to become engaged in conversation, continuing and progressing the dialogue in the same way human-to-human interaction occurs. Some examples where chatbots have been implemented include monitoring speech degeneration in patients with Parkinson's Disease, disease self-management, encouraging behaviour change, and provision of health education. Case Study 24 presents a project to develop a chatbot to assist patients in decision making for the provision of genomic information.

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Human Language Understanding Case Studies

CASE STUDY 19 HIGHLIGHTED – AUTOMATING CANCER REGISTRY TASKS TO ENHANCE CLINICAL DATA QUALITY

- Information about cancers are gathered from a variety of different modalities – including imaging and from biopsy and resections – and then typically written into a narrative report and sent to the treating clinician. CSIRO has worked with Cancer Alliance Queensland to extract information from pathology and radiology reports and death certificates, using AI technologies, for a variety of reporting purposes – including cancer notifications, cancer staging and synoptic reporting.

- The AEHRC Medtex technology uses a mix of symbolic and statistical AI methods to process the clinical reports. A natural language processing (NLP) engine is used to break the discourse of the text into statements and then features are extracted from each statement. The meaning of these features is then inferred through using ML models, which are trained from ground truth (human judgements) data using deep neural networks. For some features a formal logic rule-based approach using the relationships encoded in **SNOMED CT** is utilized.

- The software now supports the extraction of over 20 different clinical features from the text of the histopathology reports covering a range of cancers. Studies have shown that the accuracy of the AI algorithms is very high. The algorithms have a 96% recall and precision for classifying notifiable cancers. Detailed extraction and coding of specific cancer notification items include basis of diagnosis, histological type and grade, primary site and laterality. Visual explanations and feedback from AI decisions are supporting clinical coders in their cancer abstraction task.

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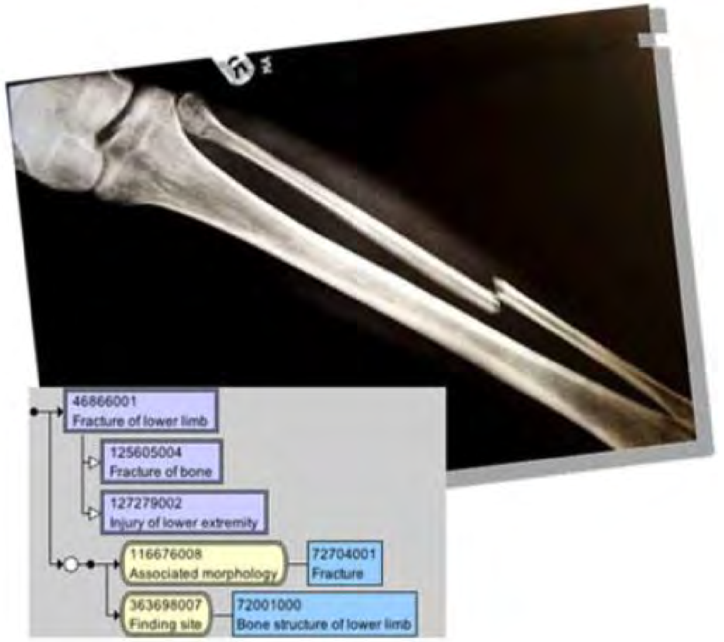
Human Language Understanding Case Studies

CASE STUDY 20 HIGHLIGHTED: CHECKING RADIOLOGY REPORTS TO PREVENT MISSED FRACTURES

- Patients admitted to a hospital emergency department (ED) with a suspected fracture are X-rayed, treated and then discharged. However, when the X-ray report is later finalized by a radiologist, ED specialists have to manually match the report from the radiologist with the patient's discharge diagnosis to ensure that subtle fractures were not missed. The manual checking process is an essential but laborious task.

- The Medtex system (See Case Study 19) was used to perform this check automatically and then flag any potential inconsistencies. The solution uses NLP to extract features from the reports. ML models including support vector machines and deep neural networks are then used to find associations between features in the radiology report. SNOMED CT clinical terminology concepts are used as features to reliably identify limb fractures and other abnormalities documented in radiology reports (see diagram to right of this page).
- Medtex automatically matches fractures identified in the radiology reports with patients' ED discharge diagnosis to provide decision support for the current manual checking process. Studies have shown that this checking can be done with high precision and recall across three different hospital ED settings. By fast-tracking diagnoses and streamlining test result reviews, emergency departments can save time and deliver improved patient outcomes.



