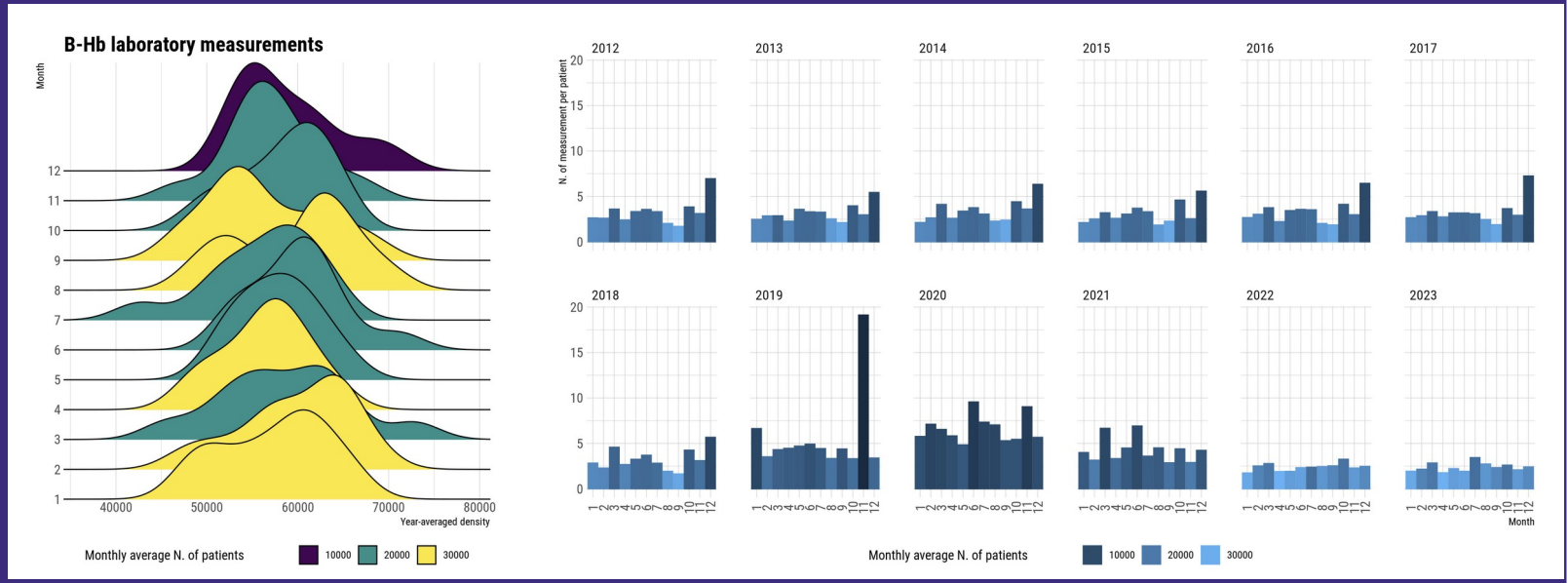
Varsinais-Suomen hyvinvointialue
Egentliga Finlands välfärdsområde



Using Healthcare Data for Scientific Research and Data-Driven Care: Examples from Finland

Arho Virkki

Chief Analytics Officer, Wellbeing services county of Southwest Finland (Varha)
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Contents

Background

- Turku University Hospital, Auria Clinical Informatics Unit, and the Wellbeing services county of Southwest Finland (Varha)
- The Finnish way of using health data for the secondary use: History, current practices and future Directions, including EHDS

Electronic Health Records (EHRs) and their Daily Use in Finland

- What does the EHR system in Finland look like?
- What kind of data is collected – and who has access to it?
- How do physicians use the EHR in their day-to-day work?
- Social Security Reform in Finland 2023 and onwards

Secondary Use of Health Data

- How are routine data (billing data, EHR data, etc.) used for analytics?
- The difference between scientific and operational uses of data
- Secure Processing Environmets (SPEs)
- Dashboards and benchmarking
- How do physicians or clinics benefit from the insights from data

Efficient and Safe Health Data Use (in speaker's opinion)

- The greatest barriers in data utilization
- Future directions of data utilization in healthcare
- Discussion

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Turku University Hospital and Varha

The wellbeing services county of Southwest Finland - Varha

- Responsible for organizing the regional social and health services and rescue operations (since January 1, 2023)
- Covers 27 municipalities

The duties of the wellbeing services counties include:

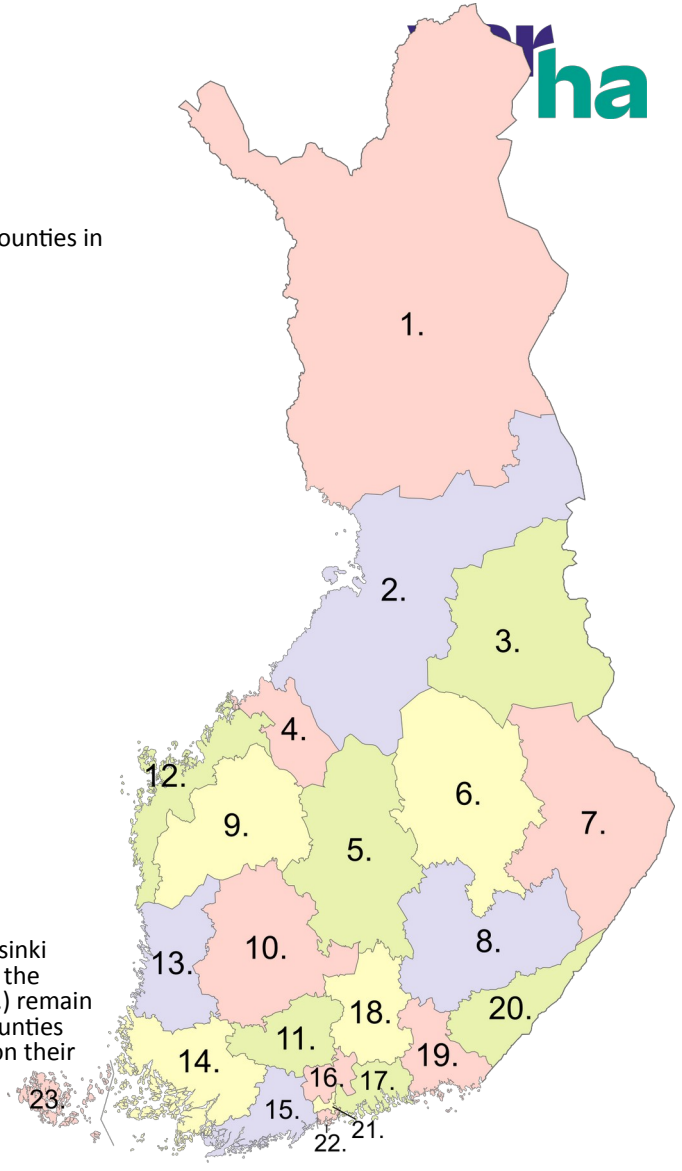
Primary healthcare
Specialised healthcare
Social welfare
Services for children, young people and families
Services for working-age people
Mental health and substance abuse services
Services for persons with disabilities
Student welfare
Rescue services
Prehospital emergency medical services

https://stm.fi/en/wellbeing-services-counties

There are 21 wellbeing services counties in Finland:

1. Lapland
2. North Ostrobothnia
3. Kainuu
4. Central Ostrobothnia
5. Central Finland
6. North Savo
7. North Karelia
8. South Savo
9. South Ostrobothnia
10. Pirkanmaa
11. Kanta-Häme
12. Ostrobothnia
13. Satakunta
14. **Southwest Finland**
15. West Uusimaa
16. Central Uusimaa
17. East Uusimaa
18. Päijät-Häme
19. Kymenlaakso
20. South Karelia
21. Vantaa-Kerava

The City of Helsinki (22.) and Helsinki University Hospital together with the autonomous Region of Åland (23.) remain outside the wellbeing services counties (exercising similar competences on their own.)



Turku University Hospital and Varha

Turku University Hospital

- Was founded in 1756 (and it is the second oldest hospital still in use in the Nordic countries after Rigshospitalet in Copenhagen. The Academy of Turku was founded earlier in 1640)
- Part of Varha since January 1, 2023
- Is used as a teaching hospital by the University of Turku Faculty of Medicine with approx 1500 students in medicine and nursery practice every year.
- Auria Clinical Informatics was started as a project for building a Hospital Data Lake in 2024 and was established as an official service unit in 2019

Auria Clinical Informatics

Services for Research and Education

- ~ 15 people
- Annual budget ~ 1.6 M€
- Full coverage of data processing and analytical skills
- https://auria.fi/en

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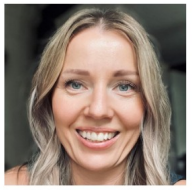

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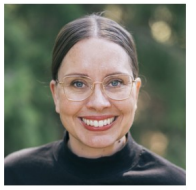

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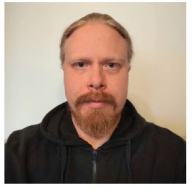
Statistical Programmer



Matti Leskinen
Data Architect

Altti Tammi
Database Expert

The Finnish way of using health data

1960's
Development of electronic information systems in Finnish health care began In the 1950s and the first health care computer programs were already in use in the 1960s, although then mainly for financial management needs, not for electronic heath records (EHRs). Also the Finnish social security id - a unique personal identifier - dates back to 1960's. It has the from DDMMYY-dddC, e.g. 310275-123X or 010103A123Z, where the separator "A" is used for people born in this millennium and "+" for people born in the 19th century.

1970-80's
In the 1970s and 1980s Finland was one of the top countries in the use of information technology internationally, and in hospitals and especially in primary health care. Development of electronic information systems, simultaneously with manual patient record data specification work, has created a foundation for electronic patient records and electronic structured for recording. The first electronic patient record was introduced at the Varkaus Health Centre in 1982.

1990's
To support the development work, the Finnish Hospital Association published a guideline on the structure of a continuous patient record system in 1991, and in the 1990s, electronic patient record systems were comprehensively introduced to Finnish primary health care. At the same time, with the introduction of electronic patient record data, work on the development of the Finnish classification of activities related to electronic structured recording also began.

Image source:
https://www.veripalvelu.fi/en/history/history-of-the-blood-services-scientific-research-activity/

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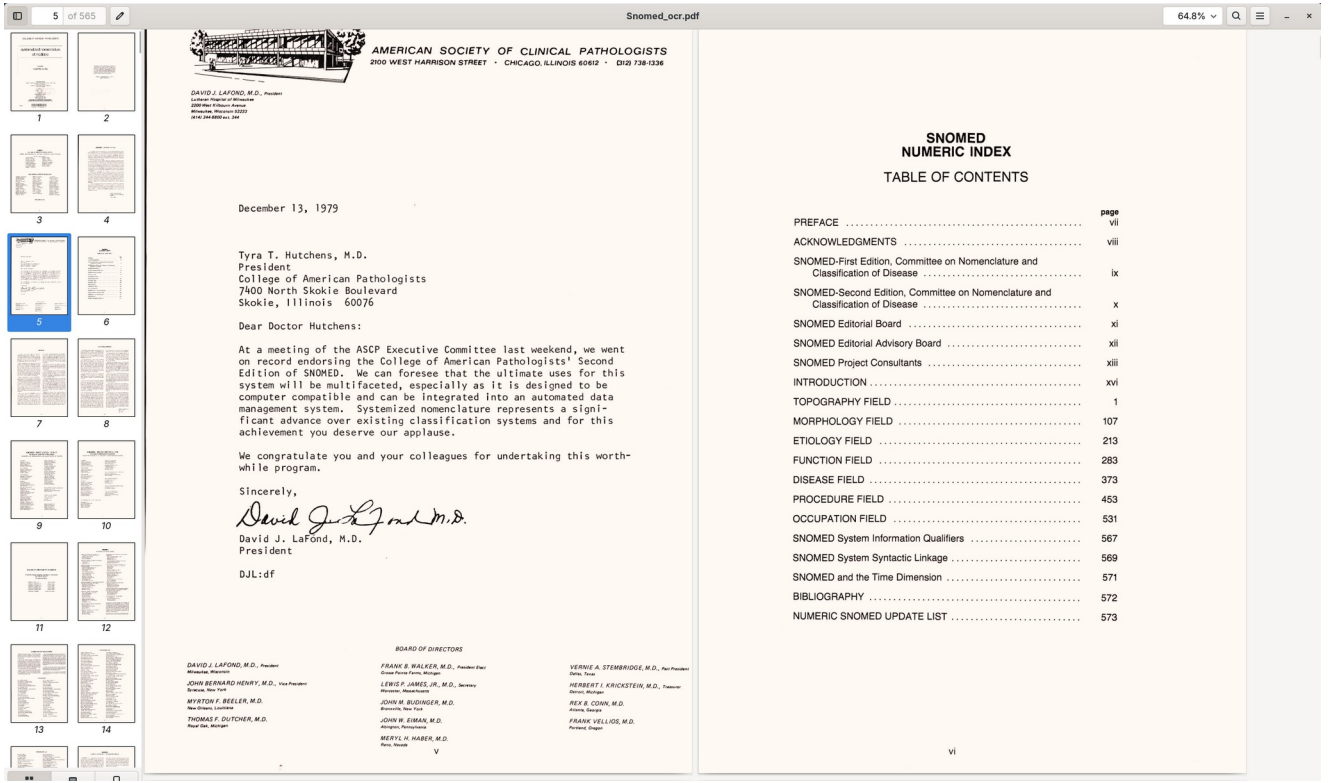
The Finnish way of using health data

For example,

Snomed v2, the systematized nomenclature of medicine from early 1980's is still in use in Finnish Biobanks.

These have been proposals and efforts in converting the historical data into mode modern (but not any more hierarchical) Snomed-CT format.

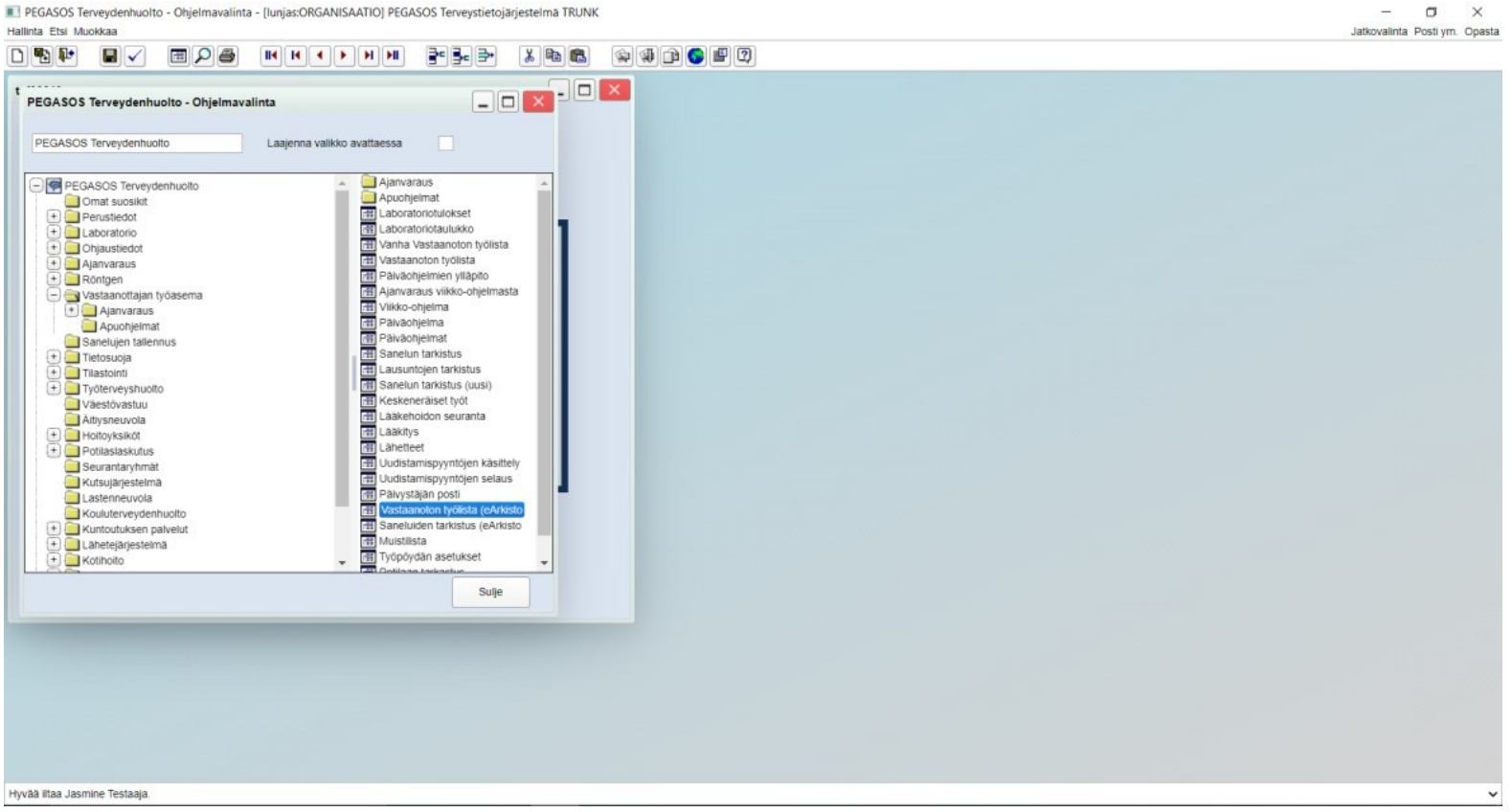


Sources:

- Finnish Biobank Cooperative – FINBB. https://finbb.fi/en/
- Carita Olkkonen, The Development of the System and Education of Staff in the Implementation of the Structured Electronic Documentation 29.8.2013 https://www.theseus.fi/bitstream/handle/10024/64246/Sahkoise.pdf

The Finnish way of using health data

Semi-random screenshots from the operational EHR systems in use at Soutwest Finland



Pegasos system for primary healthcare, main view

Source: Jasmine Lundgren, Bachelor's Thesis, Turku University of Applied Sciences, Business Information Technology, 2021. Usability Differences of Patient Information Systems' Treatment Reports. https://www.theseus.fi/bitstream/handle/10024/507822/Lundgren_Jasmine.pdf

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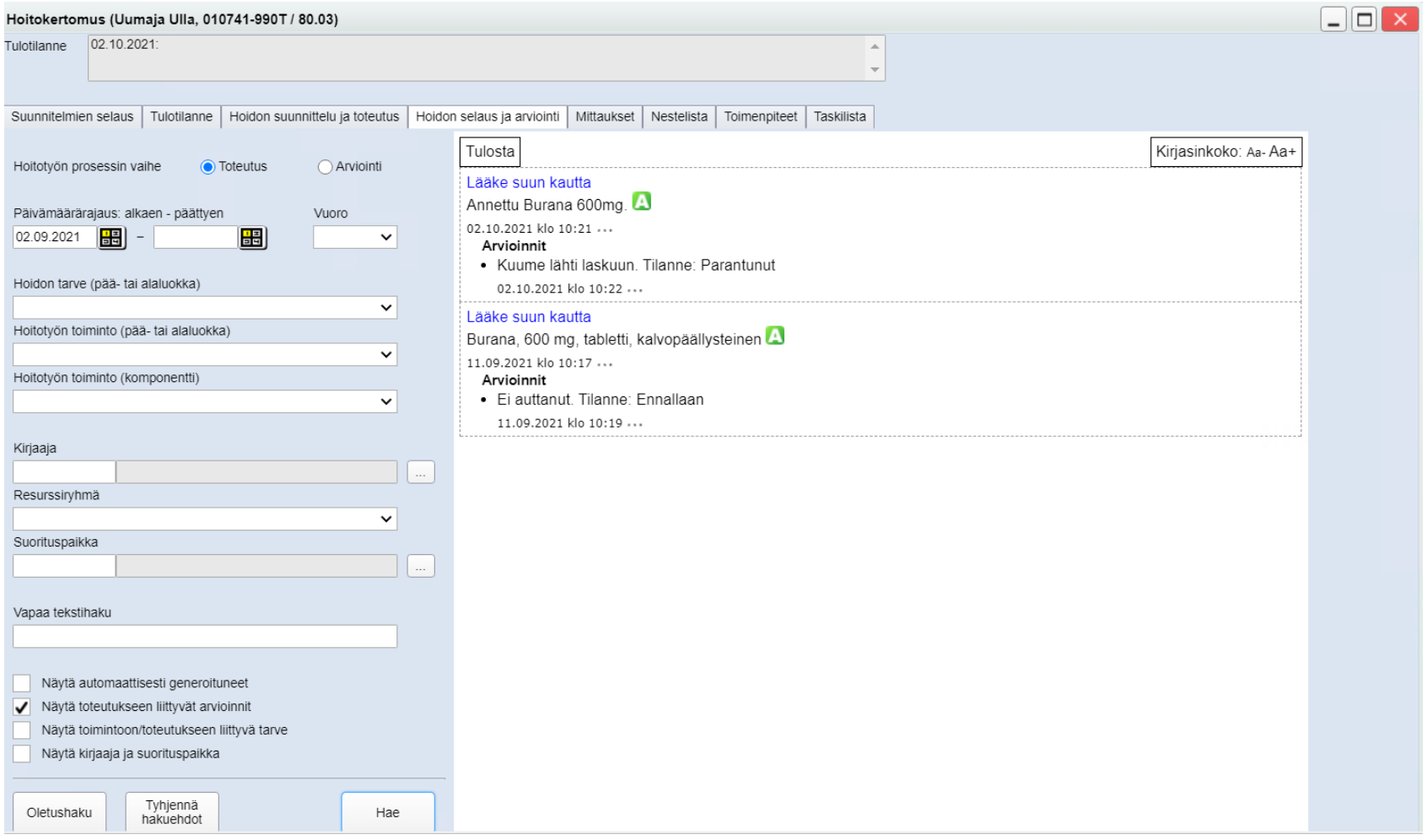
The Finnish way of using health data



Pegasos system for primary healthcare, notes view

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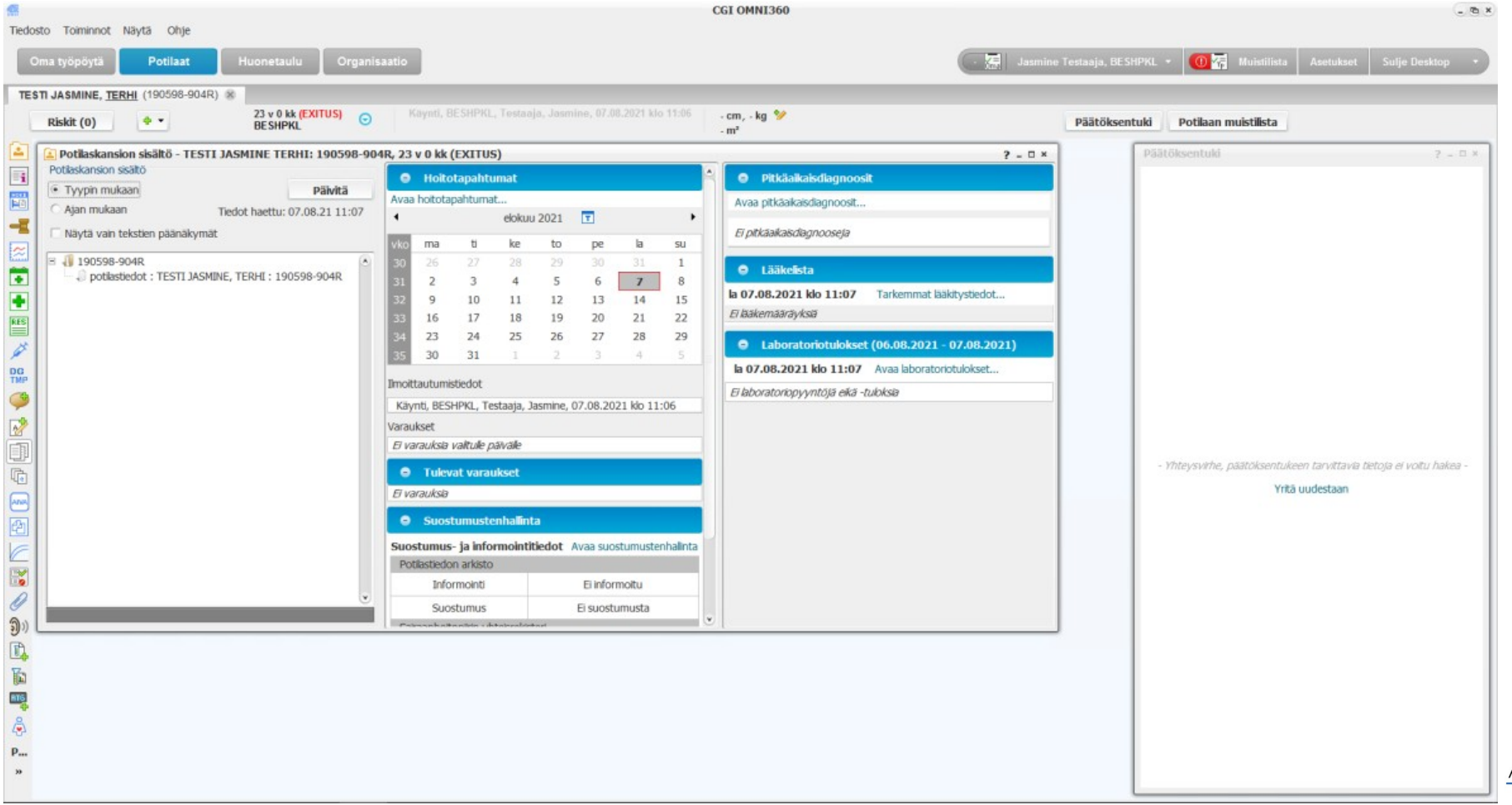
The Finnish way of using health data