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Human Language Understanding Case Studies

CASE STUDY 21 HIGHLIGHTED: TACKLING ANTIMICROBIAL RESISTANCE WITH TEST RESULT REVIEW

- Antibiotic overuse contributes to antimicrobial resistance, which could cost the global economy US$100 trillion by 2050 and cause up to 10 million deaths per year. Patients with suspected infections are tested for the presence of bacterial organisms with antibiotic resistance. These test results are then manually reviewed to ensure patient's infections are not resistant to the antibiotics they are taking. This project aims to automate this process in two parts: 1) streamline Emergency Department microbiology test result review to identify bacterial organisms and their antibiotic sensitivities; and 2) match these with antibiotic prescriptions extracted from Emergency Department discharge letters.
- Our NLP methods extract antibiotic prescriptions detailed in discharge letters. Then we parse microbiology reports for bacterial organisms and antibiotic sensitivities. Given these two sources, we exploit the semantics in **SNOMED CT** to match antibiotic prescriptions (e.g. generic and trade names) with the bacteria's sensitivities for a given antibiotic class. This provides clinical decision support to identify patients that have been prescribed an antibiotic for which the bacterial organisms are resistant. The patient can then be contacted for follow-up treatment, such as a change of antibiotic treatment.
- An example scenario is when the discharge letter notes that a patient was prescribed with "ampicillin". When the microbiology test result returns, it notes the bacteria present was "Escherichia-coli" (E. coli): a bacterium known to be resistant to ampicillin. The system would pick this up immediately and alert the clinician, enabling the patient to be contacted and provided with a more appropriate antibiotic.

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Artificial Intelligence: A Look into Now and a Peek into the Future

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Imaging and Vision (10)

- **Medical Image Analysis -** Medical image analysis employs a range of supervised and unsupervised AI and ML techniques to extract clinically relevant information or knowledge from medical images.
- **Using Imaging for Early Detection of Abnormal Development -** Case Study 25 is a cloud-based 'Developing Brains' toolbox using ML to analyze MRI scans of very preterm-born infants to identify biomarkers that predict later motor, neurological and neurobehavioral problems. Case Study 26 describes AssessCP, a clinical support tool for pediatric brain injury.
- **Image Guided Treatment and Disease Monitoring -** Case Study 27 shows how software that integrates with MRI machines can be used to quantify the changes in cartilage indicating osteoarthritis – this guides surgery such as joint replacements. Case Study 28 uses MRI images to help guide the delivery of radiotherapy for prostate cancer. Case Study 29 uses PET imaging to generate quantified measures for risk of Alzheimer's Disease. In Case Study 30, deep learning methods are used on ocular images for automated detection of macular degeneration that can cause blindness. Case Study 31 uses image processing for segmentation of flecks in the eyes to track Stargardt disease progression.
- **AI-Based Telehealth-** Case Study 32 presents a tele-oral care system that provides AI-driven oral mucosal disease classification and specialist-based clinical decision support. Case Study 33 provides face detection and automated classification of patient emotion from video for tele-health.
- **Robotics -** Case Study 34 shows how socially-assistive robots are used to supplement traditional therapy and education for children with autism.

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Artificial Intelligence: A Look into Now and a Peek into the Future

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IN SUMMARY

- Artificial Intelligence, including Machine Learning and Deep Learning is rapidly being adopted in healthcare systems around the world, as a way to achieve access, quality and productivity gains.
- **SNOMED CT** is uniquely positioned to support the expansion of AI in:
  1. Predictive Analytics and Data-Driven Intelligence (i.e. data driven insights from clinical information systems)
  2. Knowledge Representation and Reasoning (i.e. knowledge representation to support analytics and research)
  3. Human Language Understanding (i.e. natural language processing).
- Looking forward, the full power of **SNOMED CT** comes from using its semantic network, which is perfectly positioned to support symbolic artificial intelligence opportunities in healthcare.