CGI OMNI360 patient notes view

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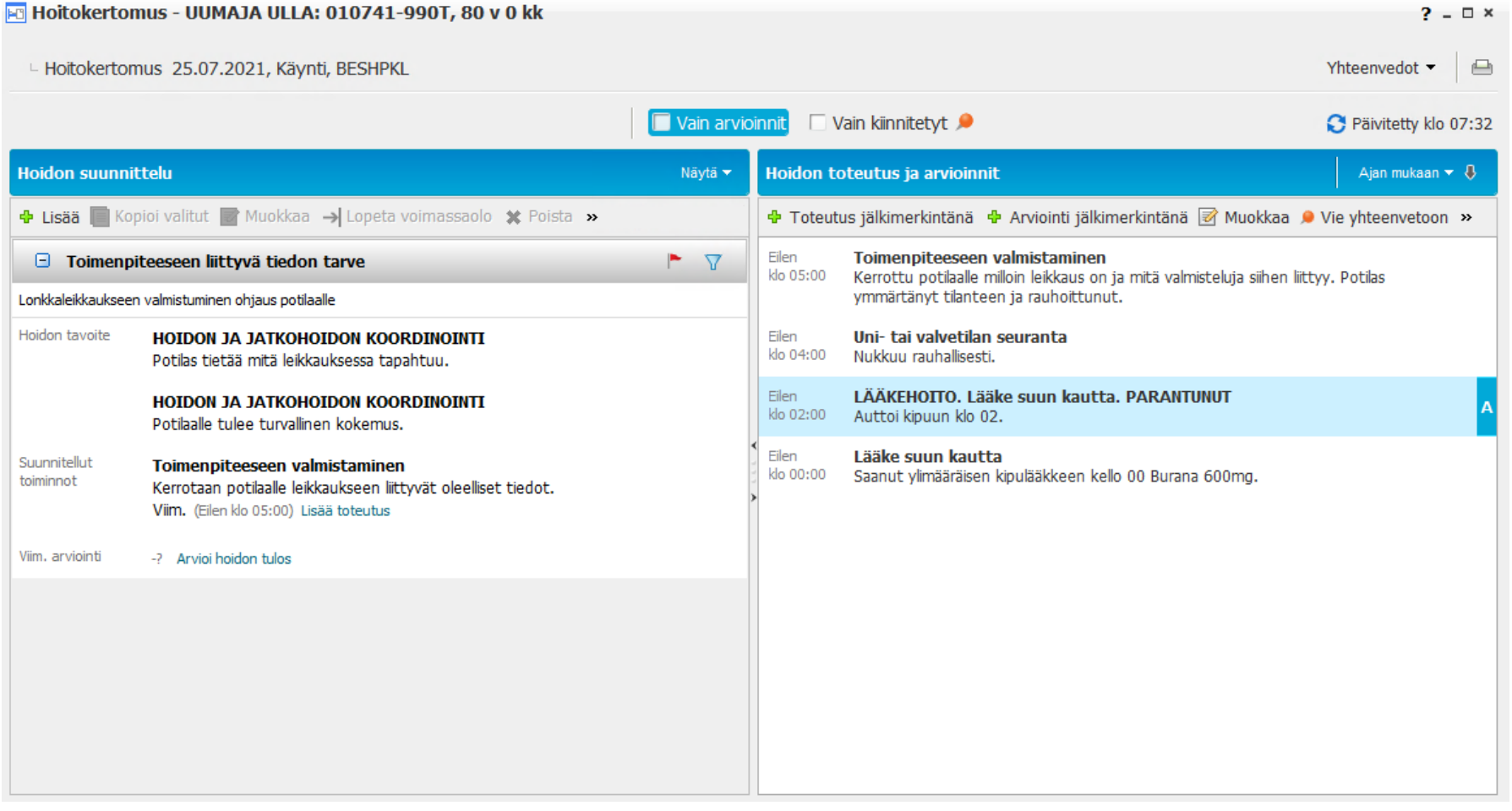
The Finnish way of using health data



CGI OMNI360 patient notes view

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The Finnish way of using health data

In 1989, The Act on Special Hospital Care (1062/89) defined three important tasks for Finnish university hospitals:

1) special level medical care,
2) teaching and
3) scientific research.

University hospitals teach doctors, nurses and other health care professionals (e.g. therapists, psychologists). In addition, university medical faculties conduct a lot of small-scale, but medically important, researcher-oriented applied and basic research that utilizes information from electronic health records.

Thus, in addition to patient care, the data from the ERHs is used also

- In connection with advanced studies that are mandatory for medical education, if the student chooses a registry study as the method.
- In a researcher-oriented register study, where, for example, part of the data may be asked based on consent and the extensive control material to be mirrored is obtained based on the secondary law.
- In the work of a doctor, where one's own actions and the effectiveness of treatment decisions are examined in the light of history in order to develop one's own competence.
- When developing the service system as part of the organization's data-driven management.

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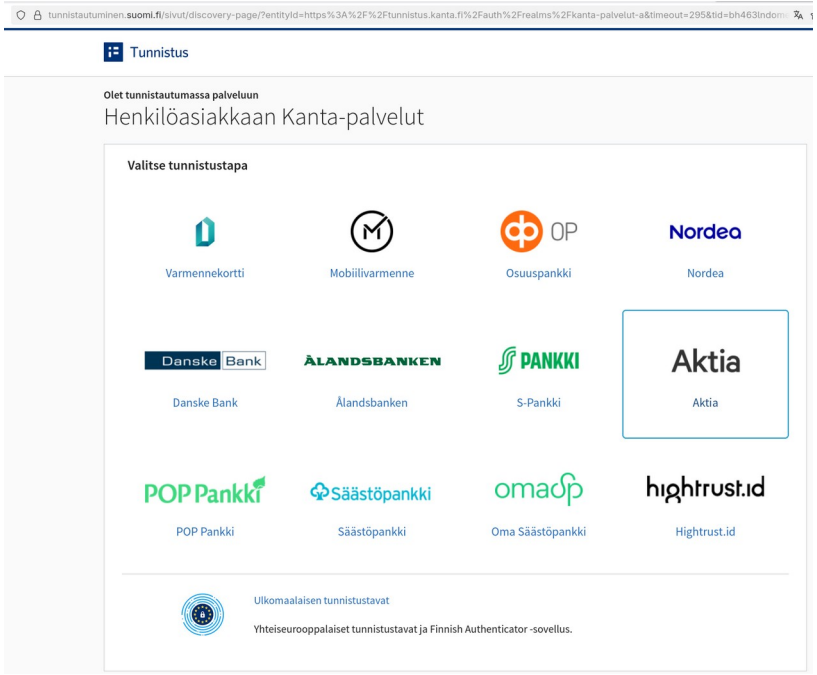
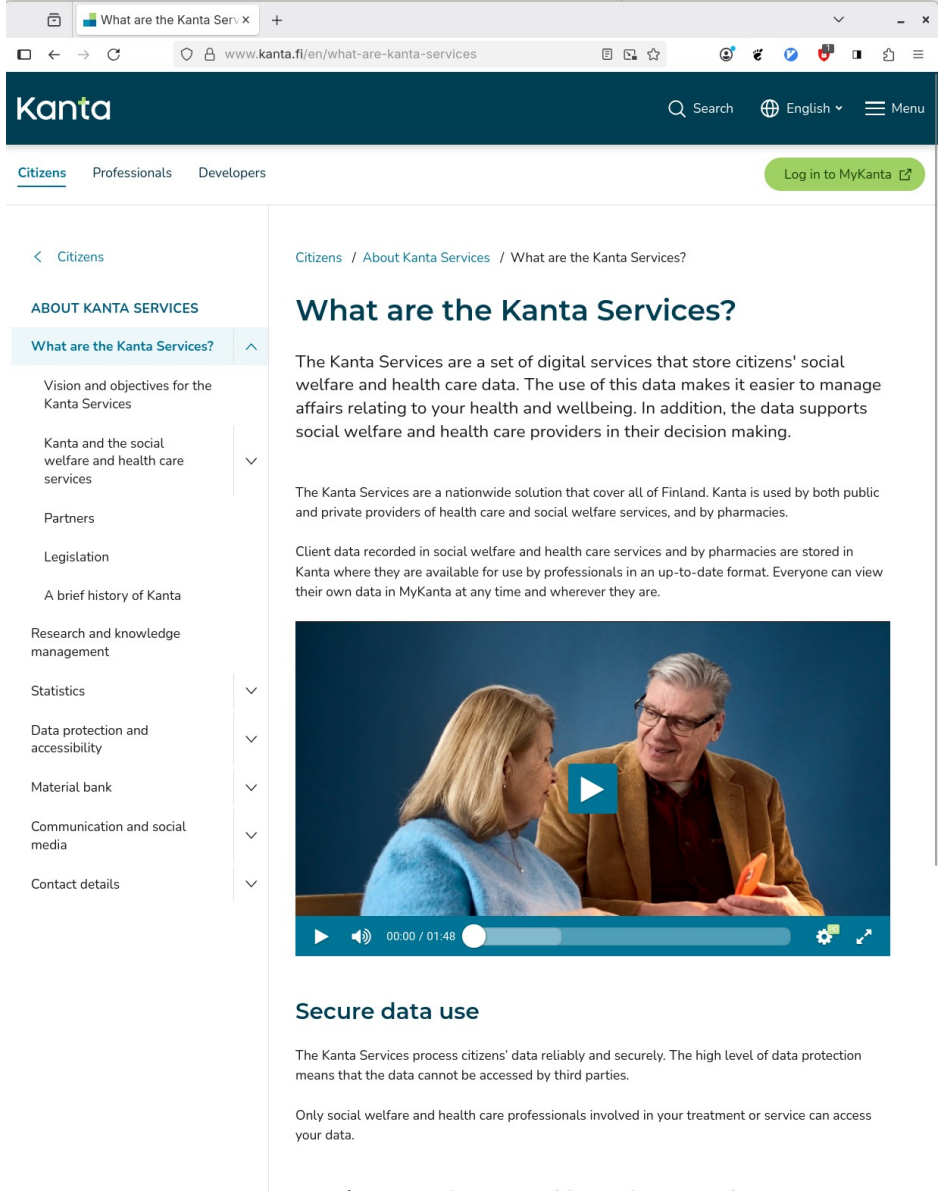
The Finnish way of using health data

2010

The use of electronic prescription via Finnish national Kanta Services became mandatory in 2017.

Kanta is hosted by **Kela**, the Social Insurance Institution of Finland, which is supervised directly by the Finnish Parliament. Kela is thus an independent social security institution with its own administration and finances.

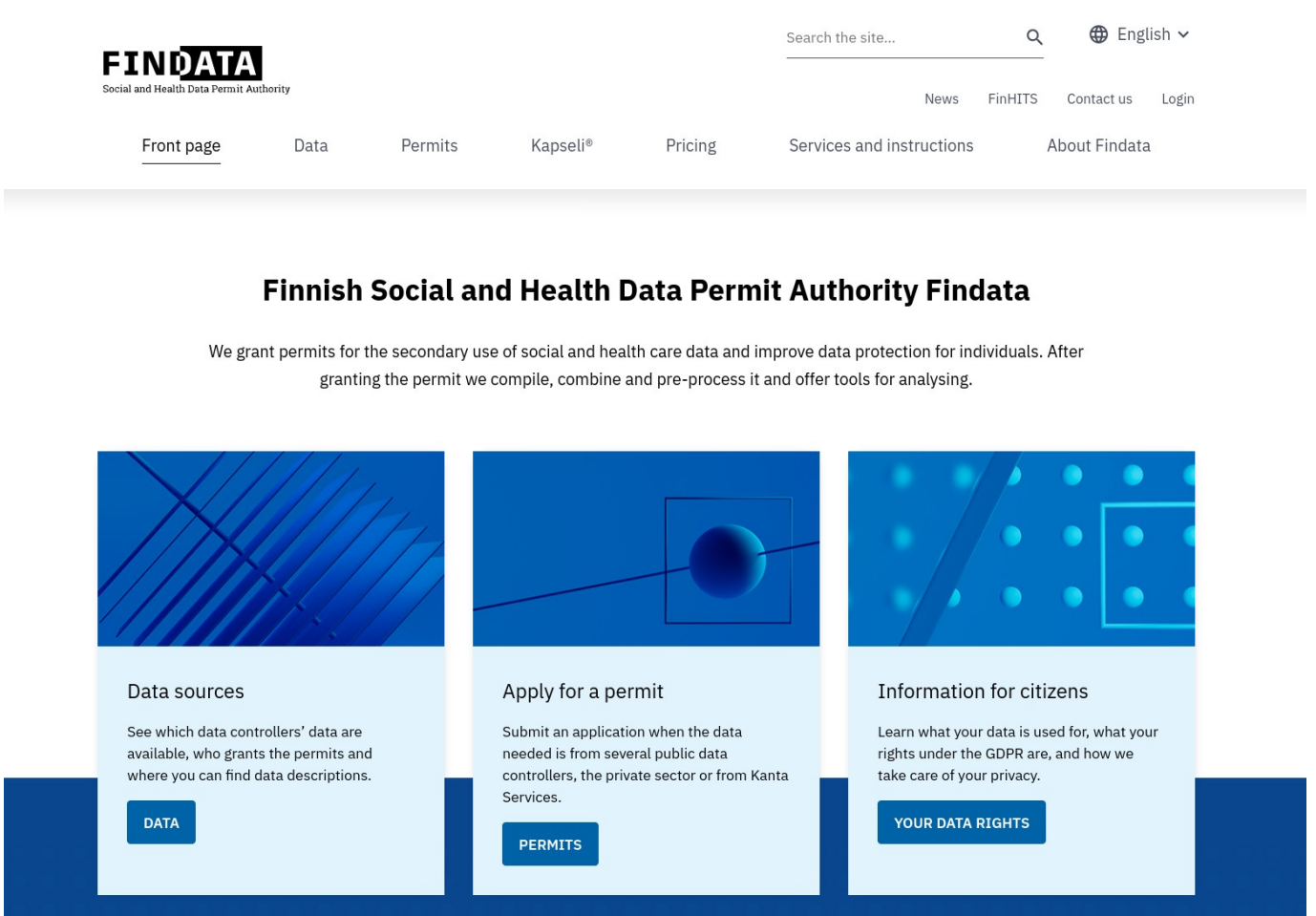




The Finnish way of using health data for the secondary purposes

2019 Findata - a national data access body - started its operations in Finland due to the *Act on the Secondary Use of Health and Social Data*.

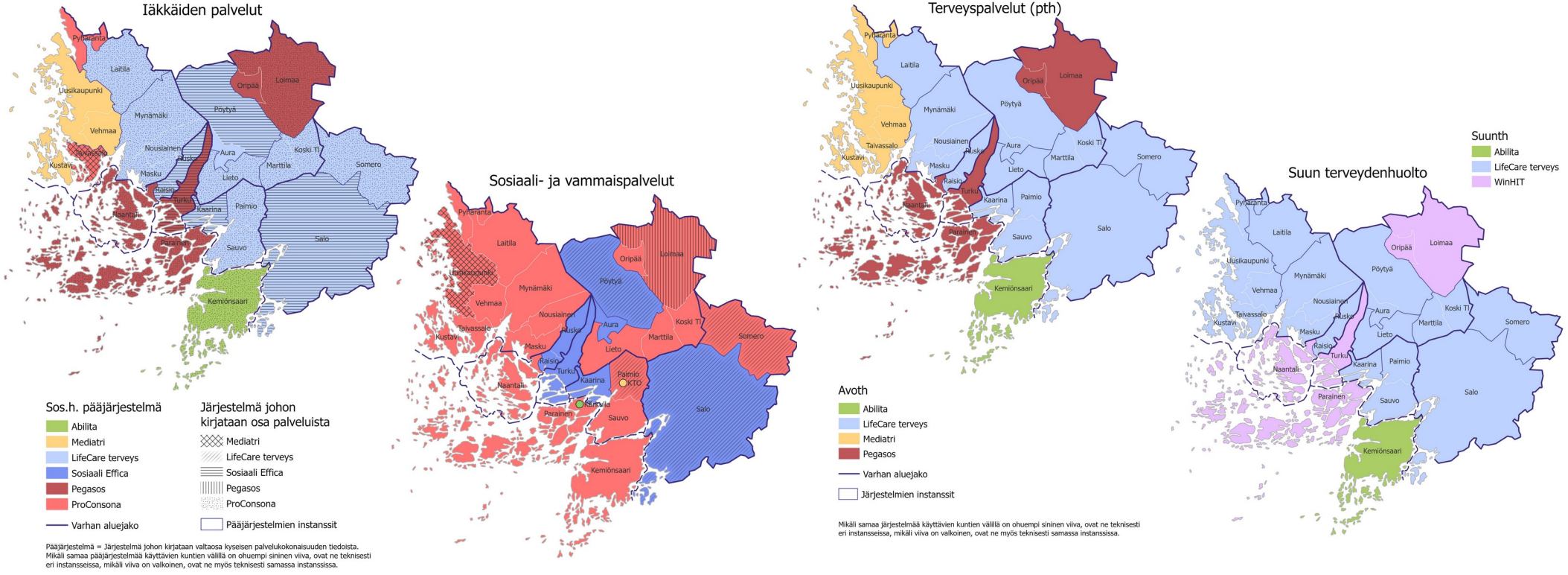
See: https://stm.fi/en/secondary-use-of-health-and-social-data



The Finnish way of using health data for the secondary purposes

Current Reality

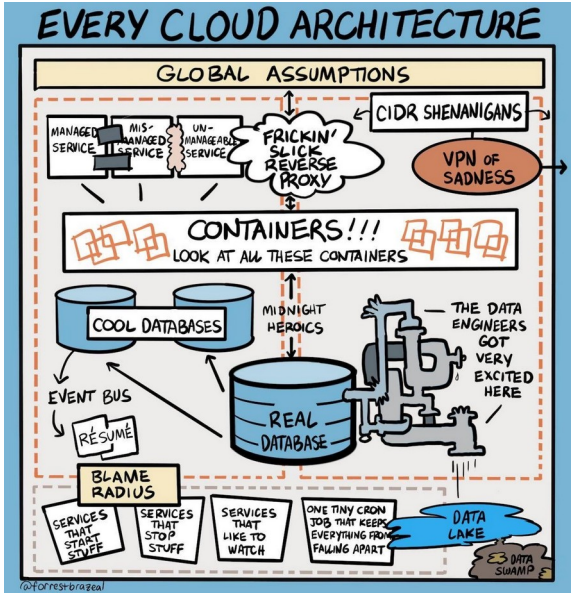
Due to the incremental and distributed history of the ICT systems in heath and social services, the amount of different databases and their instances is large. The Social Security Reform, active since the 1st of January 2023 (which was planned since 2005!) aims to consolidate and simplify the current jungle of databases.

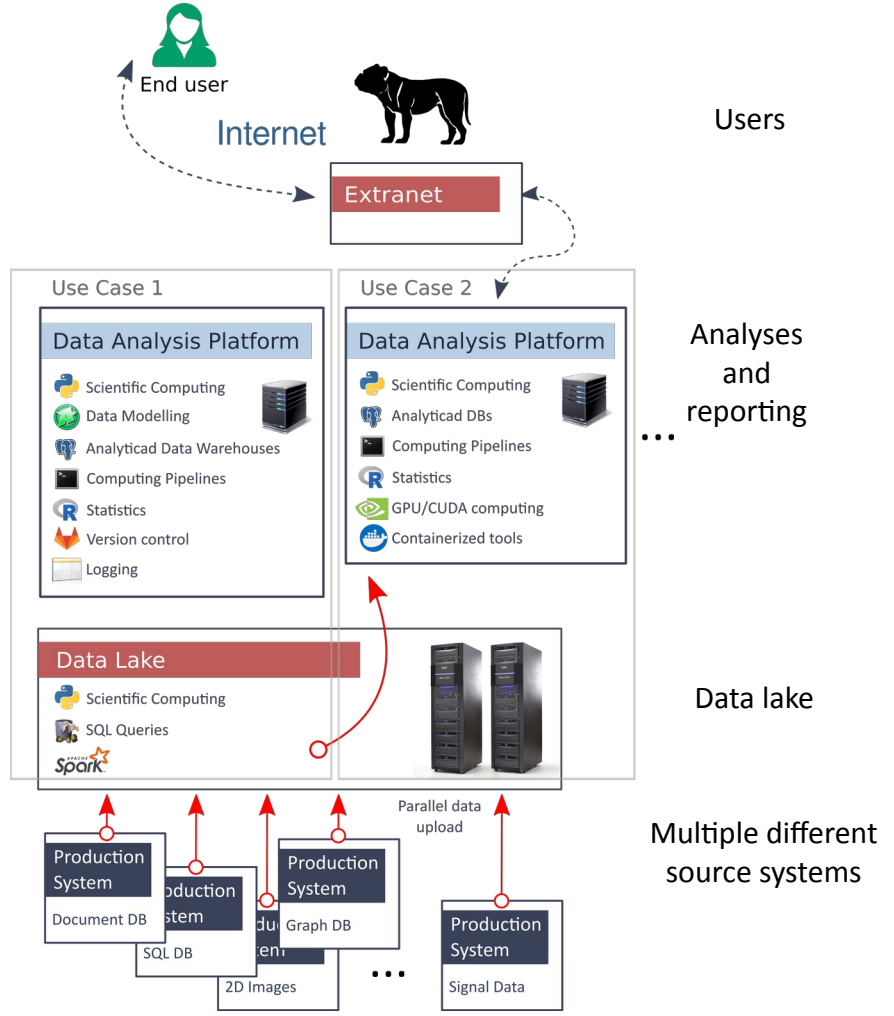


The Finnish way of using health data for the secondary purposes

Current practiceiis to combine data with a layered architecture, which consists of

1) Source systems
2) Centralized raw data lake
3) Different data warehouses (currently, one for reporting and other for scientific data extractions)
4) Utilization layers (e.g. reporting or Secure Data Platform, SDP, for science)



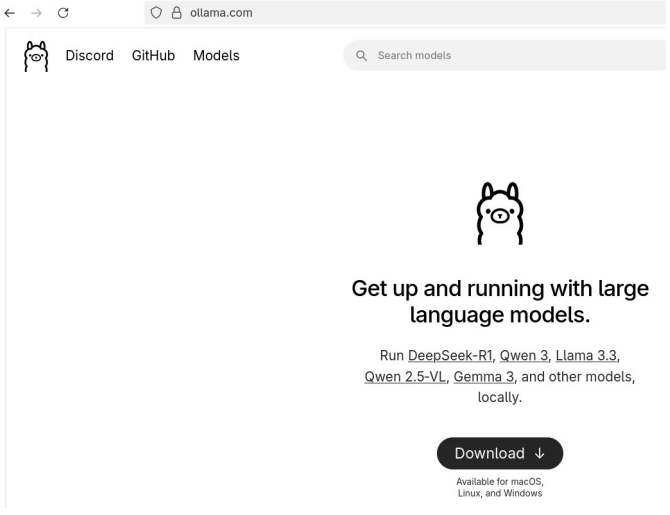


Current Data Infrastructure at Varha

In-house servers with some Azure cloud services for reporting (with aggregated, anonymous data)

Traditional data warehouse technology (SQL Server) for data-driven management and reporting

Free and open sourced (FOSS) solutions for scientific research, development and innovation purposes. => Mixture of traditional and well-established technologies (PostgreSQL and R language for data and Python for orchestration) with varying state-of-art tools, e.g., AI Large Language Models (LLMs) via Ollama and Hugging Face frameworks.



Current Data Infrastructure at Varha

Yes – In-house setup is possible.

At the moment, there seems to be rougly 25 TiB of categorical and text data in our analytical PostgreSQL data warehouse.

The problem of social and healcare data is not its sheer volume (e.g. it is not that Big Data), but its varying nature and usually free textual form.

```
$ df -h -x tmpfs -x devtmpfs
Filesystem                  Size  Used Avail Use% Mounted on
/dev/mapper/vg_sys-lv_root  207G   36G  171G  18% /
/dev/sda2                  1014M  319M  696M  32% /boot
/dev/sda1                   200M  6.9M  193M   4% /boot/efi
/dev/sdb1                    42T   25T   17T  60% /data
```

Auria Clinical Informatics Mission and Vision

Mission:

We support data-driven scientific research in healthcare, which contributes to better and more efficient future treatments and health services.

We provide insight and services for national and EU-level in

1) Scientific research,
2) Development activities,
3) Innovation work and
4) Education.

In 2025, we

- Embrace AI – in a sovereing way (open sourced models and local server hall)
- Develop Atolli Secure Processing Environment (SPE) towards AI and Federated Learning tasks
- Focus on external scientific funding for 2026 – 2028 to enable these goals

Vision:

- Digitalization and automation - including AI - will change society thoroughly during the next 30 years
- The data should be used for the best of the people. Thus, information security means that confidential health data *is secured to be available for scientific research and medical decision support* in legal and ethical way.
- The only way for Europe to stay relevant is to invest in in people and knowledge
- Digital Sovereignty, cost effectiveness and and future-proof IT-infrastructure is best ensured, at least in R&D, by using Free and Open Sourced Software (FOSS).

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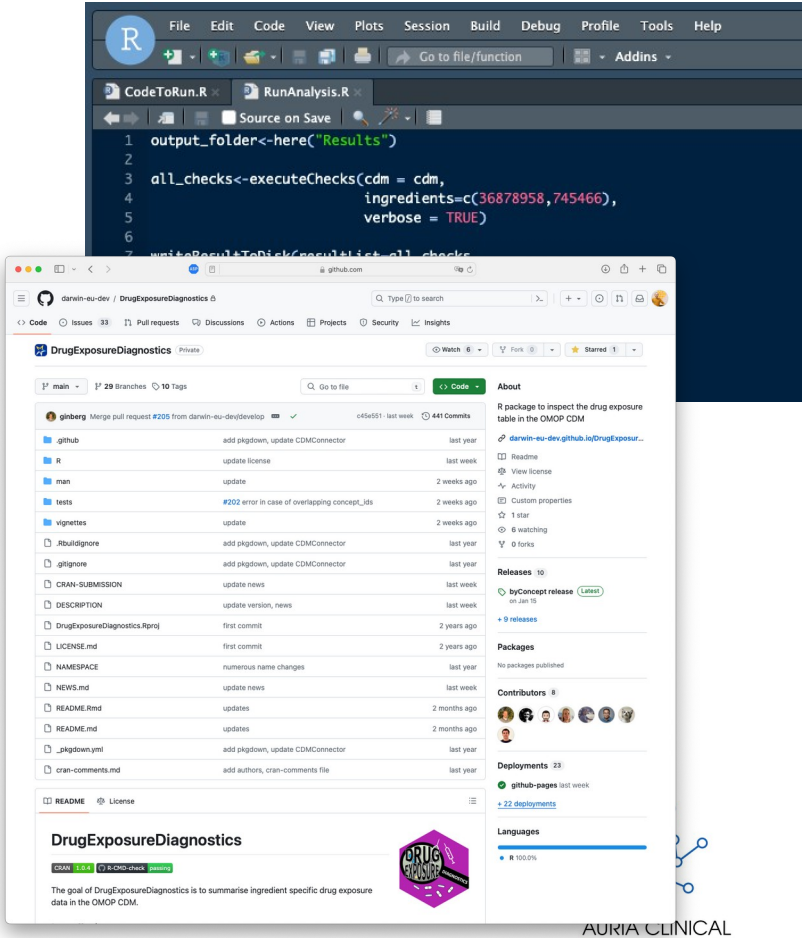
Auria Clinical Informatics Services

Auria Services:

- Data advisory service
- Secure data processing environment (SPE), Auria's Atolli, required by Finnish law
- Data extractions and processing in accordance with data permits granted by Findata and Varha (including cost estimates, advice on data permits)
- Project-funded biostatistical, data processing and scientific computing services
- Biostatistical analyses as contract research
- Data for regulatory clearances

Auria Clients:

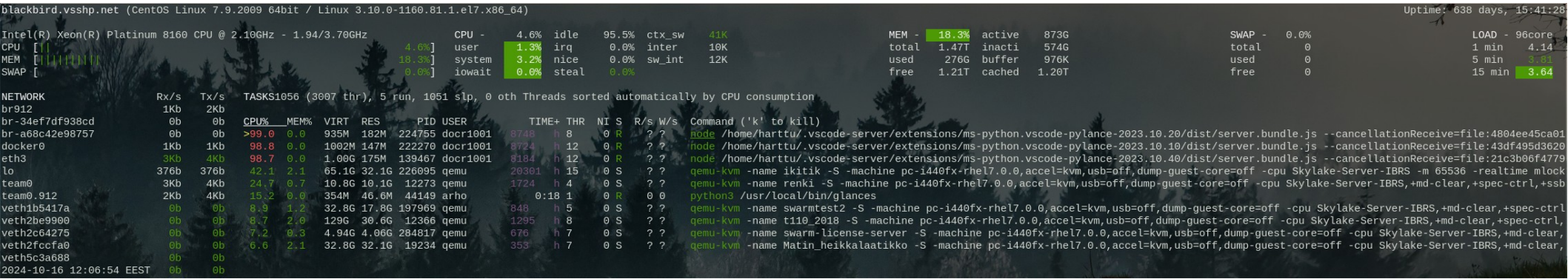
- Varha researchers and project personnel, Auria Biobank
- Academic researchers from outside Varha
- Pharmaceutical companies and clinical research organizations (CROs) serving pharmaceutical companies
- Public authorities such as Finnish Ministry of Social Affairs and Health, Finnish Institute for Health and Welfare and Findata
- Regulatory authorities such as Fimea and the European Medicines Agency EMA
- Consortiums and foundations, such as the EHDEN community formed around the international OMOP data model



AURIA CLINICAL INFORMATICS

In-House Knowledge:

- **Research services**: Understanding the needs of academic and commercial research and strong service expertise, which is reflected in the positive images associated with the customer and the Auria brand during the rapid response times
- **Data extractions**: High-quality formation of research material in accordance with the service request and research plan, as well as a broad understanding of the content and technical structure of the material. Excellent technical ability to develop knowledge-picking methods. Close and good contact with clinical experts at Varha and other registrars.
- **Data management**: Data technical chapter, aggregation, commensurability and code conversions (such as OMOP format) and quality assurance methods
- **Data analytics**: KPIs, methods of statistical reasoning and prediction (e.g., biostatistics of drug efficacy and safety evaluation) and nonparametric statistics, e.g., artificial intelligence applications (e.g., for the needs of research and development projects).
- **Scientific computing**: Audited secure processing environment Technologies required by atolls, such as applications of computer networks, servers, software and protocols, and cryptography. Technical security and high-performance computing applications, including GPU computing required by artificial intelligence.
- **Data protection**: In addition to technical and organizational security, statistical disclosure control methods such as knowledge of differential data protection and anonymization capabilities for different data. In-depth knowledge of Finnish data protection legislation and official position in its interpretation as part of data protection groups in secondary schools



Data Types

1.Numeric and categorical data and free text such as

Demographic variables, gender, date of birth, time of death, municipality of residence and address, hospital district, mother tongue, profession, days spent in the hospital (department, specialty, reason for admission, arrival and departure date), from and where the patient was transferred, IDC10-coded diagnoses, surgery information (anesthetics and doses), pathological diagnoses (topology and morphology), radiotherapy data, imaging studies (CT images, magnetic resonance images, PET images,...), neurophysiological studies, prescriptions and drugs administered in the hospital (brand name, active substance and dose), laboratory studies, nurses' and doctors' records, hospital infections, spirometry tests,...

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Data Types

2. Signal data such as

Intensive care unit biosignals (pulse, electrocardiogram, pain-indicating muscle tension signals,...), remote monitoring signals (pressure curve produced by the CPAP device and periods of apnea)

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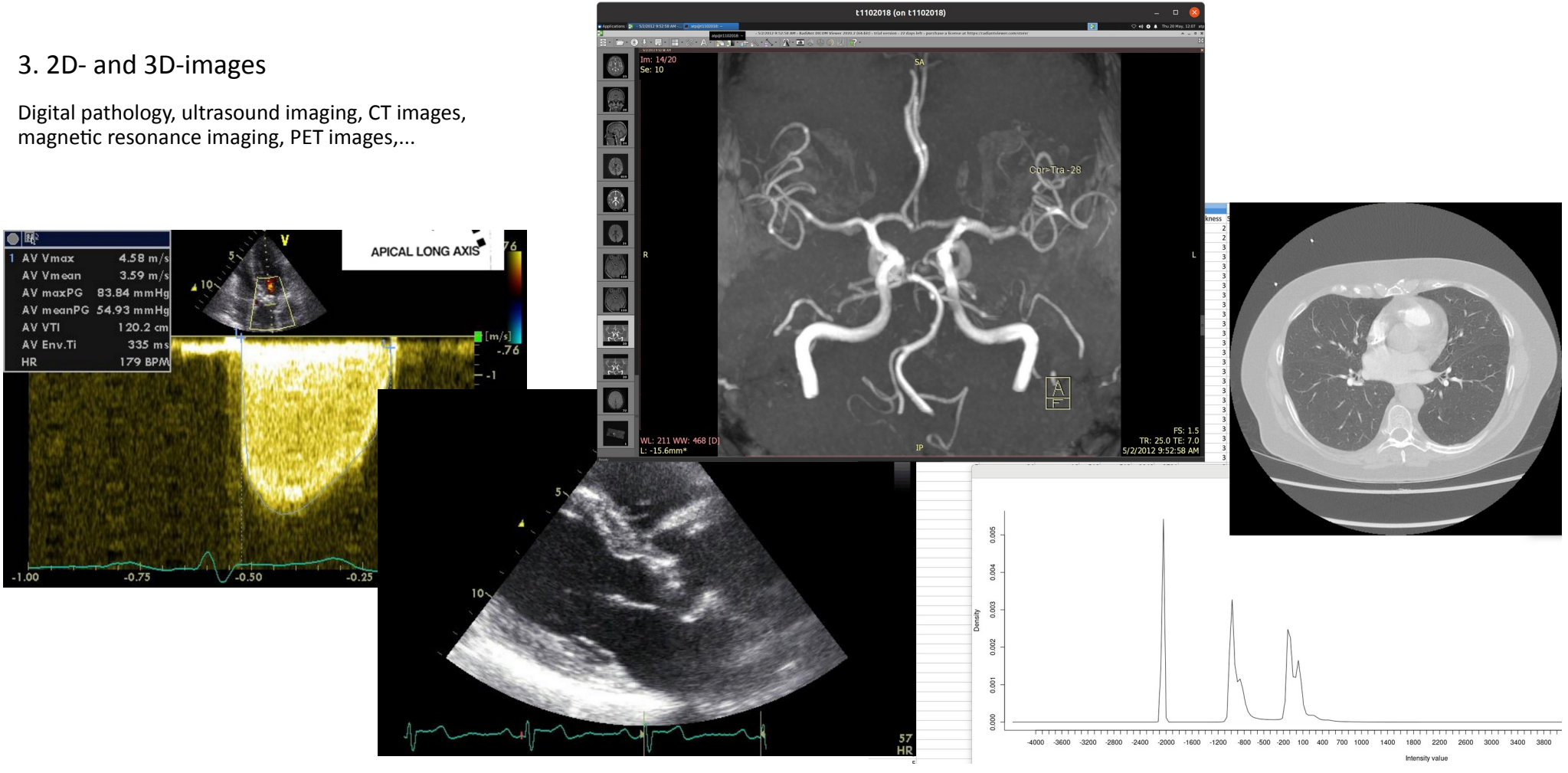
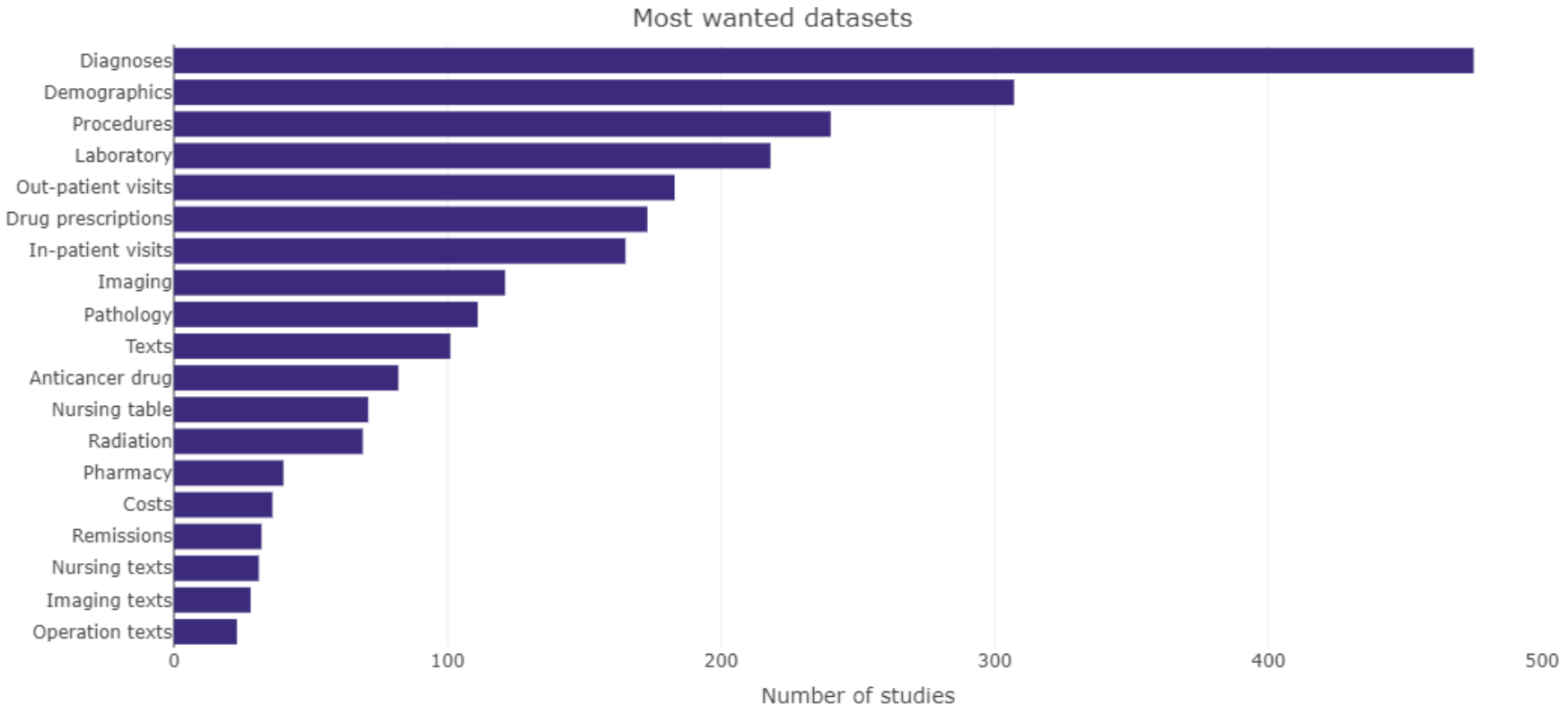
Data Types

3. 2D- and 3D-images

Digital pathology, ultrasound imaging, CT images, magnetic resonance imaging, PET images,...



The Most Frequently Used Data Types in Research



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Uses of Patient Data:

Typical Pharmaceutical Company-Oriented Studies

Need for real-life data	Research outcome	Beneficiaries
Understand the burden of disease and current treatment practices	Unmet medical need, the size of target population	Public authorities*, taxpayers, clinicians
Understard current healthcare costs	A health economic model of treatment effectiveness	Health technology assessment (HTA), payers
Assemble a control cohort for a clinical drug trial	Efficacy and safety information for the marketing authorization application	Marketing authorization authority
Show product efficacy and safety vs. clinical trials and alternative treatments	Real-world efficacy and safety information	Marketing authorization authority, clinicians
Show the actual cost effectiveness of the product	Evidence for the price and reimbursement application (or renewal).	Public authority
Shows the preliminary applicability of the product to other than the original target population/indication	Real-world efficacy and safety information outside the original target group	Public authority, payers Marketing authorization authority, Clinicians

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Secure Processing Environment (SPE) Auria Atolli

Features
- Linux operating system
- Browser-based remote desktop (independent of client machine, no plugins or client software needed)
- Easily customizable to most needs, often installed additional programs SPSS and SAS
- Atoll website (standard software, machine packages, price lists): https://www.auria.fi/tietopalvelu/en/atolli/index.html

User Statistics:
- Environments ordered in total 51
- Total number of users about 200

Terms and Conditions:
- A data permit under secondary law must be valid
- The service is paid

Contact persons:
- Research material advice: tutkimuksentietopalvelut@varha.fi
- Product owner: Service Manager Annika Pirnes, annika.pirnes@varha.fi
- Responsible officer: Arho Virkki, Director of Analytics, arho.virkki@varha.fi

varha

ATOLLI

AURIA CLINICAL INFORMATICS

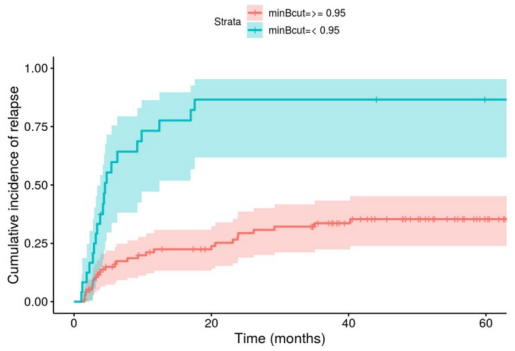
Atolli’s Audit

Some pictures taken on 2022-09-28 at the Turku University Hospital during Atolli service audit by KPMG

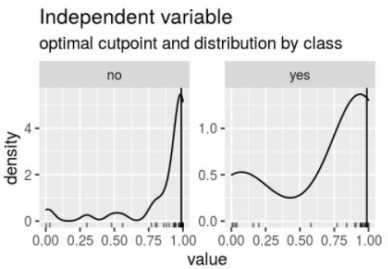
Atolli supports both traditional and modern statistics

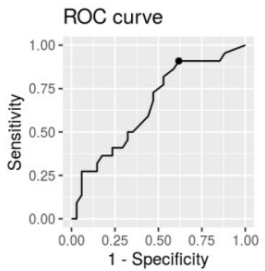
Relapse	no (N=73)	yes (N=49)	Overall (N=122)
Gender			
female	28.0 (38.4%)	25.0 (51.0%)	53.0 (43.4%)
male	45.0 (61.6%)	24.0 (49.0%)	69.0 (56.6%)
Age at transplantation (years)			
Median (Q1, Q3)	53.0 (42.0, 60.0)	57.0 (46.0, 62.0)	55.0 (43.0, 61.0)
Min, Max	19.0, 69.0	23.0, 68.0	19.0, 69.0
Diagnosis class			
g1	30.0 (41.1%)	29.0 (59.2%)	59.0 (48.4%)
g2	7.00 (9.6%)	5.00 (10.2%)	12.0 (9.8%)
g3	5.00 (6.8%)	3.00 (6.1%)	8.00 (6.6%)
g4	31.0 (42.5%)	12.0 (24.5%)	43.0 (35.2%)
Donor			
mud	59.0 (80.8%)	36.0 (73.5%)	95.0 (77.9%)
sibling	14.0 (19.2%)	13.0 (26.5%)	27.0 (22.1%)
Graft source			
blood	64.0 (87.7%)	46.0 (93.9%)	110 (90.2%)
bone marrow	9.00 (12.3%)	3.00 (6.1%)	12.0 (9.8%)
Graft cell count			
Median (Q1, Q3)	6.00 (4.29, 9.20)	6.48 (4.70, 8.76)	6.34 (4.70, 9.09)
Min, Max	0.750, 15.6	1.00, 13.5	0.750, 15.6
Missing	2.00 (2.7%)	0 (0%)	2.00 (1.6%)
Condition regimen			
MAC	26.0 (35.3%)	14.0 (28.6%)	40.0 (32.8%)
RIC	34.0 (46.3%)	22.0 (44.9%)	56.0 (45.9%)
sequential	13.0 (17.8%)	13.0 (26.5%)	26.0 (21.3%)
DRI stage			
high	21.0 (28.8%)	18.0 (36.7%)	39.0 (32.0%)
low	52.0 (71.2%)	31.0 (63.3%)	83.0 (68.0%)
EBMT risk score			
Median (Q1, Q3)	4.00 (3.00, 5.00)	3.00 (3.00, 5.00)	4.00 (3.00, 5.00)
Min, Max	1.00, 6.00	1.00, 6.00	1.00, 6.00

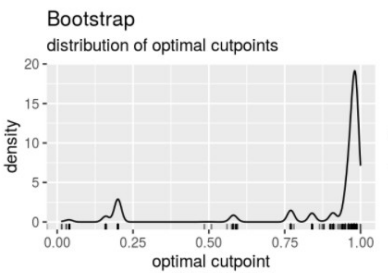
Minimum B all

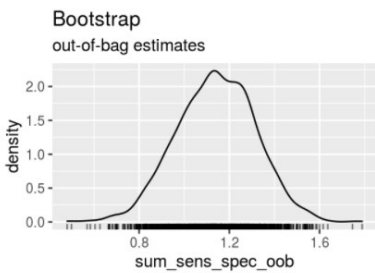



```
Median survival with 95% CI

median lower  upper
[1,] "minBcut=>= 0.95" "NA"   "NA"   "NA"
[2,] "minBcut=< 0.95"  "4.50" "3.80" "12.42"

Log-rank test

Call:
survdiff(formula = Surv(relapsetime, relapse_stat) ~ minBcut,
data = analysisdata)

N Observed Expected (O-E)^2/E (O-E)^2/V
minBcut=>= 0.95 99       29  42.4821    4.2787    32.913
minBcut=< 0.95  24       20   6.5179   27.8871    32.913

Chisq= 32.9  on 1 degrees of freedom, p= 9.64e-09
```









AURIA CLINICAL INFORMATICS

Some Ongoing Projects

PHASE IV AI

EU Project number: 101095384
Project name: Privacy Compliant Health Data As A Service For AI Development
Call: HORIZON-HLTH-2022-IND-13

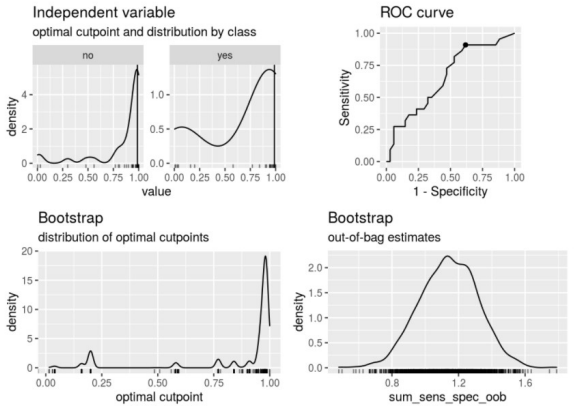
HealthHub Finland EDIH

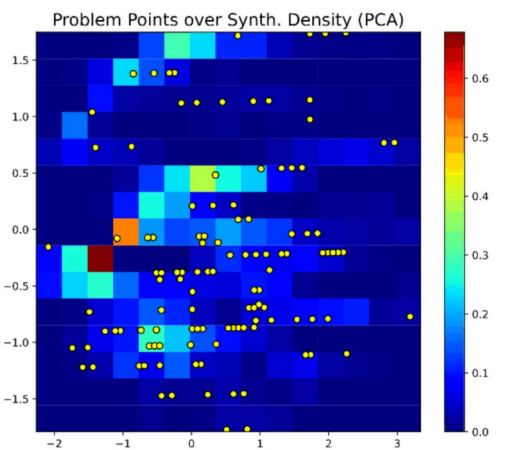
EU Project number: 101083544
Project name: HealthHub Finland - the future of Healthcare shaped by a Hub of partners facilitating data-driven digital solutions in Finland and Europe
Project acronym: HHFIN
Call: DIGITAL-2021-EDIH-01
Topic: DIGITAL-2021-EDIH-INITIAL-01

The test platform for synthetic health data supports new kinds of research, development, and innovation activities. The project is carried out by the University of Turku, Turku University of Applied Sciences, Southwest Finland Welfare Area and Business Turku.