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SNOMED CT
Genealogy Example

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SNOMED CT
The global language of healthcare

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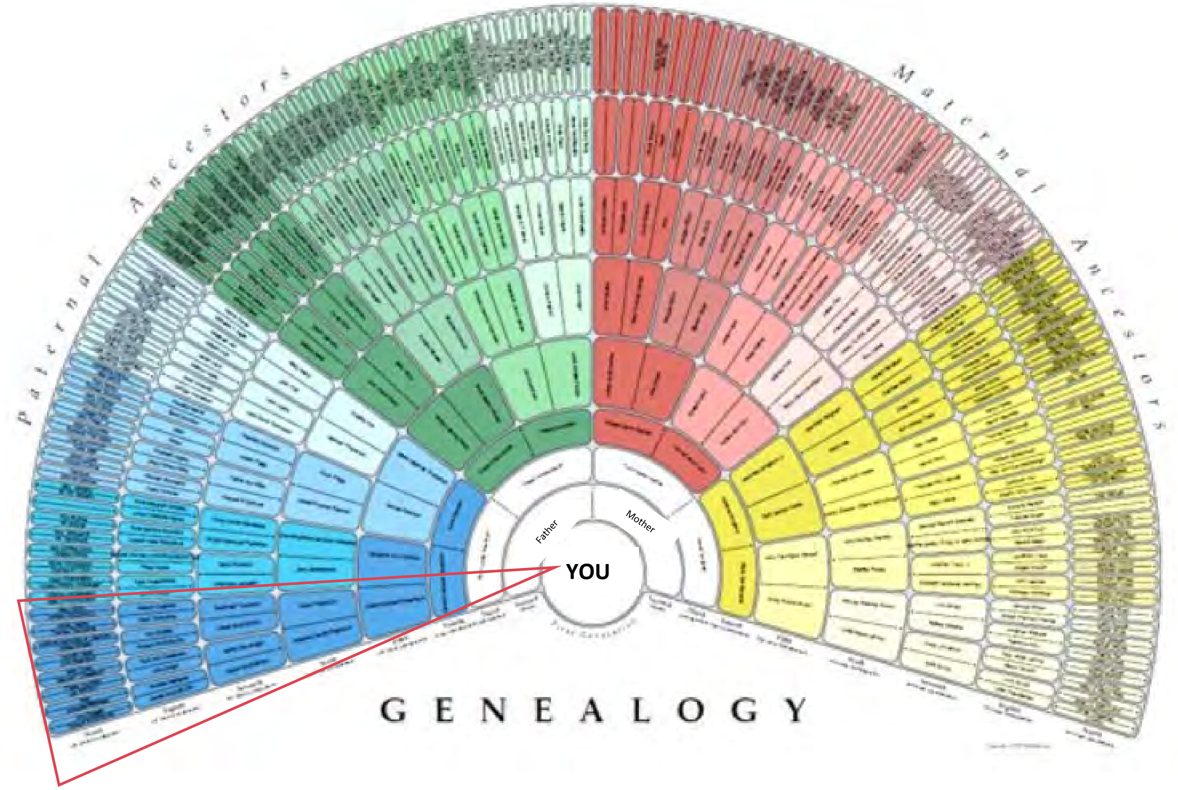
The Genealogy Analogy

Family Trees

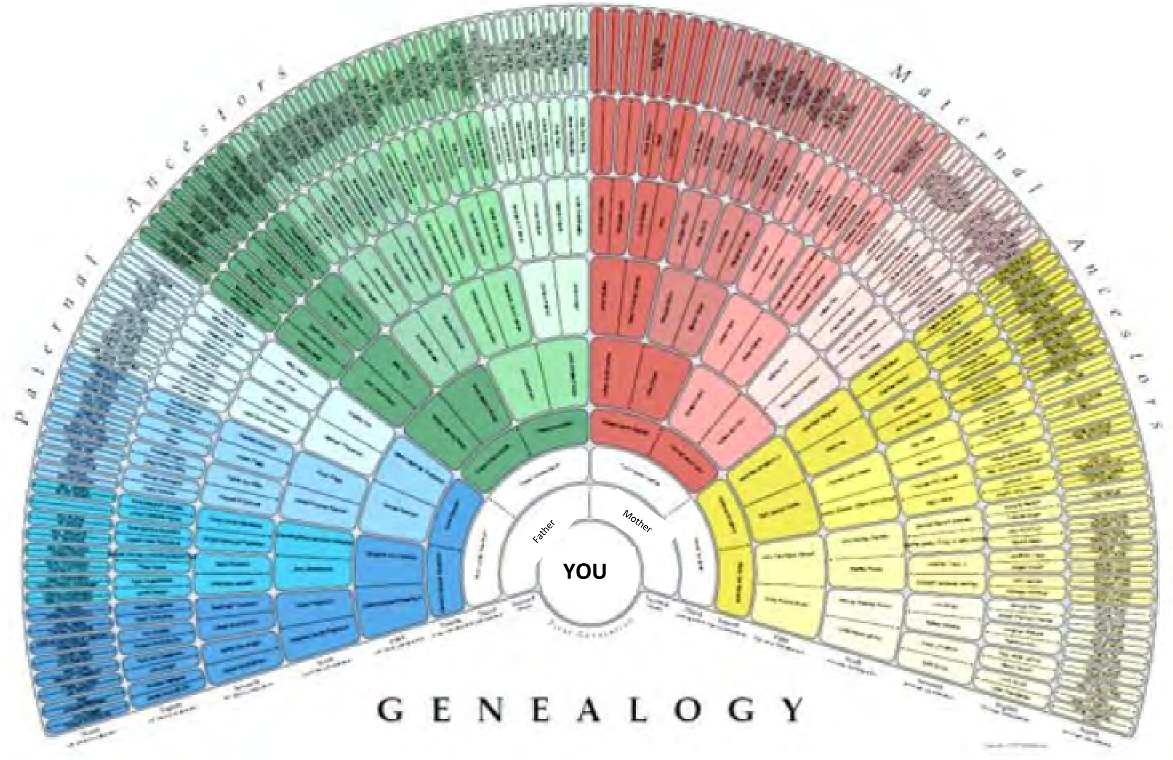
- Family trees are complex, especially when traced back through nine generations (see the family tree diagram to the right). When viewed in totality family trees include both your paternal (father) ancestors and your maternal (mother) ancestors (i.e. your gene pool).
- If you trace the **surname** of the direct paternal family back through time (i.e. father, grandfather, etc.) a single family tree hierarchy can be created. See the dark blue tree in the red triangle of the diagram.
- This single family tree hierarchy with no relationships to the other family trees is analogous to a clinical classification system (e.g. ICD-10).



The Genealogy Analogy

Family Trees

- If you trace your surname back through time, but include both the paternal and maternal ancestors (e.g. father/mother, grandfather/grandmother etc.) you quickly become part of multiple (i.e. in this case sixteen), interrelated family trees.
- These multiple, interrelated family trees are analogous to clinical terminologies like SNOMED CT.
- Further, we also know that the distinguishing feature of SNOMED CT are the defined relationships among the hierarchies, or in this case among the sixteen family trees, that allow for a deeper and richer analysis of the family tree data.