The project is co-funded by the European Union. The project is funded by the Regional Council of Southwest Finland under the European Regional Development Fund (ERDF) Programme for Regional and Structural Policy 20212027. The authority supervising the funding is the Uusimaa Regional Council

Examples of Research





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Min, Max	0.750, 15.6	1.00, 13.5	0.750, 15.6
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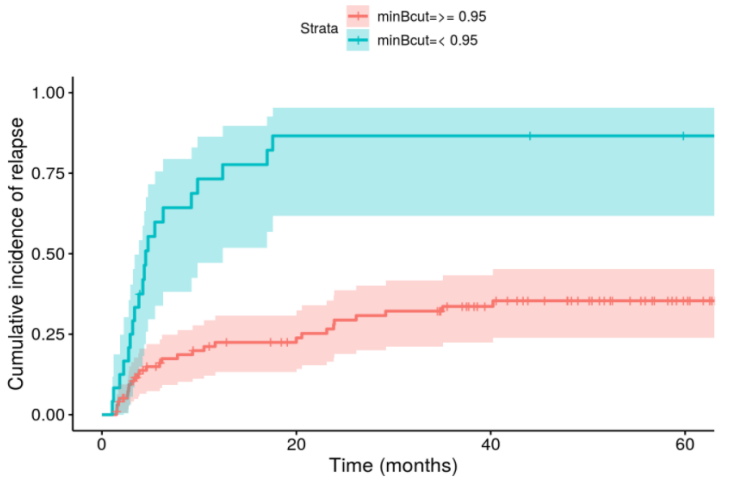
Min, Max	1.00, 6.00	1.00, 6.00	1.00, 6.00

Minimum B all




```
Median survival with 95% CI

median lower  upper
[1,] "minBcut=>= 0.95" "NA"   "NA"   "NA"
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Log-rank test

Call:
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minBcut=>= 0.95 99       29  42.4821    4.2787    32.913
minBcut=< 0.95  24       20   6.5179   27.8871    32.913

Chisq= 32.9  on 1 degrees of freedom, p= 9.64e-09
```
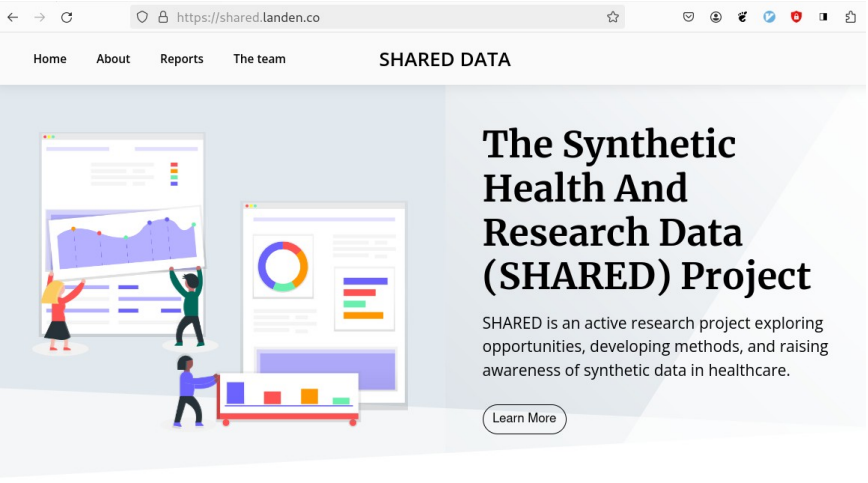

Examples of Research



Differentiaalin yksityisyyden määritelmä.

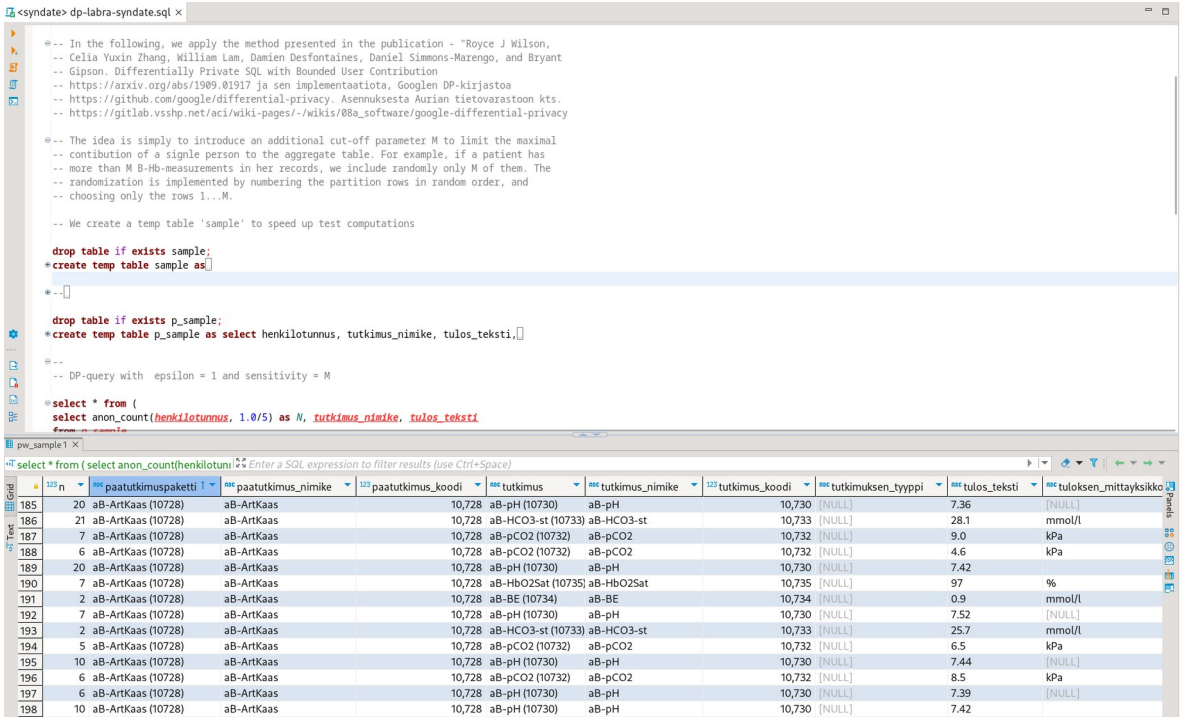
Olkoon ε ja δ valittu. Mikäli kaikilla $x, y \in \mathcal{D}$, $\|x - y\| \leq 1$ ja $\mathcal{S} \in \mathrm{Range}(\mathcal{M})$ pätee, että

$$\underbrace{P(\mathcal{M}(x) \in \mathcal{S})}_{\substack{\text{vastausten } \mathcal{S} \\ \text{osuus kannasta } x}} \leq e^{\varepsilon} \underbrace{P(\mathcal{M}(y) \in \mathcal{S})}_{\substack{\text{vastausten } \mathcal{S} \\ \text{osuus kannasta } y}} + \delta$$

niin silloin $\mathcal{M}$ on (ε, δ)-differentiaalisesti yksityinen. Jos $\delta = 0$, niin $\mathcal{M}$ on ε -differentiaalisesti yksityinen.

Määritelmä on helpompi ymmärtää asettamalla lievennysparametri $\delta = 0$ ja kirjoittamalla epäyhtälö prosessin $\mathcal{M}$ tuottamien vastausten suhteen rajoituksena silloin, jos tietokannat eroavat vain yhden askeleen verran: Mielivaltaiselle vastausten osajoukolle $\mathcal{S}$ pätee, että todennäköisyyksien

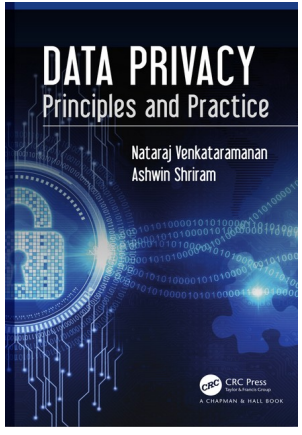
$$\text{suhteellinen ero } \frac{P(\mathcal{M}(x) \in \mathcal{S})}{P(\mathcal{M}(y) \in \mathcal{S})} \leq e^{\varepsilon} = \text{kiinteä raja, esim. } e^{\varepsilon} = \frac{3}{2}.$$

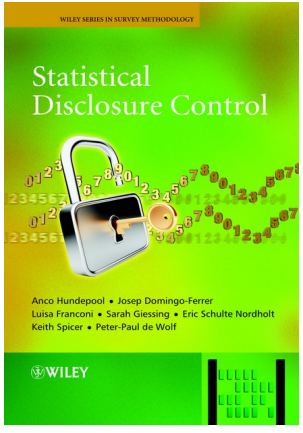


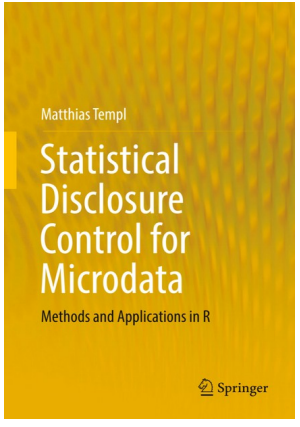
The Fundamentals of Data Protection

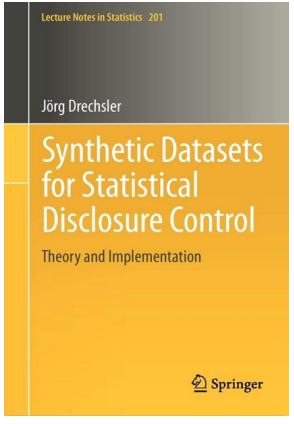
Four levels of data protection:

1) Laws and contracts (legal uses, licenses, terms and conditions)
2) Organizatorial data management rules (data access control and logging, standard operational procedures)
3) Cybersecurity (data encryption, user identification and authentication, digital key and certificate management)
4) **Statistical Disclosure Control** (different data anonymization methods)









There are many books written about Statistical Disclosure Control, but I personally suggest reading the introductory section of Damien Desfontaines PhD Thesis “Lowering the cost of anonymization” (2020) available at: https://desfontain.es/thesis/

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Protecting Sensitive Unit-Level Data

Personal information

1. **Original data:** Individual, up-to-date personal information directly from the source systems
2. **De-identified data:** Data protected with pseudonym. Direct identifiers, such as personal identification numbers are changed to codes (e.g. P001, P002, P003...)
3. **Non-anonymous synthetic data:** Bootstrap re-sampling, non-anonymous GAN models,...

Not personal information

Residual risk

4. **Anonymous synthetic data:** Data which is (i) derived from real data, is (ii) anonymized and (iii) has similar statistical properties with the original real data.
5. **Anonymous data:** De-identified (and possibly otherwise processed data) from which it is practically impossible to re-identify the person behind a given record. The identification key has also been disposed of. If the id-mapping table is stored, we call the data - according to GDPR - **pseudonymous**.

No residual risk

6. **Simulated data:** Data generated from a mathematical model (such as a mechanistic differential equation) with statistical properties similar to the real one. (e.g. Covid 19 pandemic forecasts)
7. **Fabricated data:** E.g. correctly formatted email addresses and personal IDs for software testing. No statistical predictive power.

See also the Finnish Ministry of Social Affairs and Health pages for the Anonymisation and anonymity of image and signal data written by the related expert group on data protection (https://stm.fi/en/secondary-use-of-health-and-social-data).

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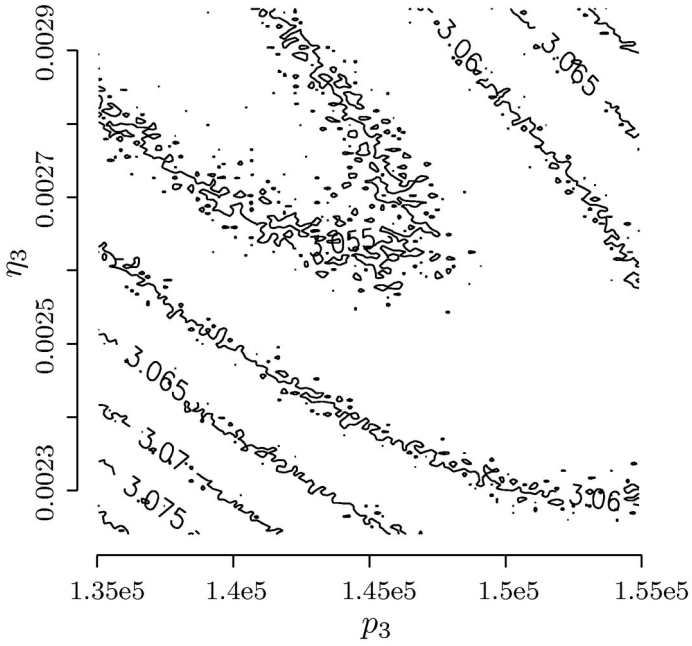
Contemporary Methods for Data Protection

1. **Employ meta-analyses** (i.e. combine data on aggregated, statistical level). Not always an option – especially if we need to match individual row data to compute the statistics.
2. **Copy data to one trusted register keeper** or public authority, such as Findata, and apply strict security policy on data access.
3. **Anonymize data before release.** Unfortunately, this usually implies the removal and heavy aggregation of attributes or adding lots of noise.



Simulated data with artificial noise for algorithm testing.

Future Trends?

- **Federated Computing.** Distributed data, unified computing.
- **Synthetic Data.** Finds ways to generate realistic, but completely artificial data through non-parametric statistical modelling

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Motivation for Anonymous Synthetic Data

Real data might be unavailable, because

- the use case is incompatible with the security requirements, or
- the data does not exist yet.

In the absence of real data, one can *fabricate data*, for example by running a dynamical simulation model.

Fabricated data makes sense in ICT development, where e.g. user interfaces need to be tested with realistic-looking prototype data.

Nonetheless, e.g. for hackathons, we need more realistic data.

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Data Anonymization Methods

varha

According to Damien Defontaines [1], data protection methods can be divided into *syntactic* and *semantic* methods.

1) **Syntactic methods:** Use minimum frequencies (k-anonymity) and other metrics like l-diversity and masking to protect the individual records
2) **Semantic methods:** Use Differential Privacy or other methods that concentrate on the *anonymity of the data generation process* (e.g. database query), not on a particular output.

Syntactic methods are rather easy to understand and apply (similar to Bohr's atomic model in chemistry), but they suffer from certain paradoxes if scrutinized further. For example, we might get records that match real living (or yet unborn) people just by running a simulator or using a simple random number generator. This dilemma is solved by requiring that instead of concentrating the output, the *process of data generation* should guarantee anonymity.

Unfortunately, Differential Privacy (the quantum mechanics of anonymization?) is not an explicit algorithm, but a criterion. One still needs to invent algorithm that satisfy DP, such as frequency counts.

[1] See Damien Desfontaines, Lowering the cost of anonymization, 2020, ETH Zurich. PhD Thesis (https://desfontain.es/thesis/)

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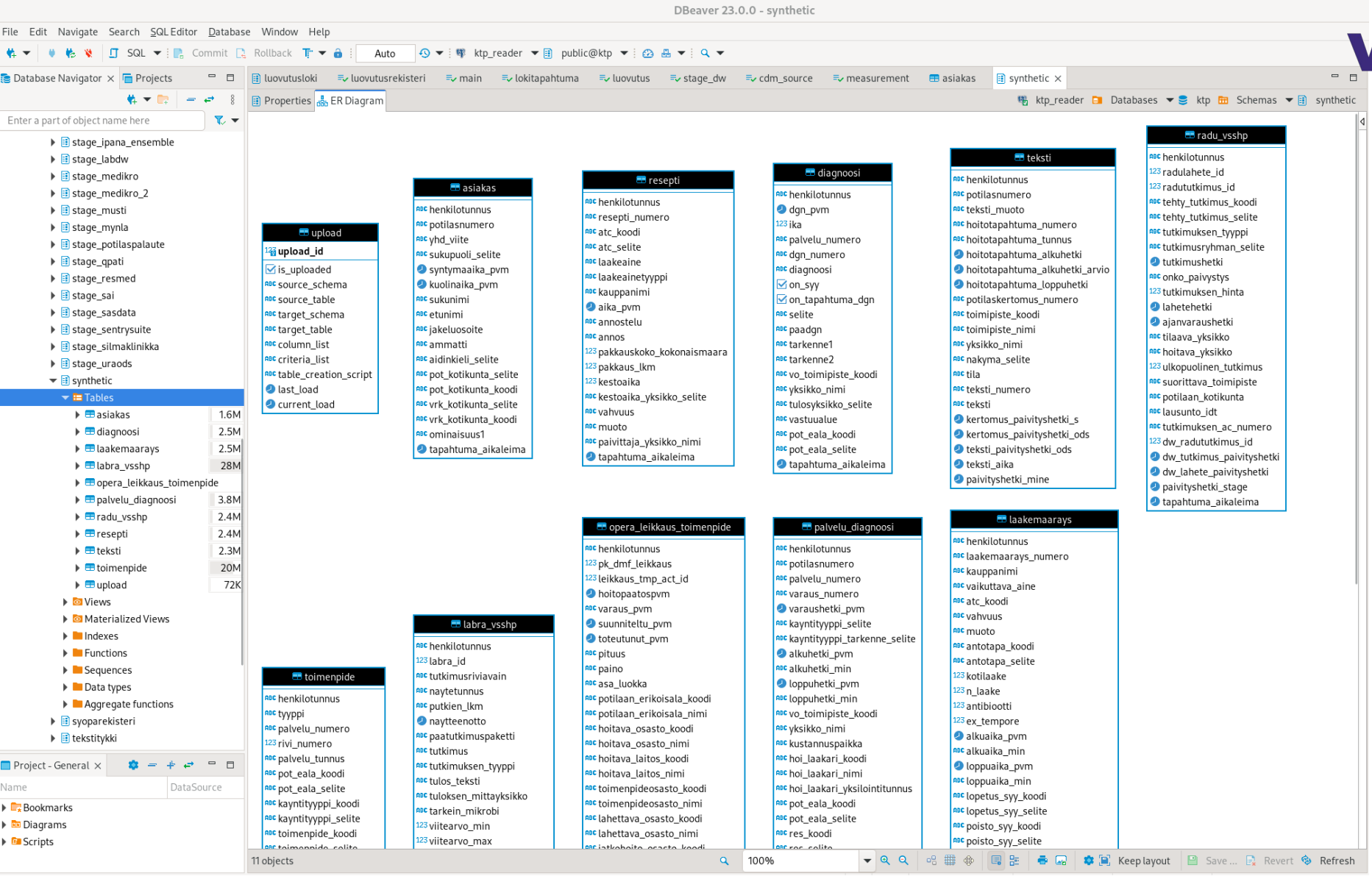
Examples of Synthetic Data

	A	B	C	D	E	F	G	H	
1	henkilotunnus	resepti_numero	atc_koodi	atc_selite	laakeaine	laakeainetyyppi	kauppanimi	aika_pvm	annostelu
2	191245-W0FM	948464332322635478	B01AB05	Enoksapariini	enoksaparііininatrium	vaikuttava_aine	KLEXANE	25.11.2014	1 tabletti 3 kertaa vuorokaudessa 7 vrk ajan. Antibiootti.
3	211071-ER4K	016062498022959001	L02BA01	Tamoksifeeni	tamoksifeenisitraatti	vaikuttava_aine	TAMOFEN	14.3.2017	1 tabletti päivässä
4	221147-1NWV	516297952406825298	M01AE01	Ibuprofeeni	ibuprofeeni	vaikuttava_aine	BURANA	24.11.2013	1 tabletti x1-3.
5	220246-XJAW	390581673860859896	M01AE01	Ibuprofeeni	ibuprofeeni	vaikuttava_aine	BURANA	12.5.2015	1 - 2 annosta aamuin illoin, suu huuhdotaan lääkkeen oton jälkeen
6	160536-Y98T	468936691601333898	S01XA20	Keinokyyneleet ja muut luokittelemattomat valmisteet	hypromelloosi	vaikuttava_aine	HYPROSAN	5.4.2016	1 tabletti tarvittaessa 1-3 kertaa vuorokaudessa.
7	260378-ATDY	934646845134571086	D10BA01		isotretinoiini	vaikuttava_aine	ISOTRETINOIN ACTAVI	23.1.2014	2 tabl iltaisin
8	221254-GIQ6	703892520511949149	M01AE01	Ibuprofeeni	ibuprofeeni	vaikuttava_aine	BURANA	15.7.2015	1 tabletti aamuisin.
9	040579-8CZN	252222573573643988	J07AL02	Pneumokokkikonjugaattirokote	pneumokokkipolysakkaridi, konjugoitu	vaikuttava_aine	PREVENAR 13	10.6.2013	1*3 tarv. särkyyn.
10	060960-9XP1	376039765490494225	J01CE02	Fenoksimetyylipenisilliini	fenoksimetyylipenisilliinikalium	vaikuttava_aine	V-PEN 1500	20.4.2016	1 tabl. 2:sti päivässä tulehduksen hoitoon.
11	190646-WOV3	055494077593879689	A04AA02	Granisetroni	granisetronihydrokloridi	vaikuttava_aine	GRANISETRON STADA	14.9.2014	1annos aamuin illoin astmaan. Pahenemisvaiheissa 2+2 1-2 viikkoa.
12	241228-TV8R	590469795430918820	H03AA01		levotyroksiininatrium vastaten levotyroksiinia	vaikuttava_aine	THYROXIN	27.5.2017	1 tabl tarv. 1-3 kertaa päivässä. Kipulääke.
13	180690-9TSM	292077063455582840			MELATONIN, melatoniini, 3 mg, -	muu_laake_tiedot		13.2.2013	1 tabl iltaisin. Mielialalääke.
14	300953-SU8H	152904720270561320	H02AB06	Prednisoloni	prednisoloni	vaikuttava_aine	PREDNISOLON	7.6.2013	1 tabletti kerran päivässä.
15	250296-Y52F	769604541680079562	C07AB07	Bisoprololi	bisoprololifumaraatti	vaikuttava_aine	BISOPROLOL RATIOPH	29.8.2016	4 ml injektio lihakseen 12 viikon välein.
16	180489-1GJN	049970884043963441	R05FA02	Opiumjohdokset ja ekspektorantit, lukuun ottamatta m	kodeiinifosfaattihemihydraatti,efedriinihydrokloridi,dit	vaikuttava_aine	CODESAN COMP	10.7.2015	1 tabl tarvittaessa kerran päivässä
17	270462-8FHK	969806661300809769	M01AE01	Ibuprofeeni	ibuprofeeni	vaikuttava_aine	BURANA	25.11.2014	D.S. 1 annos mol. sieraimeen 1-2:sti päivässä. Tukkoisuuteen.
18	220334-A56K	284347271920969936	G03GA05	Follitropiinialfa	follitropiini alfa	vaikuttava_aine	GONAL-F	17.9.2012	1 tbl 1-3 kertaa vrk:ssa kipuun.
19	240928-F2MA	615408308811748728	R06AE09		levosetiritsiinidihydrokloridi	vaikuttava_aine	XYZAL	10.12.2012	1 tabletti 2 kertaa päivässä.
20	270597-DYZA	996839916211359869	S01BA04		prednisoloniasetaatti	vaikuttava_aine	PRED FORTE	29.10.2015	1 tabletti kerran päivässä
21	031228-P947	470962128725546216	M01AB05		diklofenaakkinatrium	vaikuttava_aine	MOTIFENE DUAL	31.1.2013	1 tabl 1-2 kertaa päivässä, pahoinvoinnin hoitoon. Ja ohjeen mukaan sy
22	211173-ZC9S	511785582179482718	N06BA04	Metyylifenidaatti	metyylifenidaattihydrokloridi	vaikuttava_aine	CONCERTA	10.6.2017	Erillinen ohje, keltarauhashormoni
23	180673-CVBU	070559495848135649	M01AE01	Ibuprofeeni	ibuprofeeni	vaikuttava_aine	BURANA	2.6.2017	1 tabl 1-3sti päivässä särkylääke
24	101064-JTAR	101304519953659541	C10AA01		simvastatiini	vaikuttava_aine	SIMVASTATIN ACTAVIS	3.6.2011	1 tabl tarv 3x/pv kipuun
25	080336-UEF8	085731549209808924	L02AE02	Leuproreliini	leuproreliiniasetaatti	vaikuttava_aine	ENANTON DEPOT DUA	9.1.2016	1 pussi/vrk
26	040152-MR3H	790250060740349210	C07AB02		metoprololi	vaikuttava_aine	SPESICOR DOS	11.2.2017	Yksi tabletti kerran päivässä
27	150693-OBTY	345439526087897692	A02BC02		pantopratsolinatriumseskvihydraatti	vaikuttava_aine	SOMAC	23.8.2012	1 tabl päivässä diabeteslääke
28	171077-TMX8	802194387744663500	N05AN01	Litium	litiumkarbonaatti	vaikuttava_aine	LITO	30.10.2016	1 tabletti x1. kahdesti vuodessa kuukauden tauko.
29	290359-1EAK	960209612536429827	N06AB10	Essitalopraami	essitalopraamioksalaatti	vaikuttava_aine	ESCITALOPRAM ORION	1.12.2014	D.S. Kipulääke1 tabletti kaksi kertaa päivässä 5 päivääTämän jälkeen 1 ta
30	260735-2NBH	209913678314706540	A02BC02		pantopratsoli	vaikuttava_aine	PANTOPRAZOL ACTAV	7.11.2014	1 tabletti 1-3 kertaa päivässä tarvittaessa kipuun.
31	110988-FZ7X	197178901574453114	N02AA05	Oksikodoni	oksikodonihydrokloridi	vaikuttava_aine	OXYNORM	9.5.2011	1 tabletti 3 kertaa päivässä 5 päivän ajan.
32	080553-XAJI	074706311575004863	H02AB06	Prednisoloni	prednisoloni	vaikuttava_aine	PREDNISOLON	21.8.2015	1 tabl 3 kertaa päivässä divertikuliittiin. Kuuri loppuun
33	180178-4GBX	843818990382363714			AQUALAN	kauppanimi	AQUALAN	12.6.2014	D.s. 1 tabletti 2 kertaa viikossa emättimeen, paikallinen estrogeenihoito
34	180259-UW69	241336540479470602			Tabl Acid Folic 5 mg	muu_laake_tiedot		13.8.2014	1x2.
35	160706AXKBE	037628154449967810	M01AE01	Ibuprofeeni	ibuprofeeni	vaikuttava_aine	BURANA	14.3.2016	1 tabl 1-3 kertaa päivässä tarvittaessa kipuun
36	020435-V1KC	284817460573826452	N02BE01	Parasetamoli	parasetamoli	vaikuttava_aine	PANADOL FORTE	13.7.2013	1 tabletti tarvittaessa 3 kertaa päivässä
37	251255-DC5I	989378565818591659	N07XX09	Dimetyylifumaraatti	dimetyylifumaraatti	vaikuttava_aine	TECFIDERA	3.4.2017	DS. 1 tabl tarvittaessa 4x/vrk särkyyn
38	120949-MACI	117072610705513568	S01CA01		deksametasoni,kloramfenikoli	vaikuttava_aine	OFTAN DEXA-CHLORA	13.3.2015	1 tabletti 1-3 kertaa päivässä tarvittaessa kipuun.

resepti | toimenpide | laakemaarays | opera_leikkaus_toimenpide | radu_vsshp | palvelu_diagnoosi | diagnoosi | teksti | asiakas | labra_vs ...



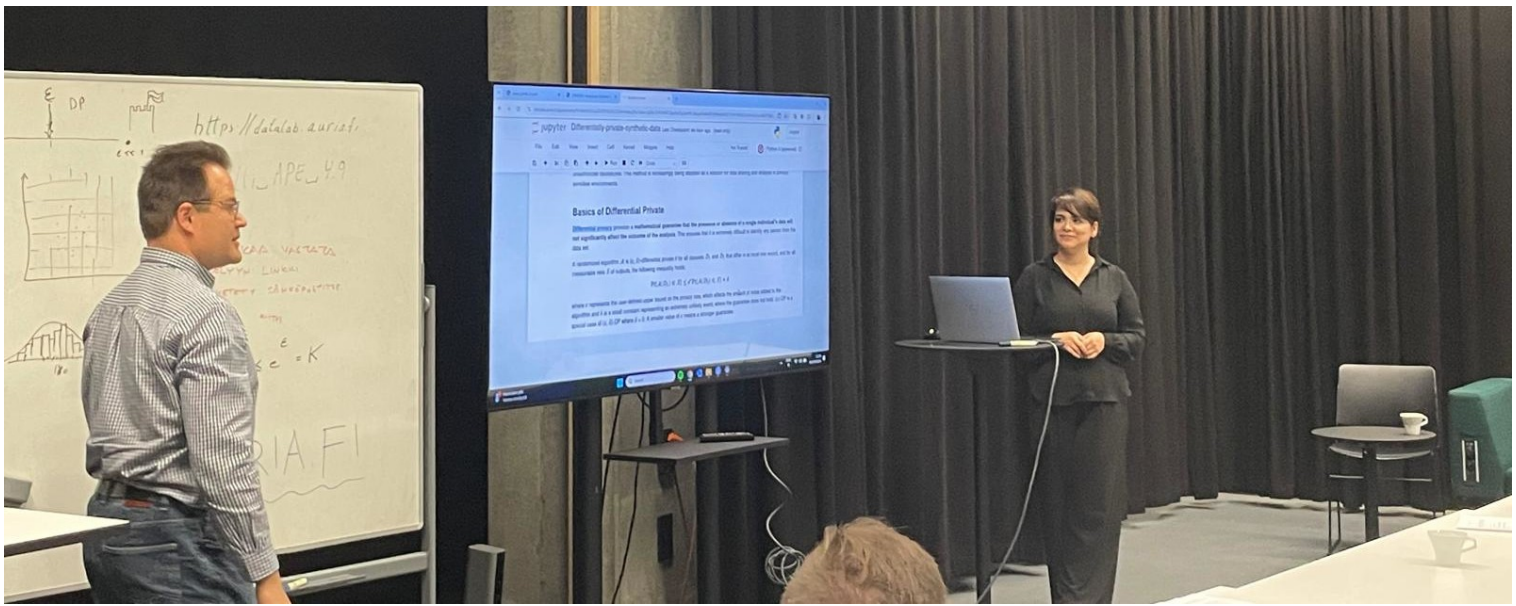
varha

AURIA CLINICAL INFORMATICS

How to Produce Anonymous Synthetic Data

Differential Privacy (DP) is the only “bulletproof” anonymization method with a rigorous mathematical proof, but it is hard to apply (beyond frequency counts).

1) For tabular data sets (e.g. with fixed measurement time), DP frequency count can be used
2) For longitudinal data set (e.g. time series), DP is not readily applicable, but other syntactic methods exist



2) E.g. Brandon Theodorou, Cao Xiao & Jimeng Sun. Synthesize high-dimensional longitudinal electronic health records via hierarchical autoregressive language model. *Nature Communications* volume 14, Article number: 5305 (2023) https://www.nature.com/articles/s41467-023-41093-0

1) Image from Syndate project workshop for companies on Wed 2024-09-04 at Educity Turku. Parisa Movahedi (right) is presenting AIM (An Adaptive and Iterative Mechanism for Differentially Private Synthetic Data), which is a synthetic data generation method based on DP, marginal distributions and noisy frequency counts.

AURIA CLINICAL INFORMATICS

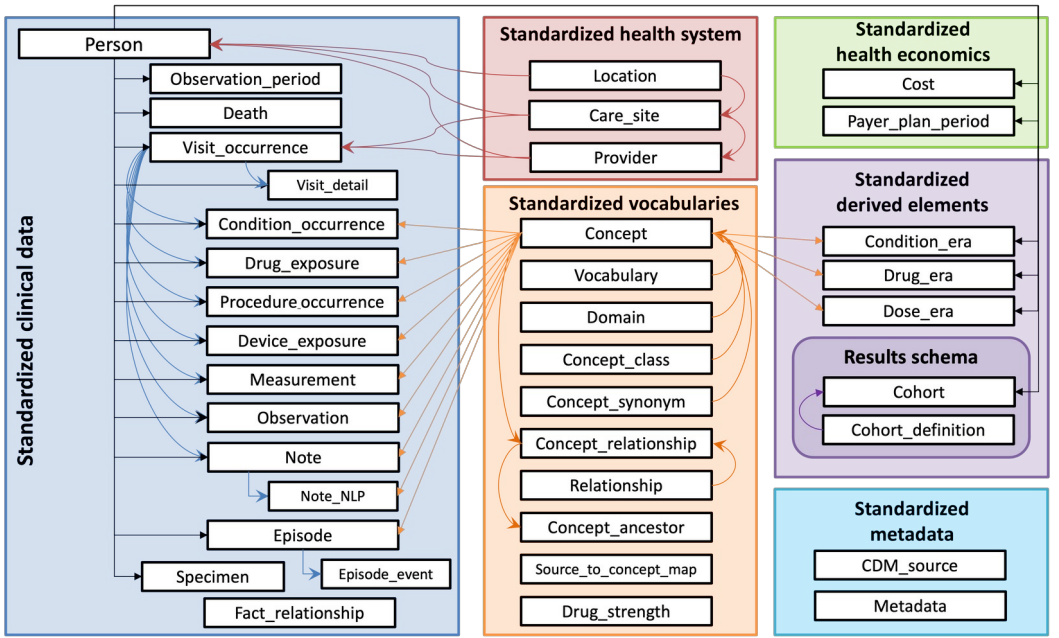
Data Modelling: OMOP Common Data Model

OMOP: Observational Medical Outcomes Partnership.

Was a public-private partnership that was set up to produce information on the use of health care databases to study the effects of medicines.

OMOP CDM: Observational Medical Outcomes Partnership Common Data Model.

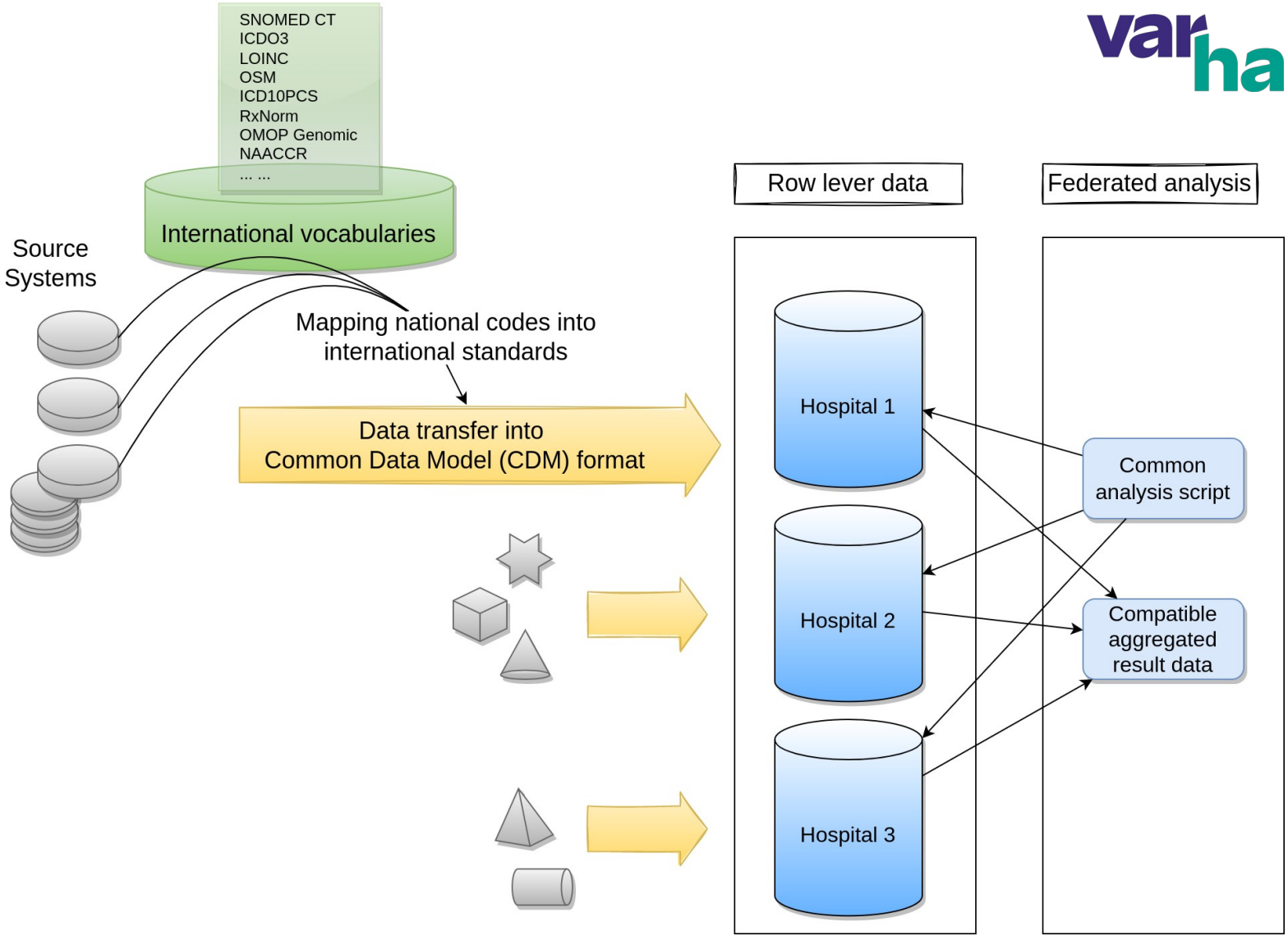
An open community data standard designed to standardize the structure and content of observational data and to enable effective analyses that can produce reliable evidence.



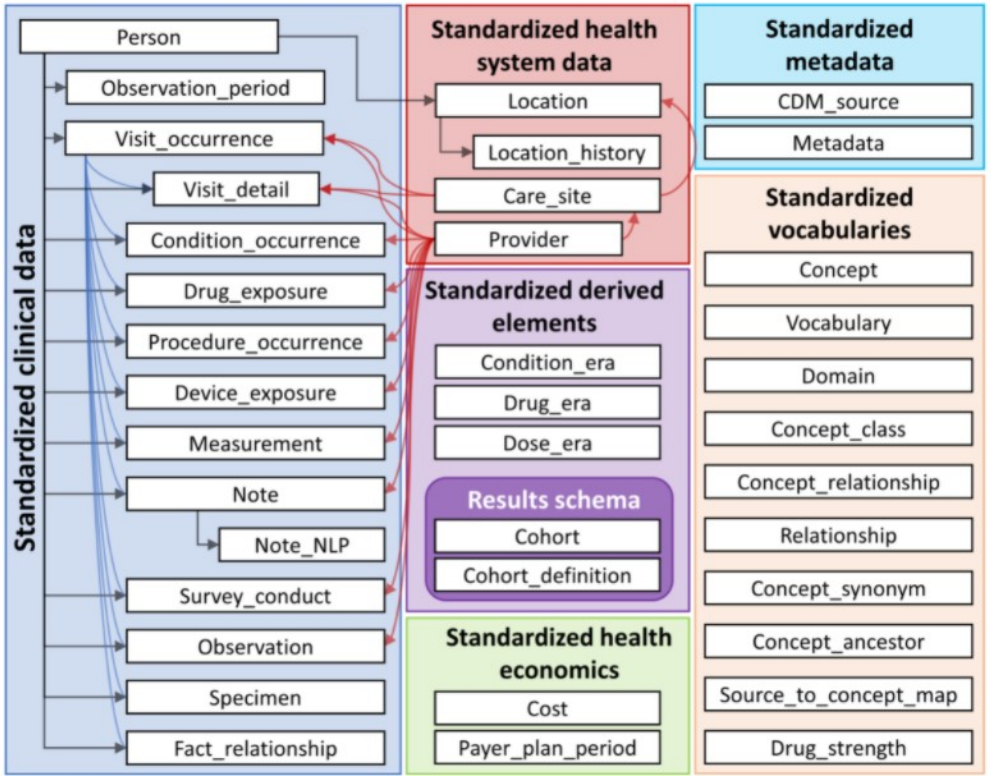
FinOMOP: In 2021, a collaboration of researchers in Finland launched an initiative to create the FinOMOP vocabulary and data model. All university hospitals, the FinnGen study (FIMM, University of Helsinki) and THL participated in it. The work has been funded as EHDEN (European Health Data Evidence Network) projects, and there have also been Finnish small and medium-sized enterprises that have received the EHDEN funding and certificate.

AURIA CLINICAL INFORMATICS

OMOP CDM in Brief



Common Data Model Schema Overview



- The schema is patient-centric (all outcomes are linked to a person)
- Fits well to hospital data, since the model includes all essential conceps

Visit_occurrence	Käynti tai osastohoito
Condition_occurrence	Diagnoosi (kliininen tai patologinen)
Drug_exposure	Lääkitys (määrätty tai annettu)
Procedure_occurrence	Toimenpide
Device_exposure	Laite tai apuväline
Measurement	Laboratoriomittaus
Observation	Muunlainen havainto

Detailed description: https://ohdsi.github.io/CommonDataModel/cdm53.html

Data Quality Control

- OHDSI provides several (partially overlapping) tools for quality control, such as
- Data Quality Dashboard, Achilles, CDM Inspection
- These tools can detect
  - Mapping coverage
  - Reference inconsistencies (e.g. diagnoses that do not appear in visit_occurrence table)
  - Infeasible values (e.g. occurrencies before birth, male diseases in women, impossible laboratory values)

DATA QUALITY ASSESSMENT

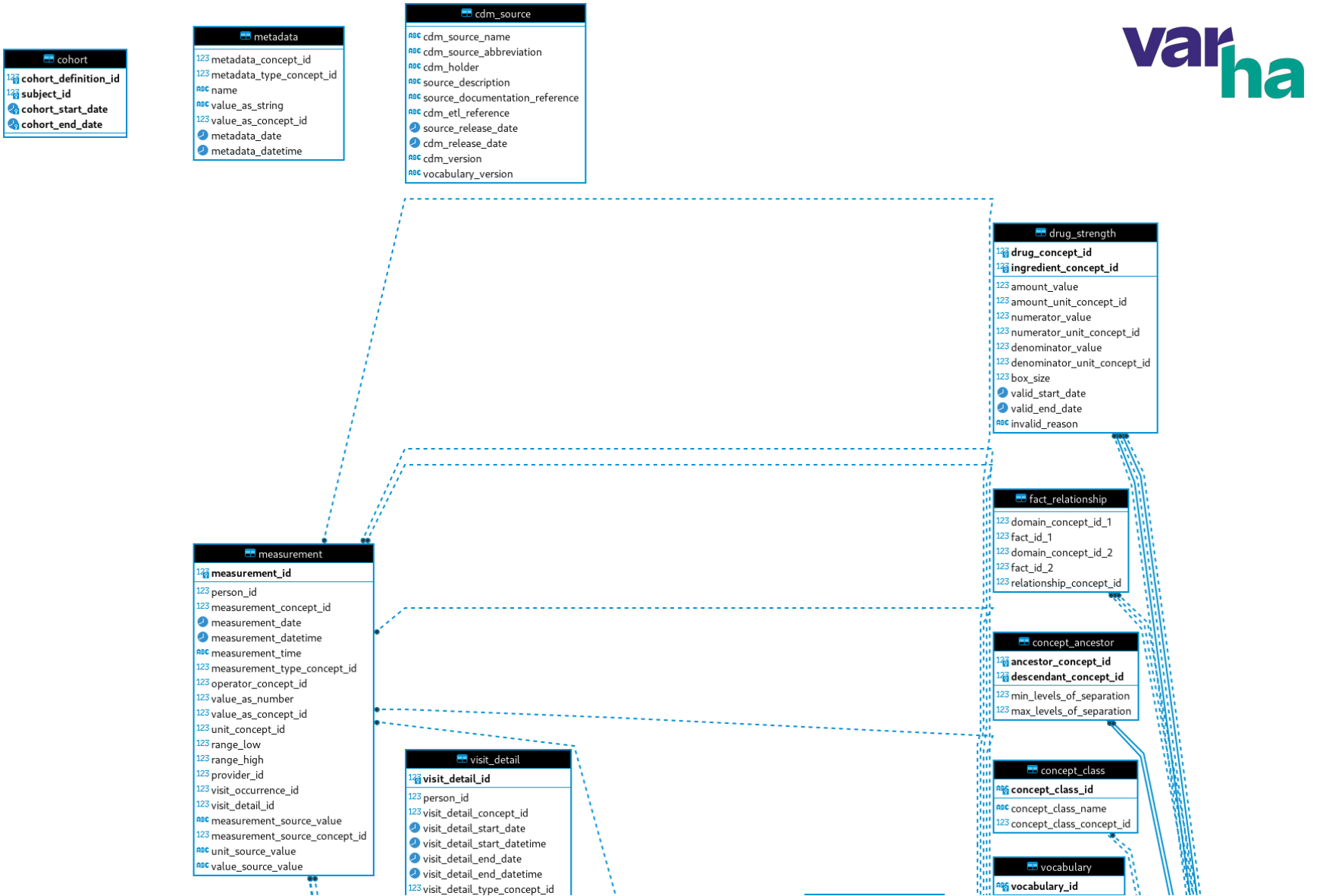
TYKS JA VARSINAIS-SUOMEN SAIRAANHOITOPIIRI - TYKS AND HOSPITAL DISTRICT OF SOUTHWEST FINLAND

DataQualityDashboard Version: 1.0.0
Results generated at 2022-01-14 01:49:23 in 7 hours