The Genealogy Analogy

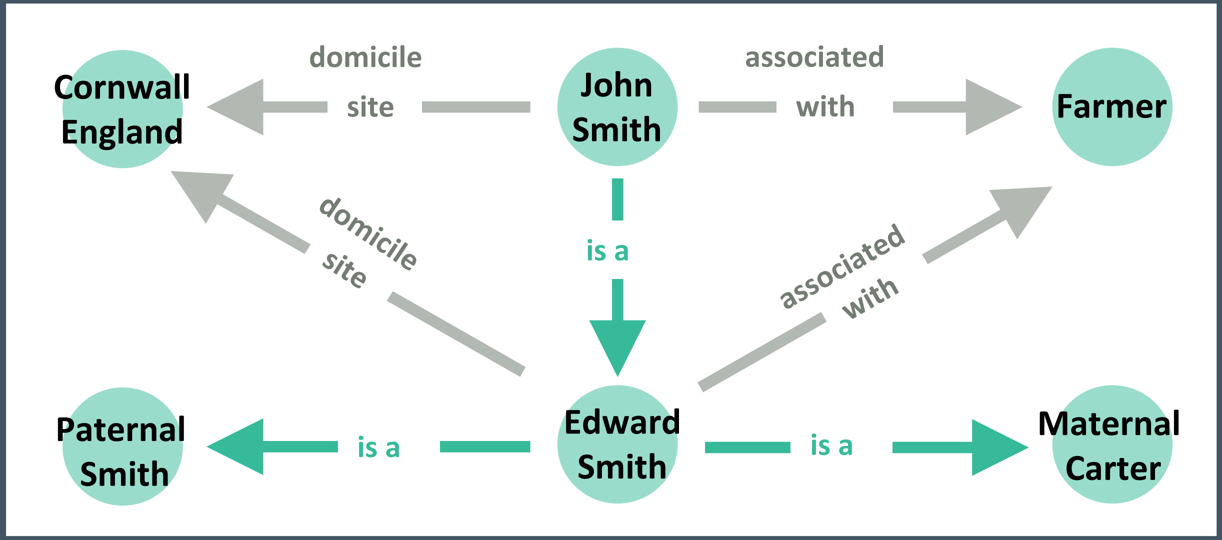
Family Trees

- For a family tree ANCESTOR, OCCUPATION, and PLACE are concepts that can be organized into hierarchies. **'IS A'** statements connect concepts **within** a hierarchy.
- Attribute relationships connect concepts **among** the sixteen interrelated family trees. So for our family tree analogy DOMICILE SITE and ASSOCIATED WITH could be deemed relationships.

For example, John Smith 'is a' ancestor (father) of Edward Smith. Edward Smith 'is a' paternal Smith (father's surname) and 'is a' maternal Carter (mother's surname).

Both John Smith and Edward Smith are 'associated with' being a farmer (occupation).

Both John Smith and Edward Smith have a 'domicile site' in Cornwall, England (place).



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The Genealogy Analogy

Family Trees

- With the Family Tree construct in mind, plus knowing that in this case the sixteen individual family trees are linked through attribute relationships, one could generate a set of computer queries that ask:
  - How many of your ancestors were farmers?
  - How many of your ancestors who were farmers were located in the United Kingdom?
  - How many of your ancestors who were farmers were located in Cornwall, England?

  And…. As one broadens the number and type of concepts and relationships
  - How many of your ancestors immigrated to another country?
  - How many of your ancestors from Cornwall immigrated to Australia or New Zealand? …… and so on
- The comprehensiveness, richness and consistency of the potential computer queries quickly becomes obvious and as a result extremely powerful for accelerating the family tree analytics process. This is the unique advantage of a terminology like SNOMED CT that is simply not possible with a classification systems like ICD-10.

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Clinical Information Systems and SNOMED CT

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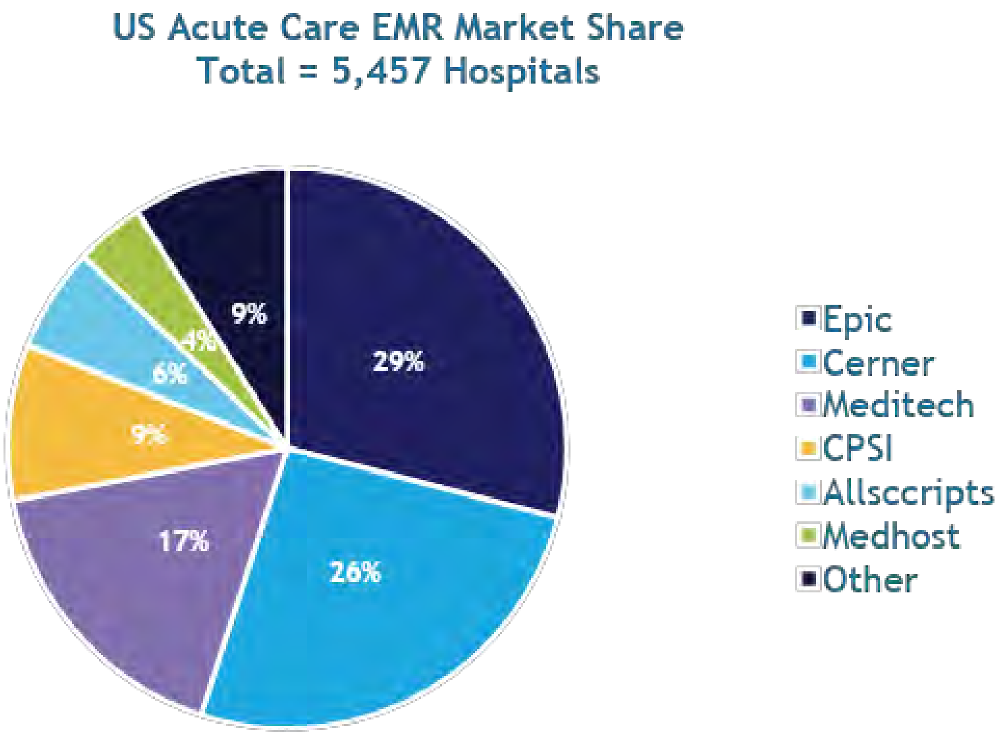
SNOMED CT
The global language of healthcare