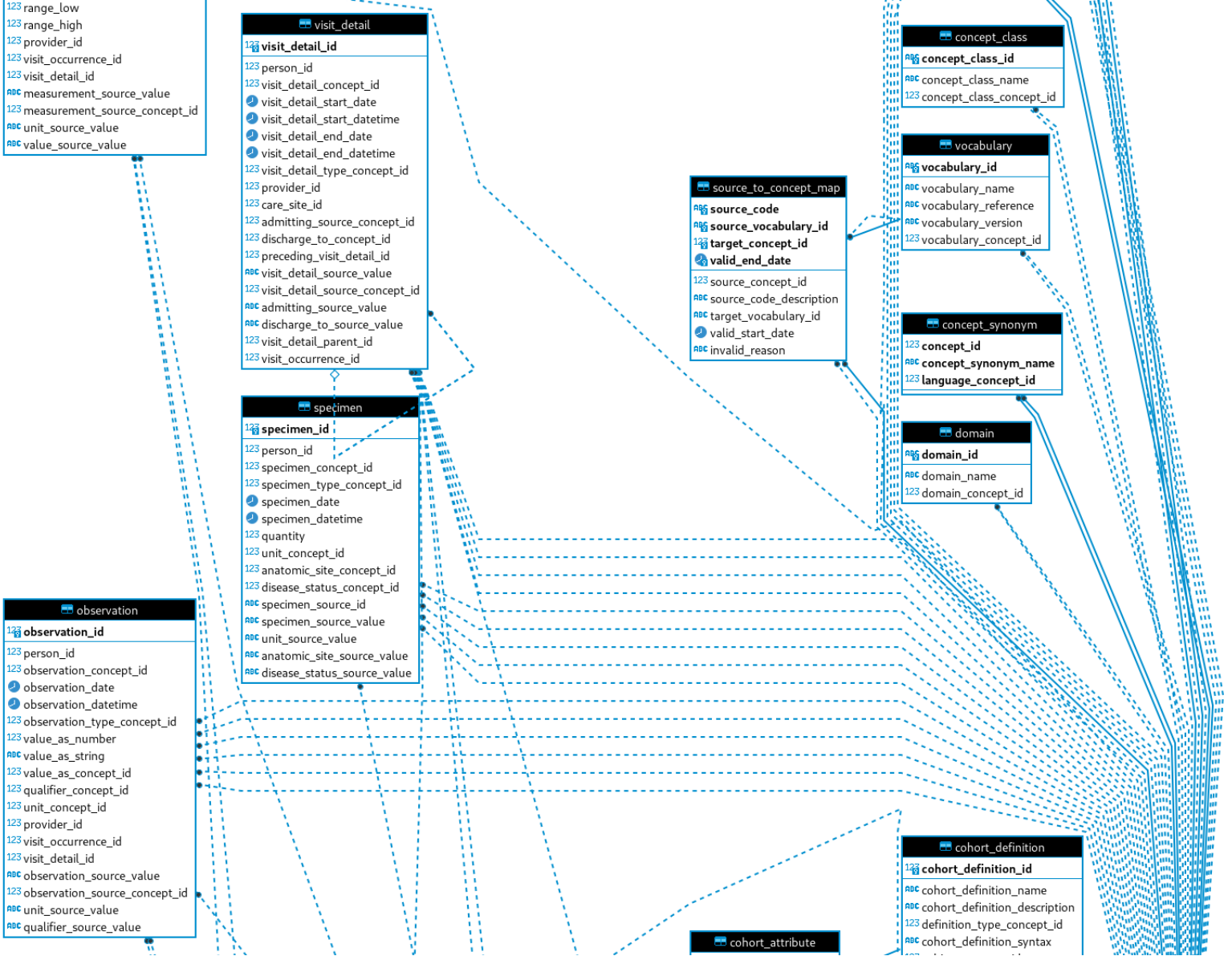
	Verification				Validation				Total			
	Pass	Fail	Total	% Pass	Pass	Fail	Total	% Pass	Pass	Fail	Total	% Pass
Plausibility	1952	27	1979	99%	286	1	287	100%	2238	28	2266	99%
Conformance	565	2	567	100%	78	0	78	100%	643	2	645	100%
Completeness	321	5	326	98%	11	0	11	100%	332	5	337	99%
Total	2838	34	2872	99%	375	1	376	100%	3213	35	3248	**99%**

- The quality of the transformed data cannot exceed the quality of the original, but the opposite is likely
  - Accuracy is occasionally lost
  - Errors can happen
  - All details cannot be saved in CDM

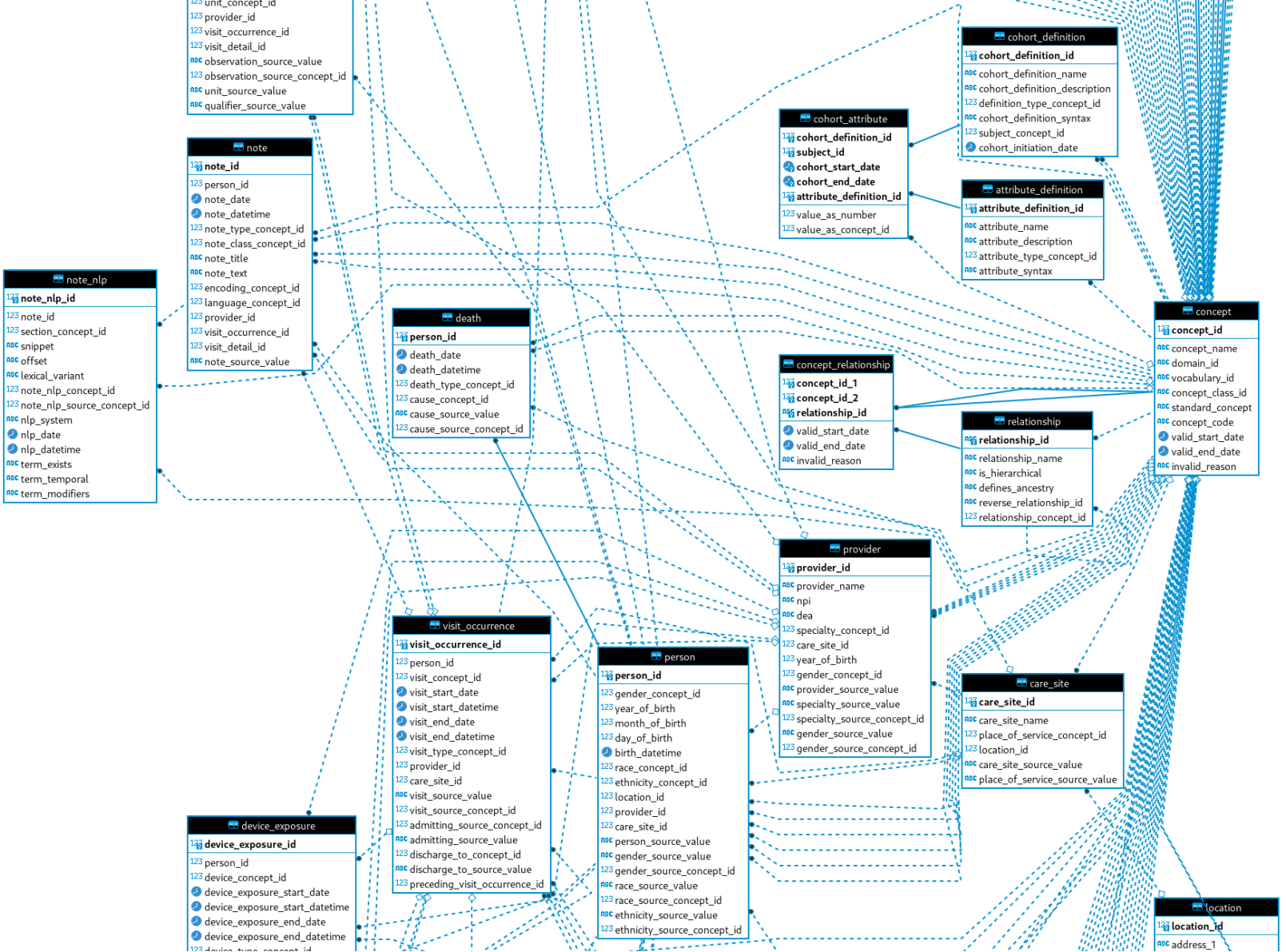
CDM in Detail



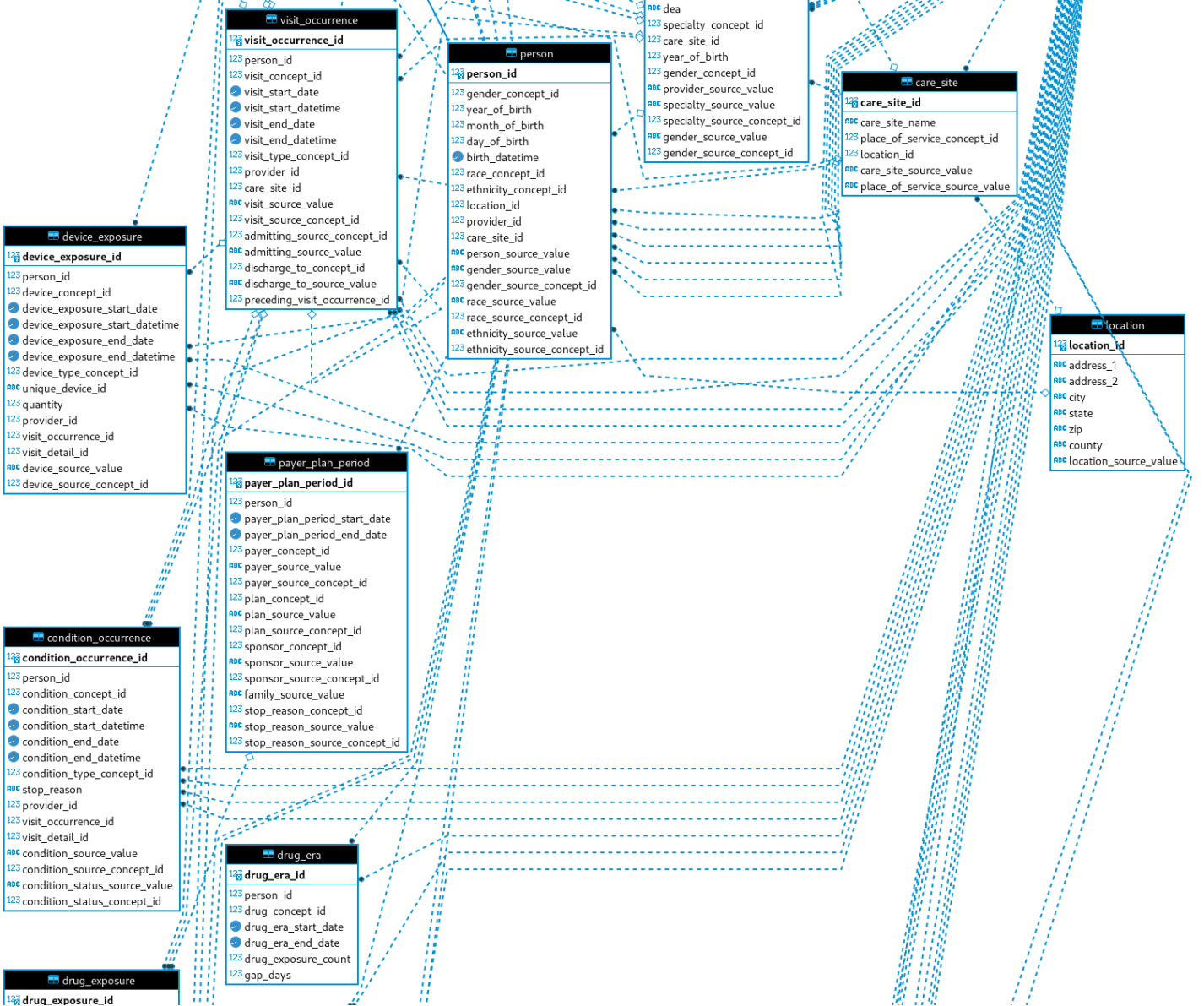
CDM in Detail



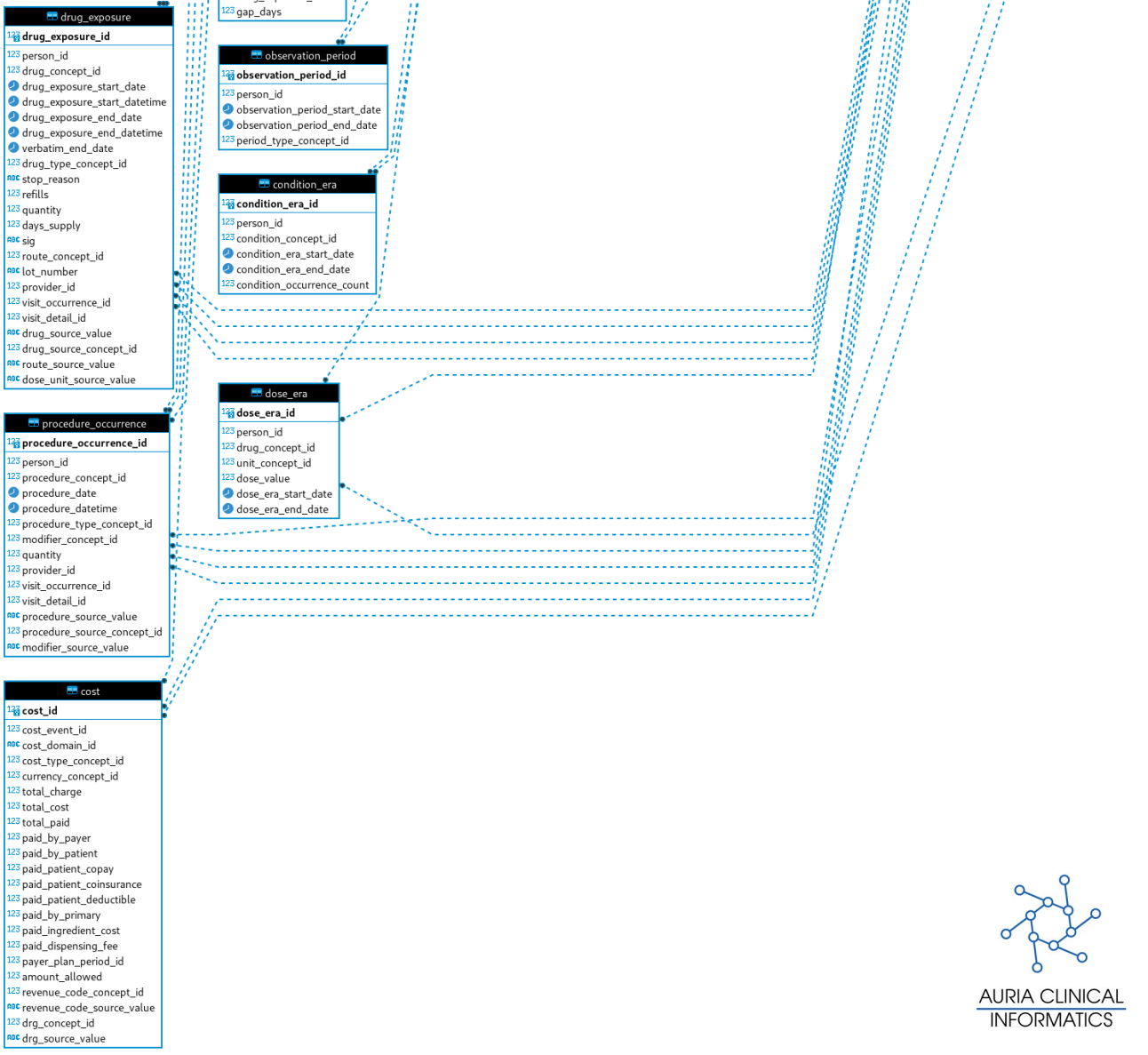
CDM in Detail



CDM in Detail



CDM in Detail



AURIA CLINICAL INFORMATICS

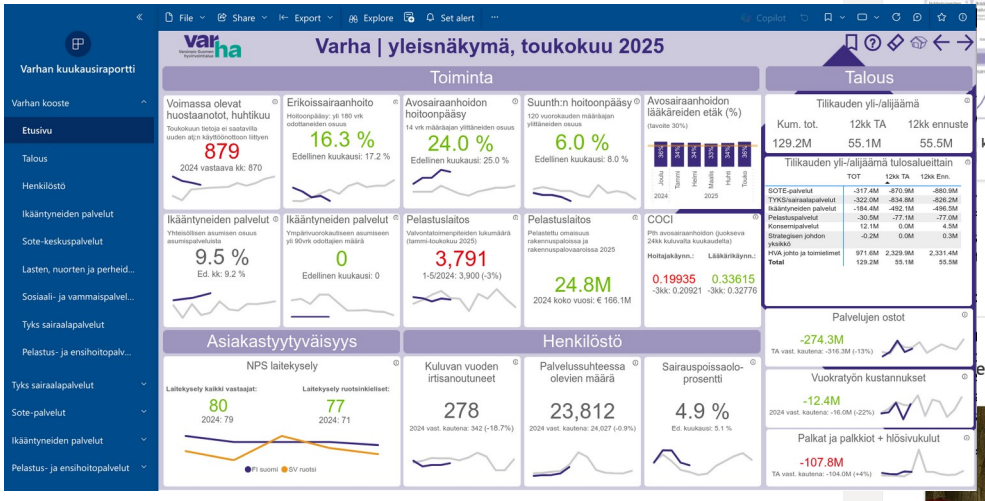
Examples of Data Use

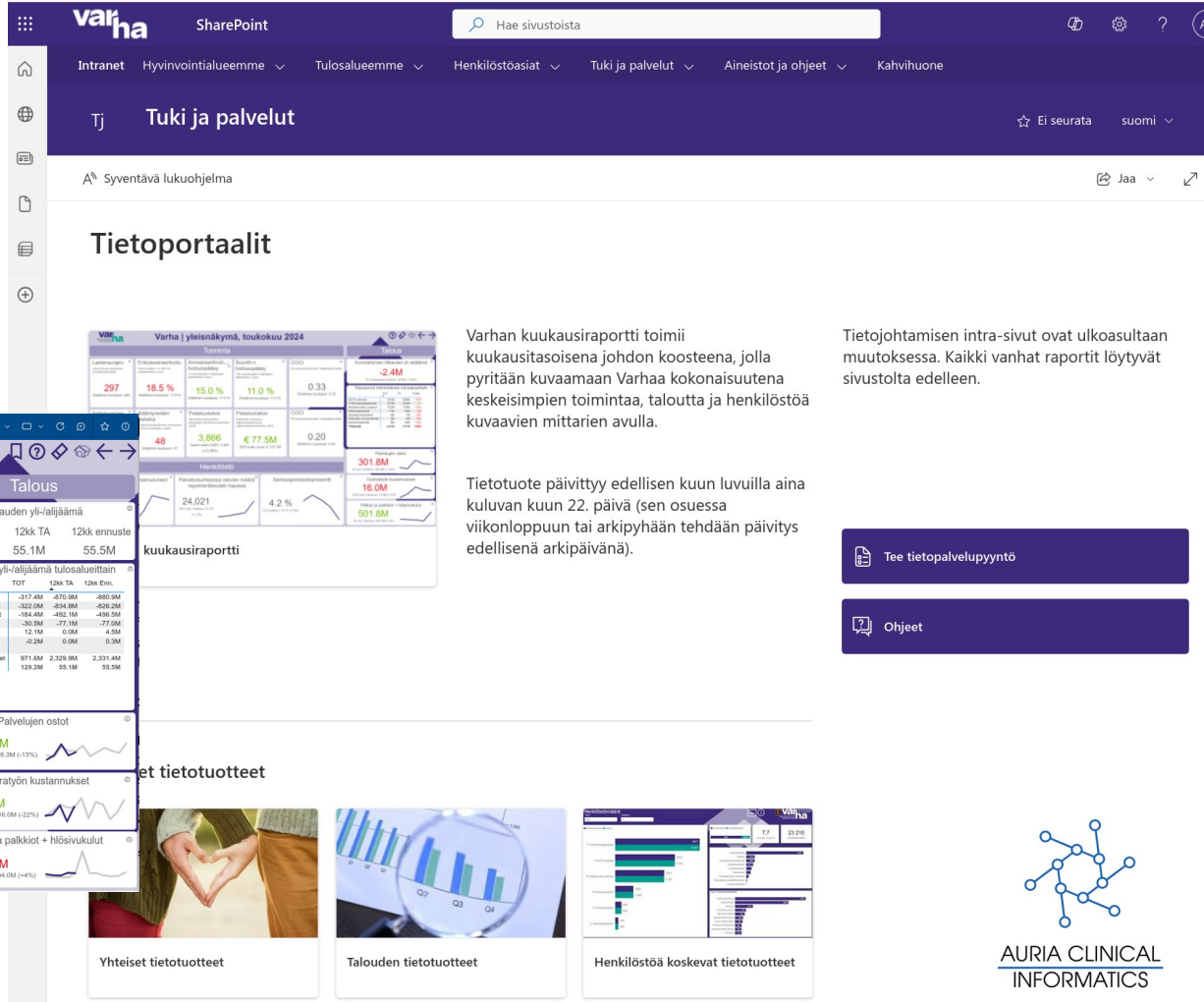
First, some official reports from Varha Intranet

There are two languages to choose, Finnish and Swedish.

There are two separate data teams:

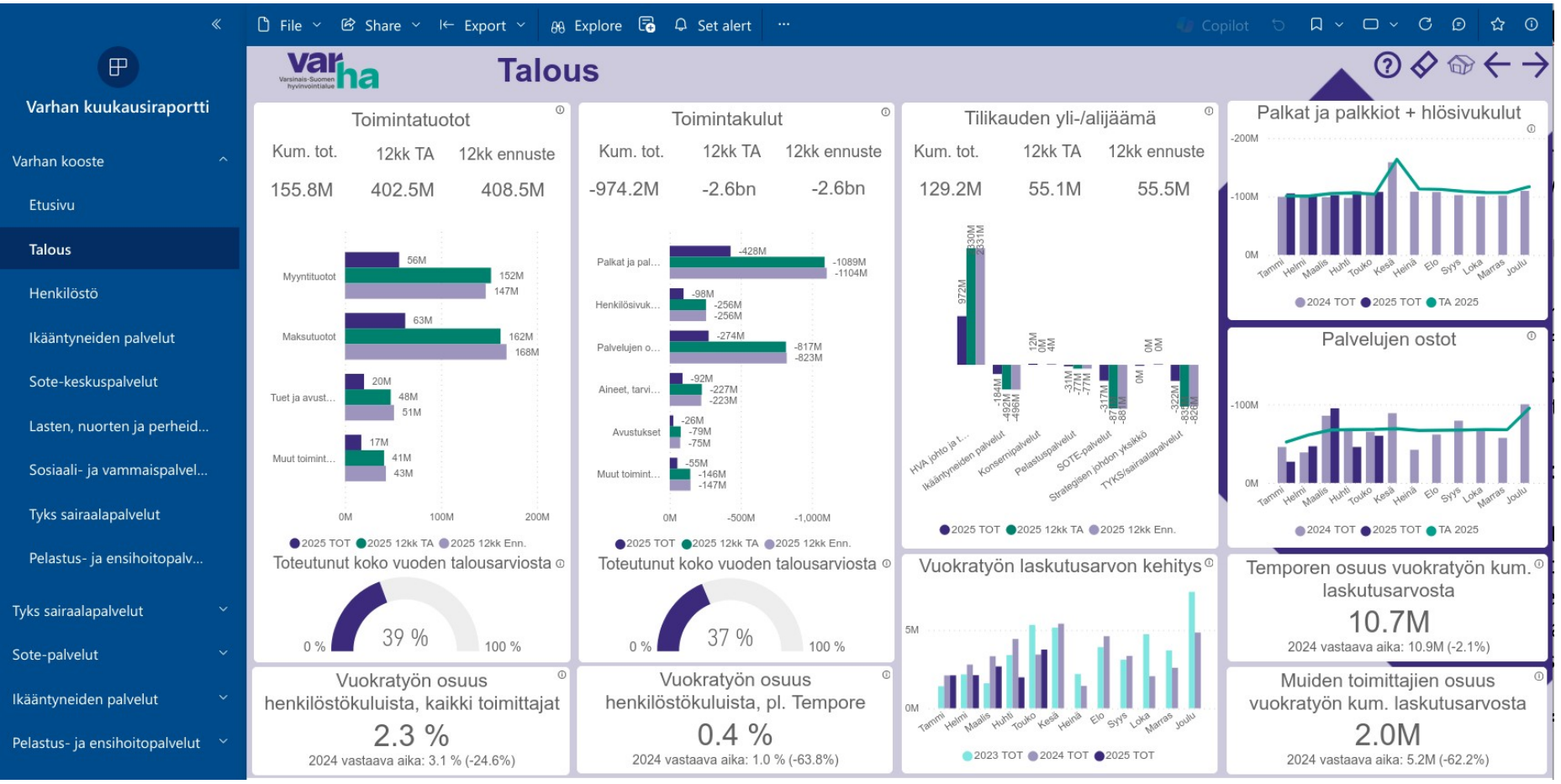
- Management's Data Services (the official figures)
- Experimental & Scientific Data Services (Auria Clinical Informatics)





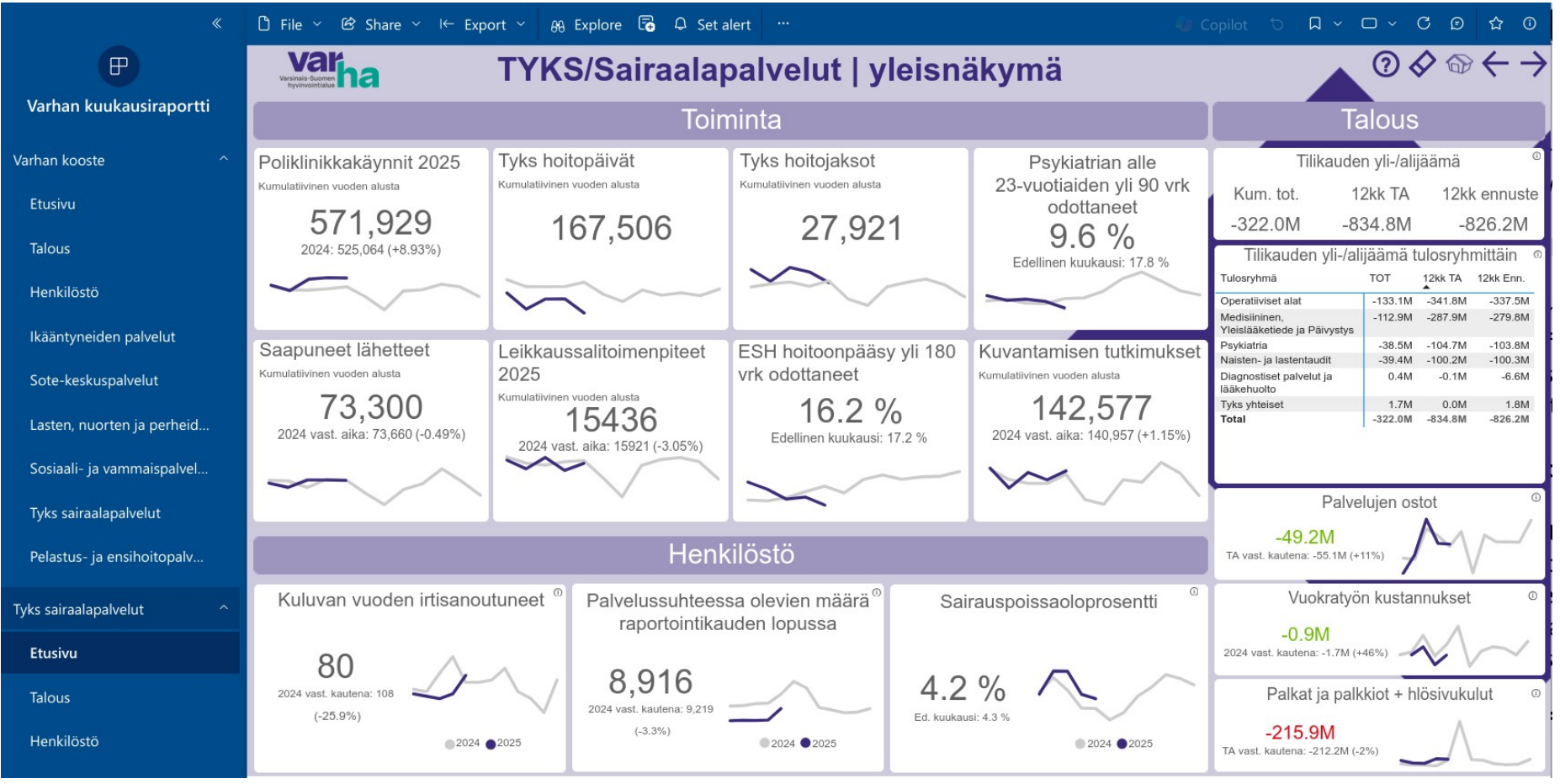
AURIA CLINICAL INFORMATICS

Examples of Data Use



AURIA CLINICAL INFORMATICS

Examples of Data Use



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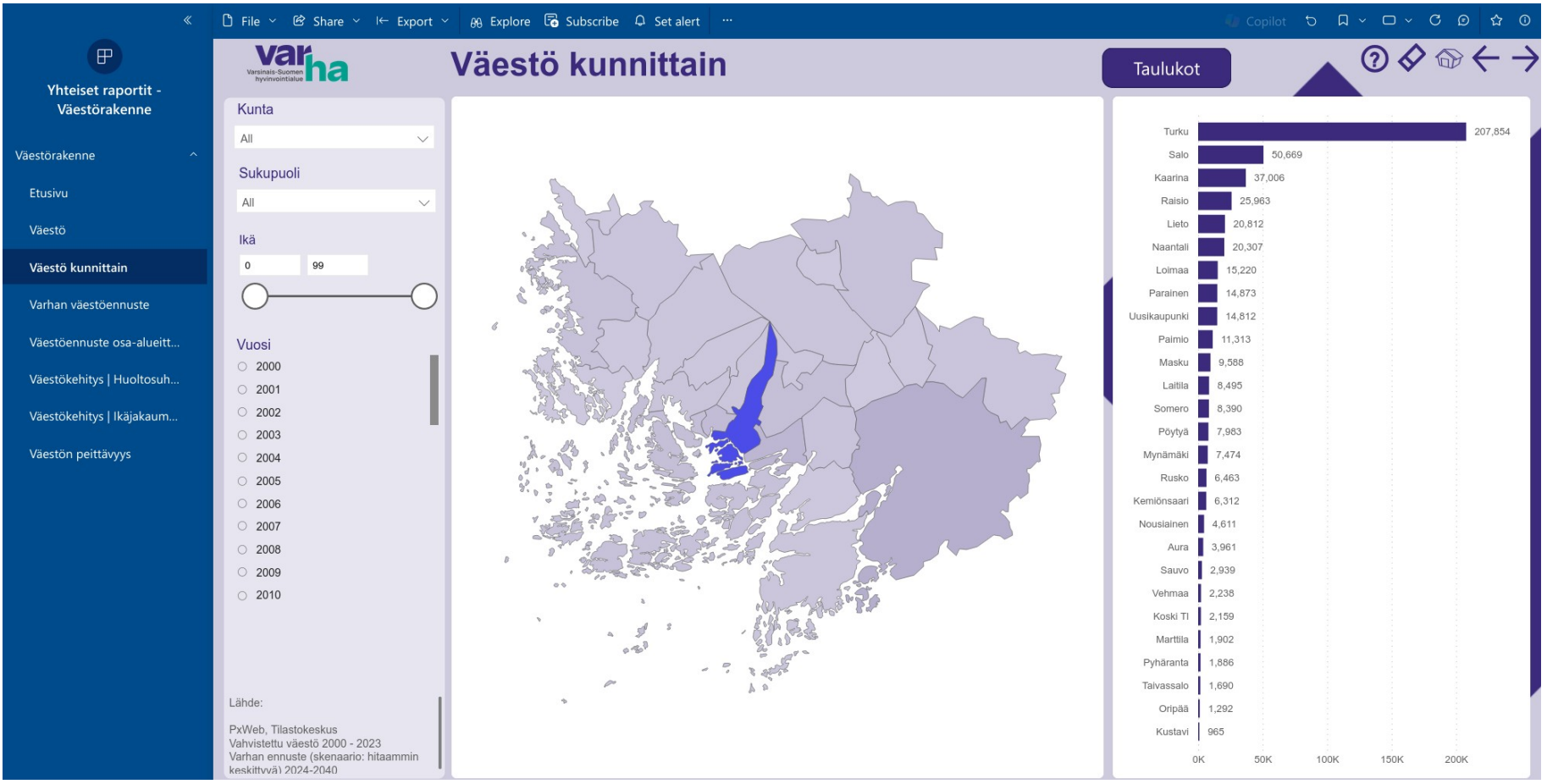
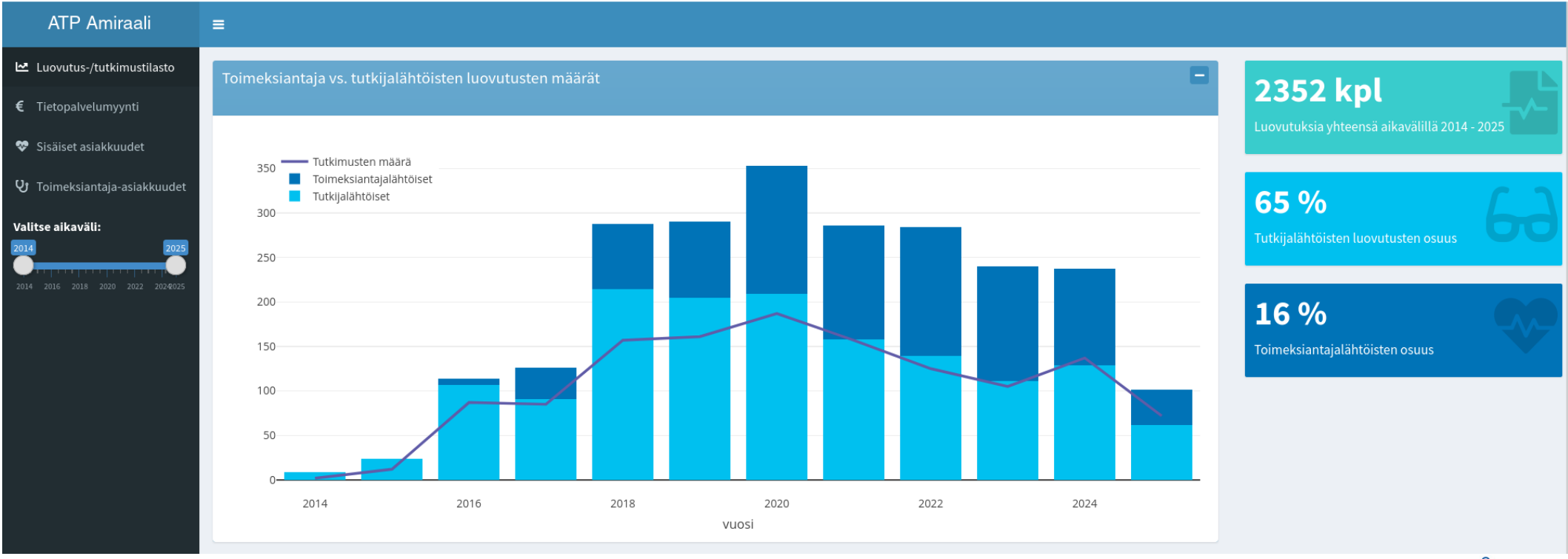
Examples of Data Use



AURIA CLINICAL INFORMATICS

Examples of Data Use

Then, some experimental reports from Auria Clinical Informatics



Unit's Data Export report with R/Shiny + ShinyProxy

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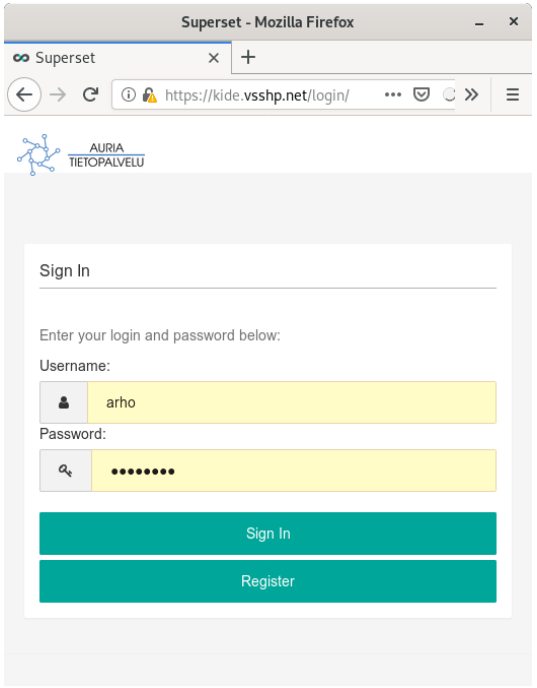
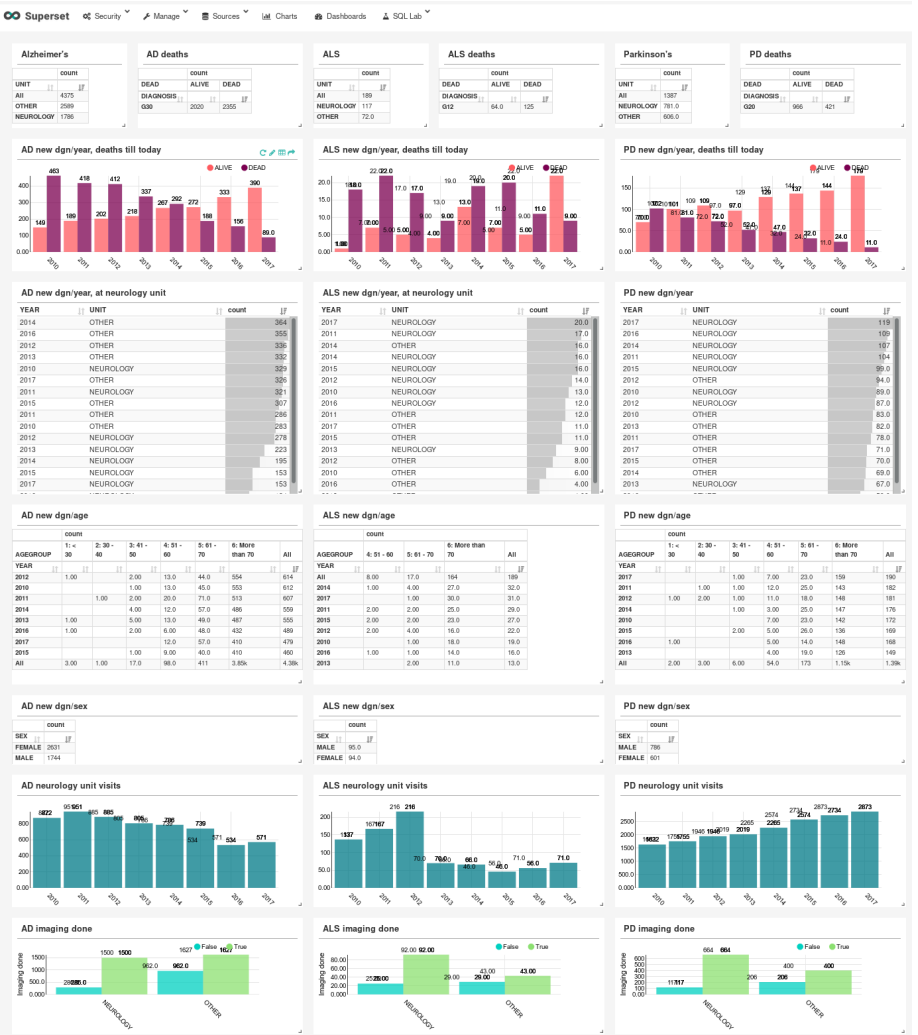
Examples of Data Use



Amyotrophic lateral sclerosis (ALS) dashboard with Apache Superset
https://superset.apache.org/



Examples of Data Use

Urology Quality Register

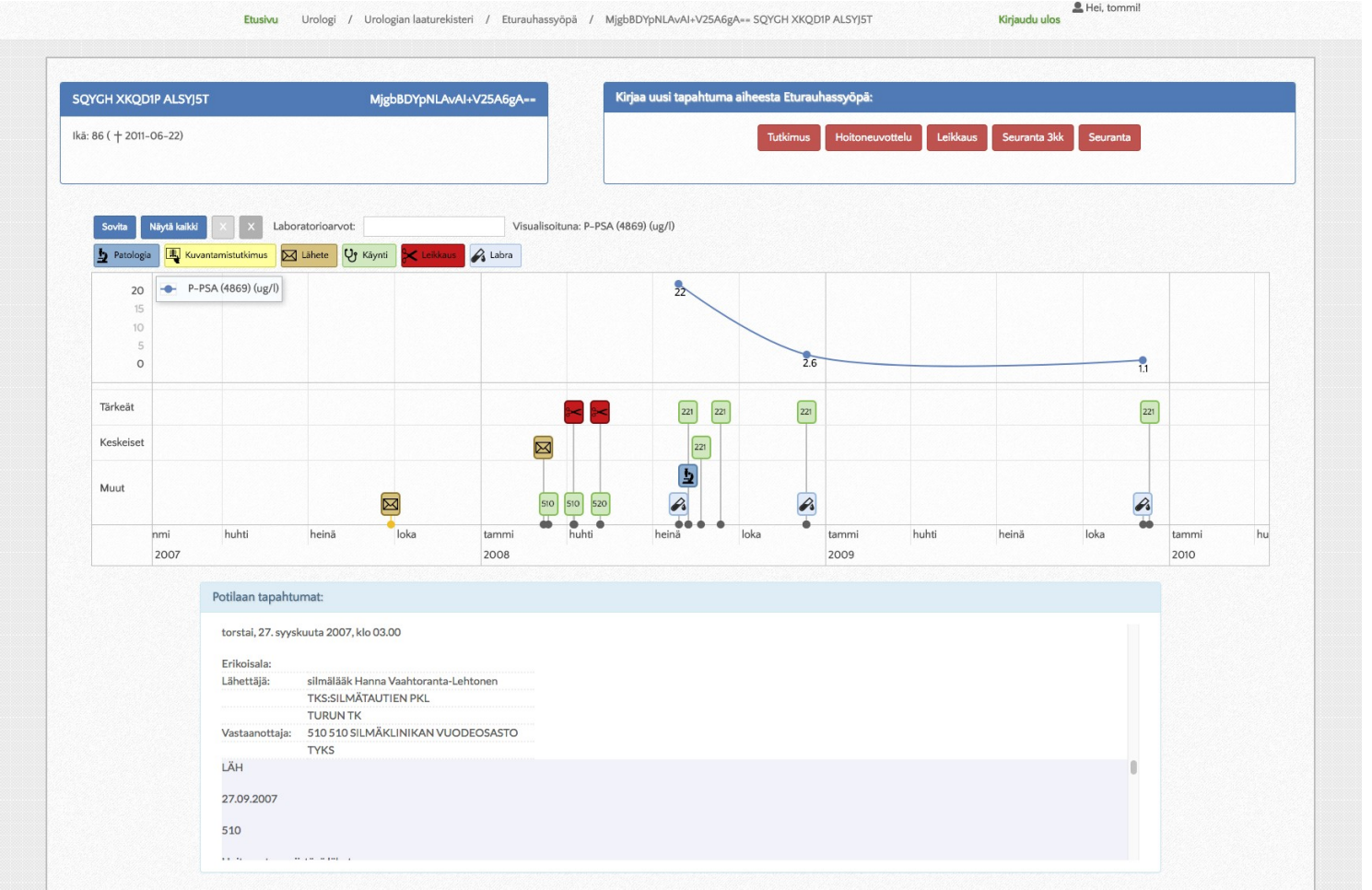
with R + Shiny (GPL) +
ShinyProxy (Apache 2) +
AD-authentication (Microsoft)

Examples of Data Use

Patient timeline (in use since 2019) for quality control in urology

Implementation: ”Full Stack” (PostgreSQL, Flask/Python, D3.js, Bootstrap, …)

Lessons learned: For better maintainability, use reporting tools, do not program from scratch.



Examples of Data Use

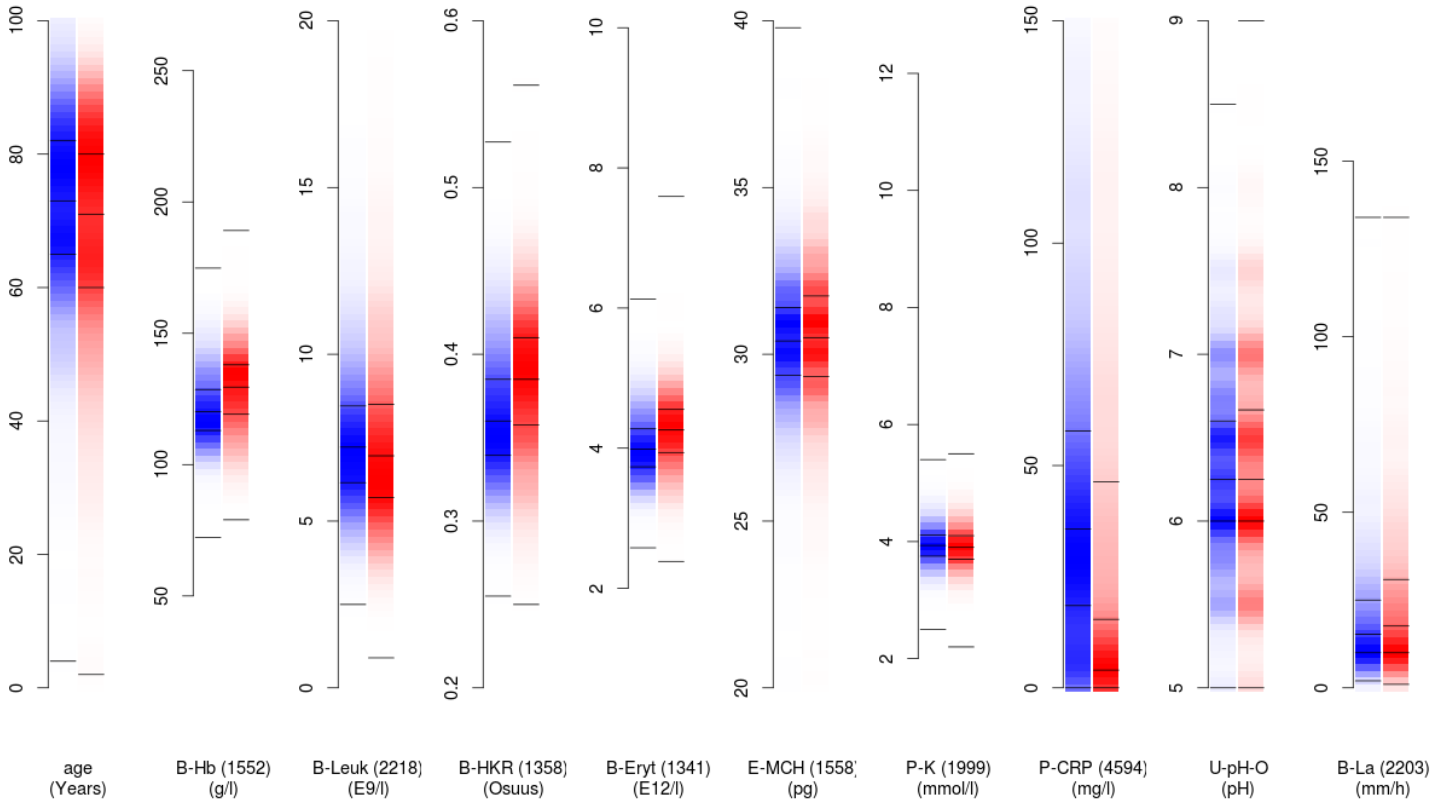
One of the earliest visualizations (2014!)
Some laboratory data seems to be missing…. There must be an error in the data transformation process.