US Acute Care EHR Market Share

Identification of EHRs with SNOMED embedded[1]

Vendor	Market Share	SNOMED CT
Epic	29%	Yes
Cerner	26%	Yes
Meditech	17%	Yes
CPSI	9%	
Allscripts	6%	Yes
Medhost	4%	
Other	9%	
Total	**100%**	**78%**



1. Source: "U.S. Hospital EMR Market Share 2020" report by KLAS Research for 5,457 US acute care hospitals

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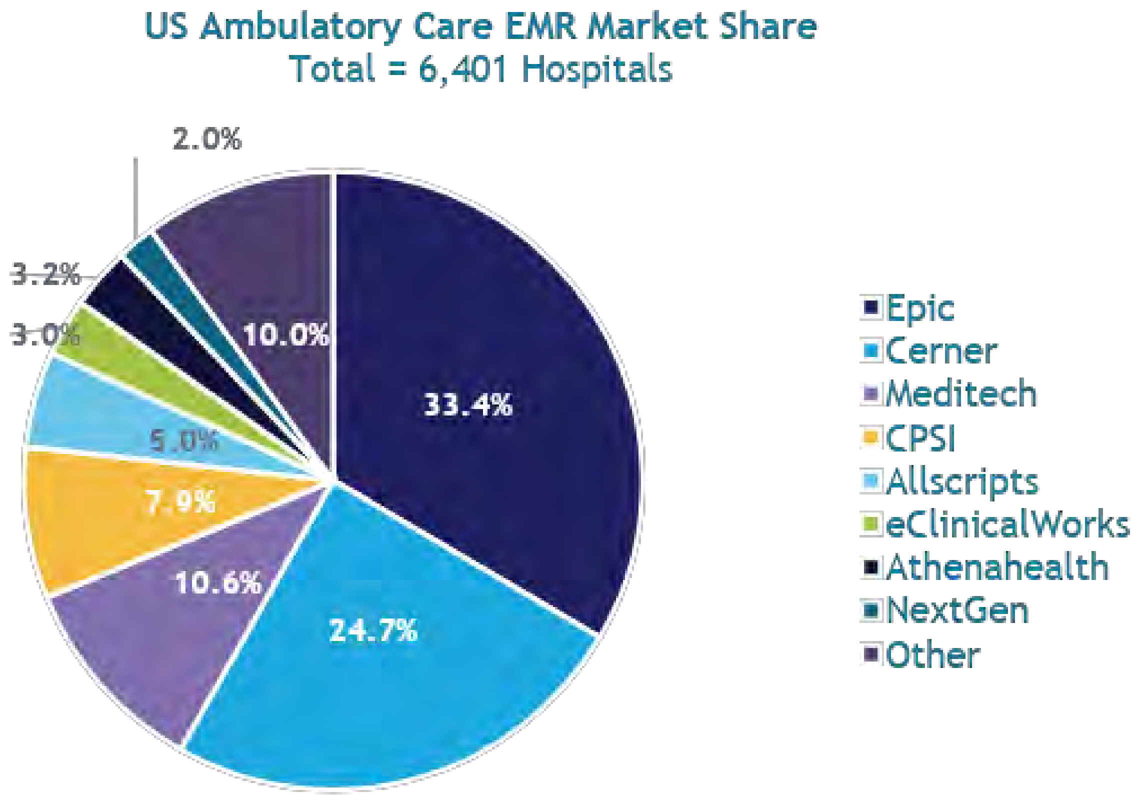
US Ambulatory Care EHR Market Share

Identification of EHRs with SNOMED Embedded[2]

Vendor	Market Share	SNOMED CT
Epic	33.4%	Yes
Cerner	24.7%	Yes
Meditech	10.6%	Yes
CPSI	7.9%	
Allscripts	5.0%	Yes
eClinicalWorks	3.0%	Yes
Athenahealth	3.2%	Yes
NextGen	2.0%	Yes
Other	10.0%	
Total	**100%**	**81.9%**



2. Source: "U.S. Ambulatory EMR Market Share 2020" report by Definitive Healthcare for 6,401 US hospitals

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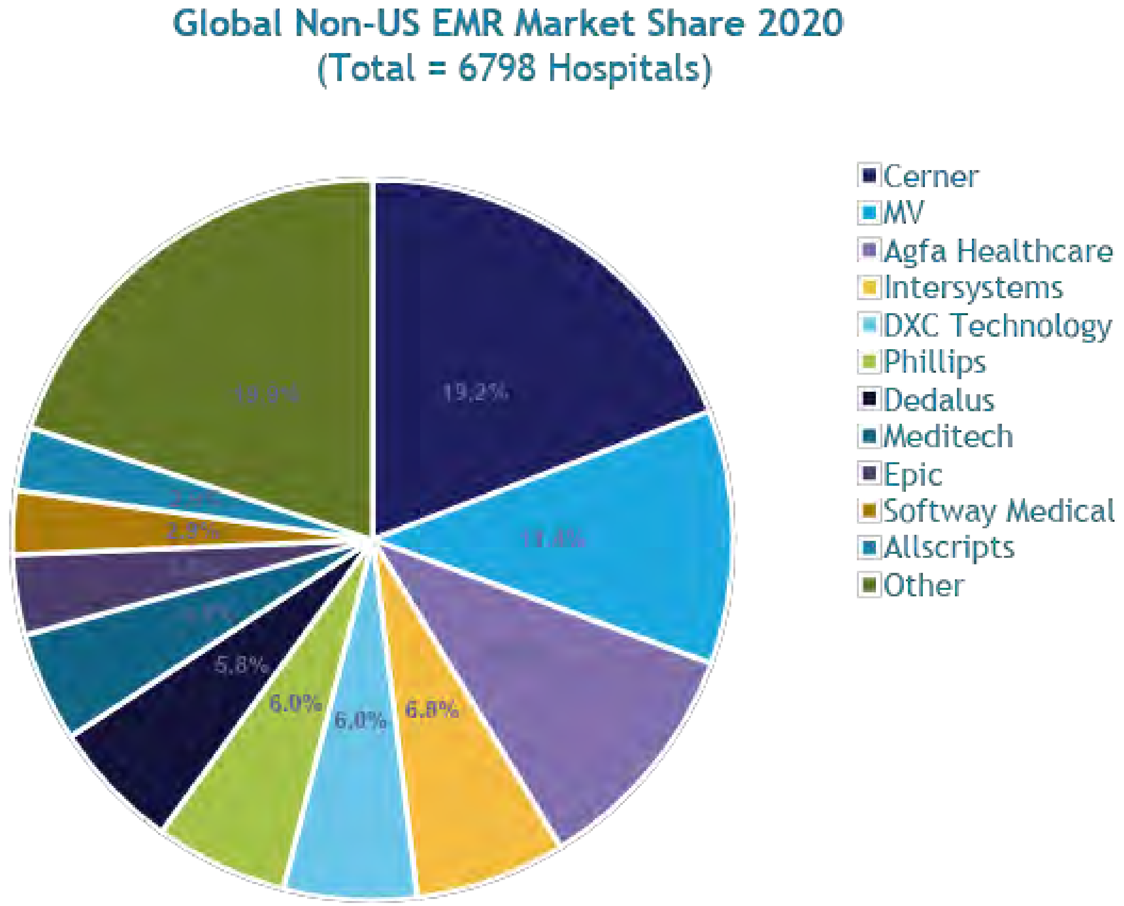
Non-US Acute Care EHR Market Share

Identification of EHRs with SNOMED Embedded[3]

Vendor	Market Share	SNOMED CT
Cerner	19.2%	Yes
MV	11.4%	
Agfa Healthcare	10.7%	Yes
Intersystems	6.8%	Yes
DXC Technology	6.0%	Yes
Philips	6.0%	Yes
Dedalus	5.8%	
Meditech	4.9%	Yes
Epic	3.6%	Yes
Softway Medical	2.9%	
Allscripts	2.9%	Yes
Other	19.9%	Yes – 6.3%
Total	**100%**	**66.4%**



3. Source: "Global Non-U.S. EMR Market Share 2020 report" by KLAS Research for 6,798 Global hospital customer base, April 2020

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Read the full report and visit the value platform at:

snomed.org/value

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