AURIA CLINICAL INFORMATICS

Implementing Data Visualizations

Implementation can be divided into three levels

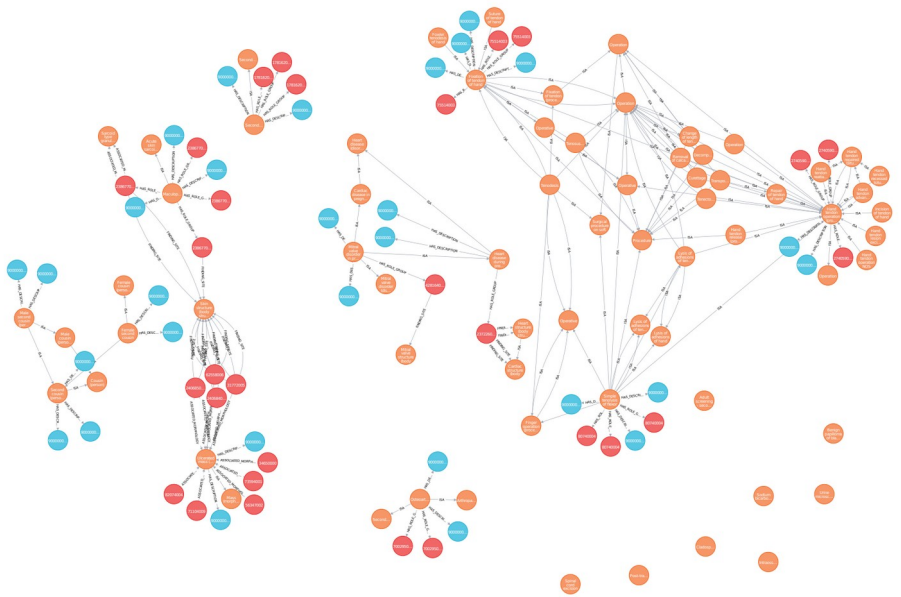
1) Self-service BI (PowerBI, Superset, Knowage, Qlik, Tableau,...)
2) Scripting with ready-made packages (R, Python,...)
3) Graphics programming (D3.js, R graphics primitives; analytical geometry)

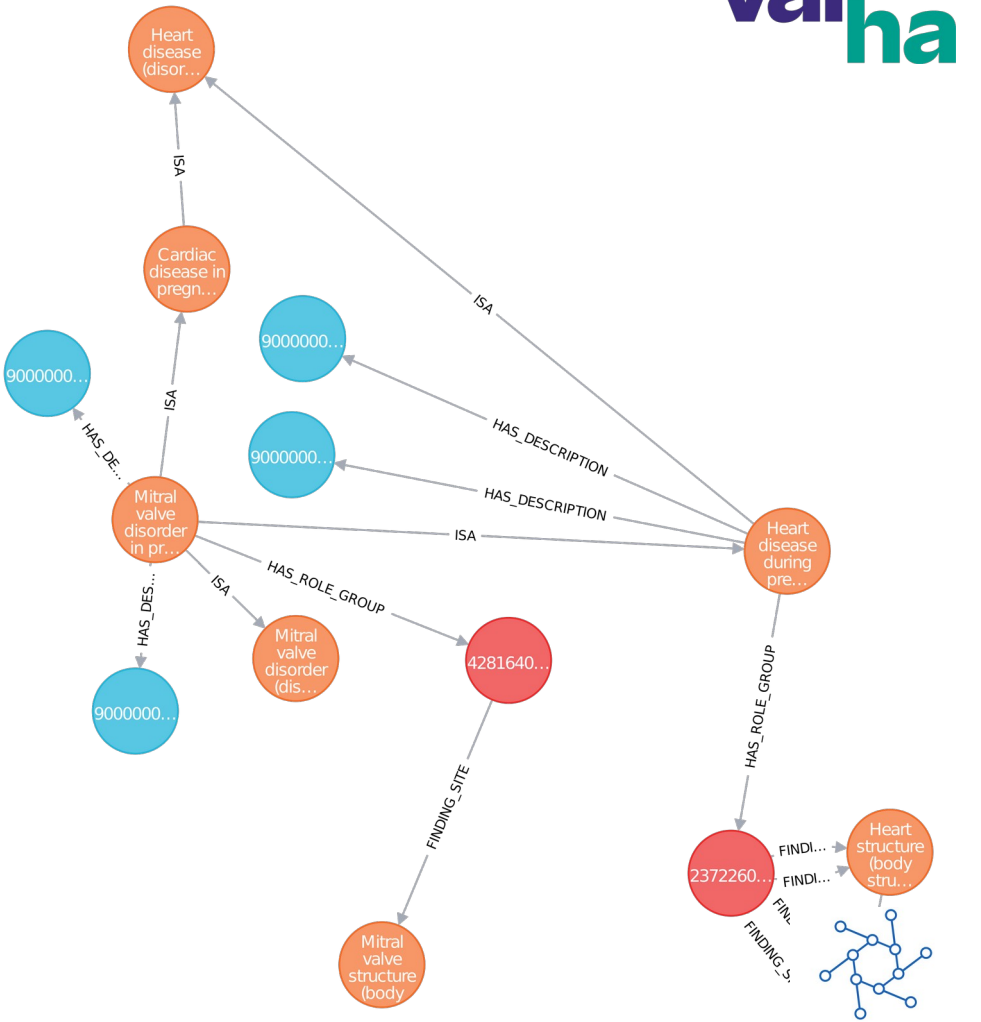


Example: Visualization of the difference between blood values (R graphics)

More Examples of Data Visualization

Graphs can visualize dependencies
between entities





Example: Snomed-CT code visualization with Neo4j-graph tool

AURIA CLINICAL INFORMATICS

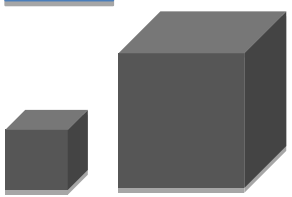
Fundamentals of Statistical Visualizations

For recap – these are the tools of a visualist

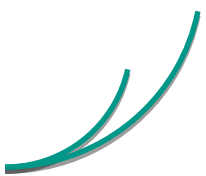
length

area

volume



curvature



angle

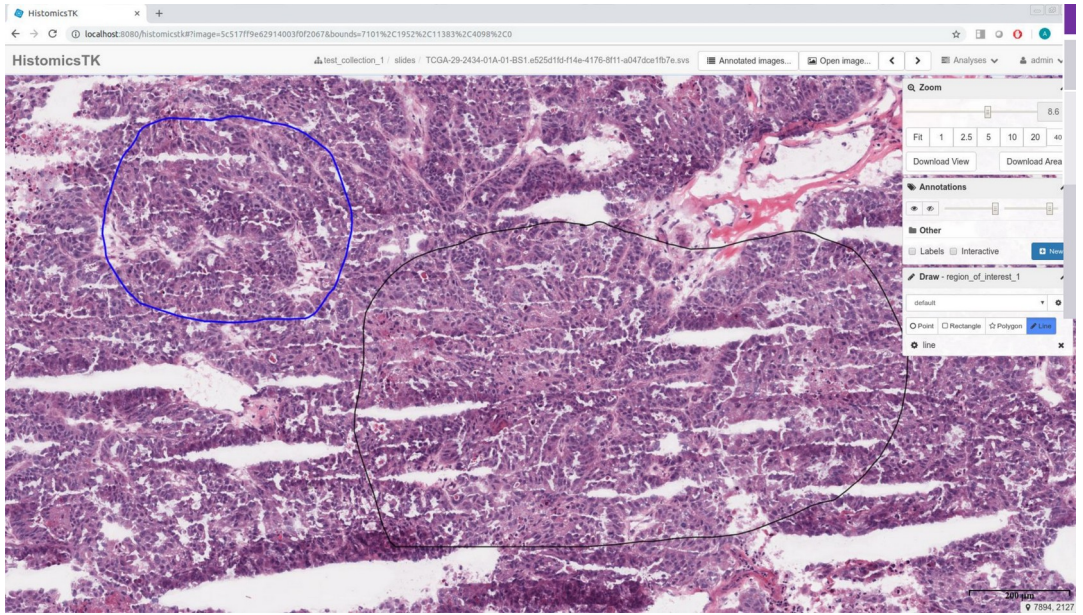
position

shape

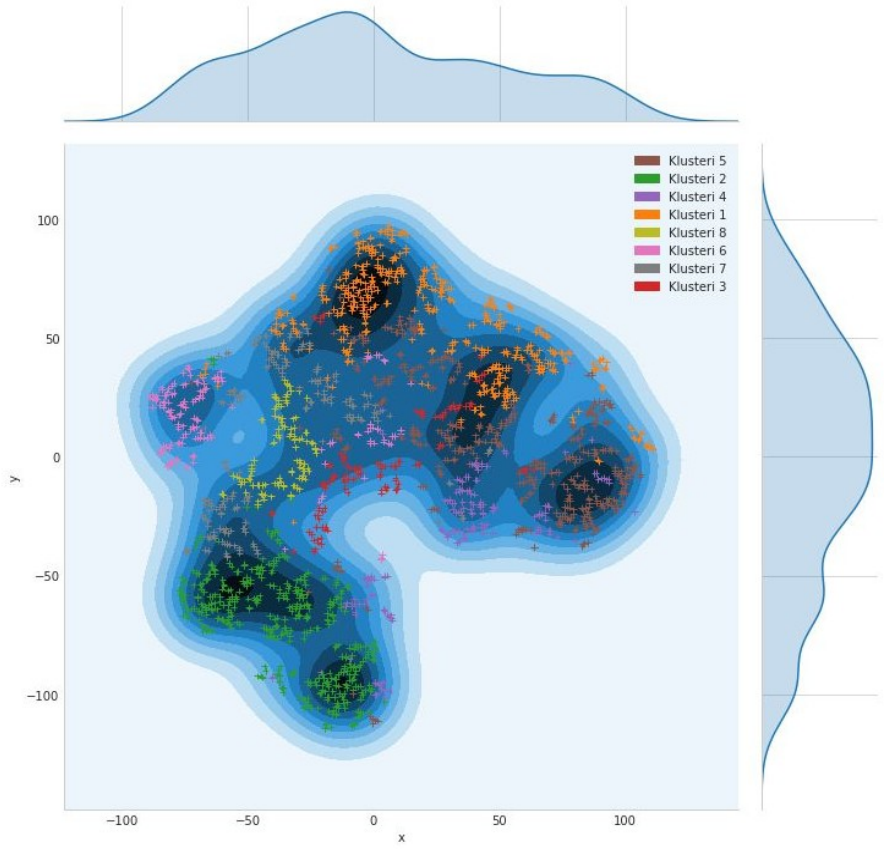
color

AURIA CLINICAL INFORMATICS

Predictive Analytics with Machine Learning / AI



Classification of pathological images in Auria Biobank



Example: Clustering of the different phenotypes of asthma in Auria Biobank

Huhtanen *et al. BMC Medical Imaging* (2022) 22:43
https://doi.org/10.1186/s12880-022-00763-z

BMC Medical Imaging

RESEARCH Open Access

Automated detection of pulmonary embolism from CT-angiograms using deep learning

Heidi Huhtanen[1*], Mikko Nyman[1], Tarek Mohsen[2], Arho Virkki[3,4], Antti Karlsson[5] and Jussi Hirvonen[1]

Abstract

Background: The aim of this study was to develop and evaluate a deep neural network model in the automated detection of pulmonary embolism (PE) from computed tomography pulmonary angiograms (CTPAs) using only weakly labelled training data.

Methods: We developed a deep neural network model consisting of two parts: a convolutional neural network architecture called InceptionResNet V2 and a long-short term memory network to process whole CTPA stacks as sequences of slices. Two versions of the model were created using either chest X-rays (Model A) or natural images (Model B) as pre-training data. We retrospectively collected 600 CTPAs to use in training and validation and 200 CTPAs to use in testing. CTPAs were annotated only with binary labels on both stack- and slice-based levels. Performance of the models was evaluated with ROC and precision–recall curves, specificity, sensitivity, accuracy, as well as positive and negative predictive values.

Results: Both models performed well on both stack- and slice-based levels. On the stack-based level, Model A reached specificity and sensitivity of 93.5% and 86.6%, respectively, outperforming Model B slightly (specificity 90.7% and sensitivity 83.5%). However, the difference between their ROC AUC scores was not statistically significant (0.94 vs 0.91, $p = 0.07$).

Conclusions: We show that a deep learning model trained with a relatively small, weakly annotated dataset can achieve excellent performance results in detecting PE from CTPAs.

Keywords: Artificial intelligence, Emergency radiology, Pulmonary embolism, Deep learning, Automated detection

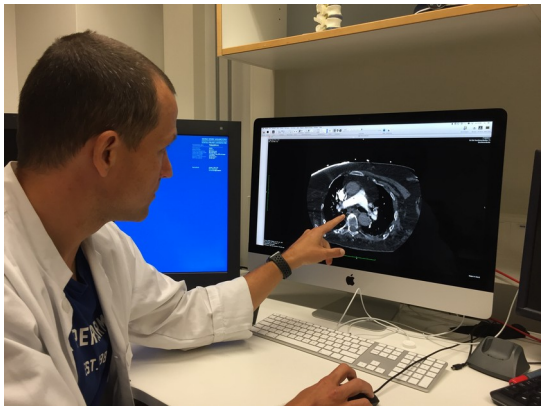
Example

Publication available at:
https://doi.org/10.1186/s12880-022-00763-z

AURIA CLINICAL INFORMATICS

Automated detection of pulmonary embolism

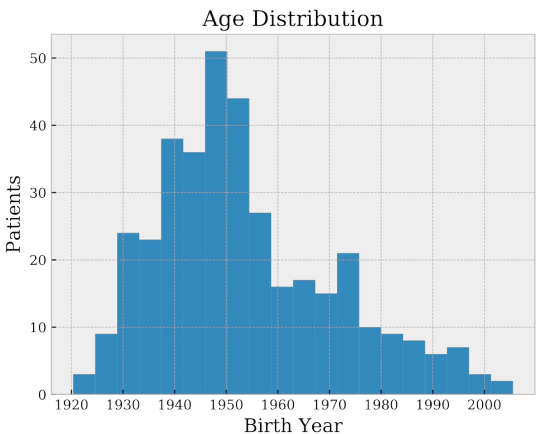
Motivation: If the patient can be diagnosed and treated < 10 minutes after arrival in the ICU, the probability of surviving increases significantly.

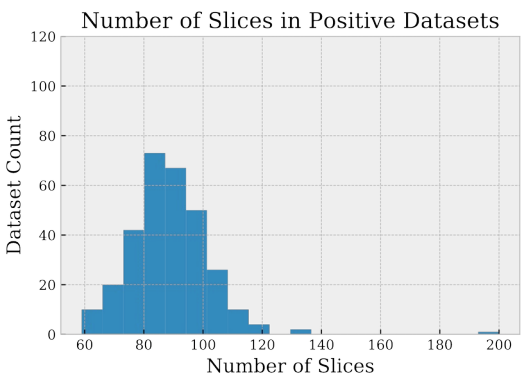


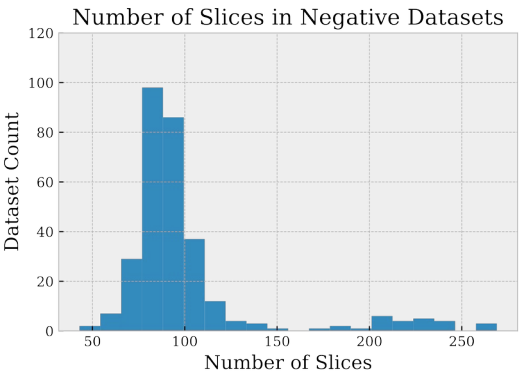
Dataset (58 057 slices)

2.1 Dataset

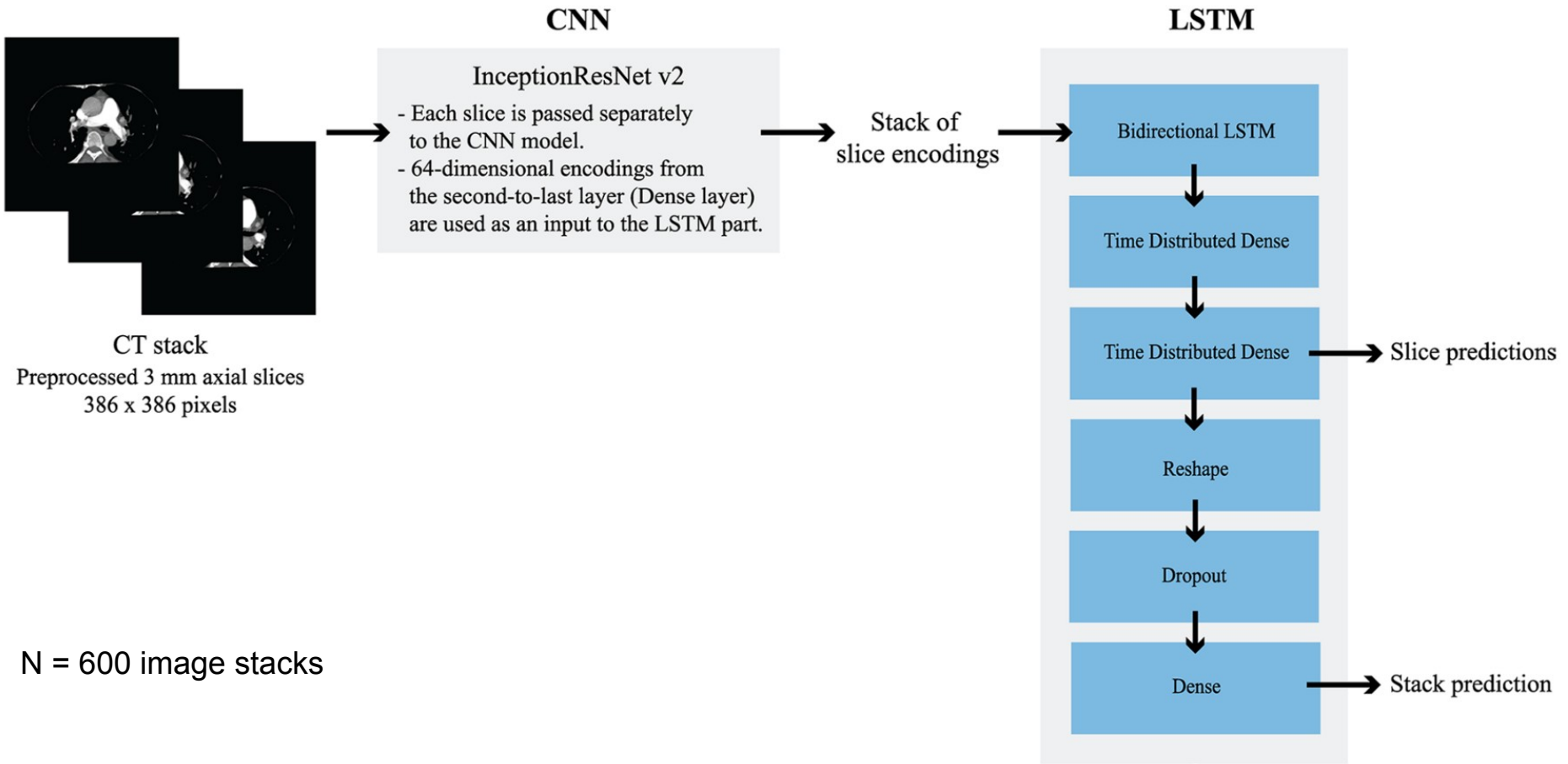
In this work a balanced dataset of 610 contrast enhanced CT images from 569 patients was collected retrospectively from period between October 2016 and September 2018. As the numbers imply, some patients had multiple images in the dataset due to re-takes or follow-ups of a chronic condition. Although most of the original DICOM studies were imaged using 1 millimeter slices with projections in axial, sagittal and coronal directions, we decided to restrict the scope to 3 millimeter reformatted axial slices. The purpose for this was to keep the amount of needed annotation work reasonable. On average each dataset contained of approximately 90 reformatted axial slices. In total there were 58057 individual slices from which 7229 had positive findings. The dataset contained images from 319 females and 250 males.







Model Technical Structure



N = 600 image stacks

Fig. 1 Scheme of the model architecture

Results

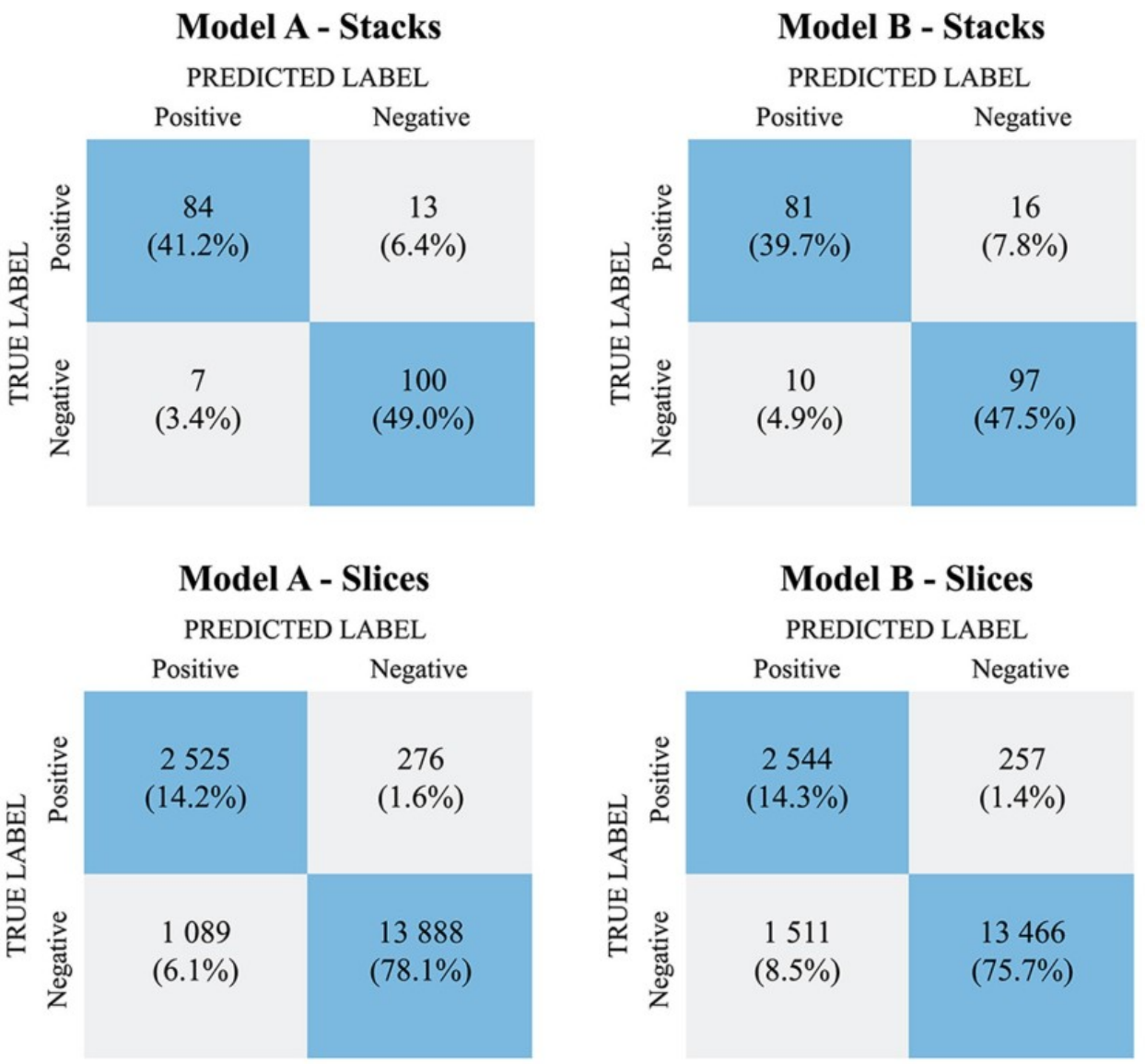
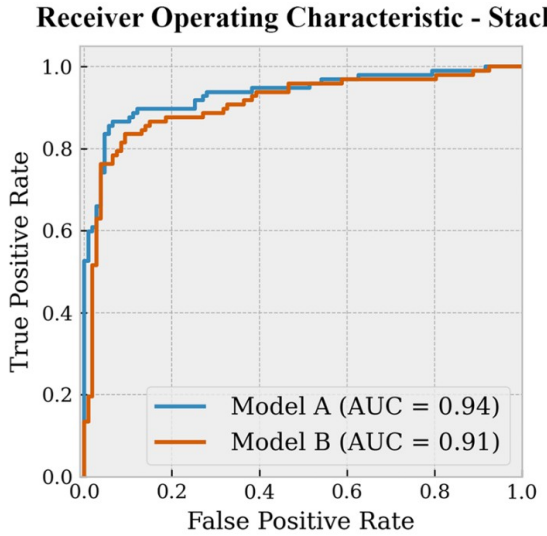
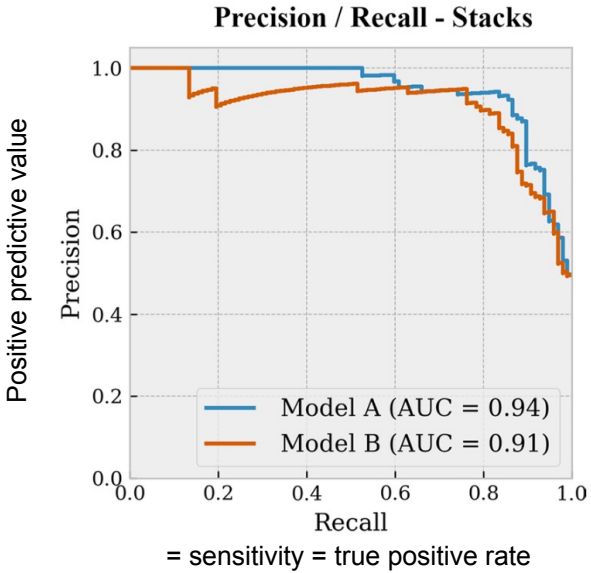


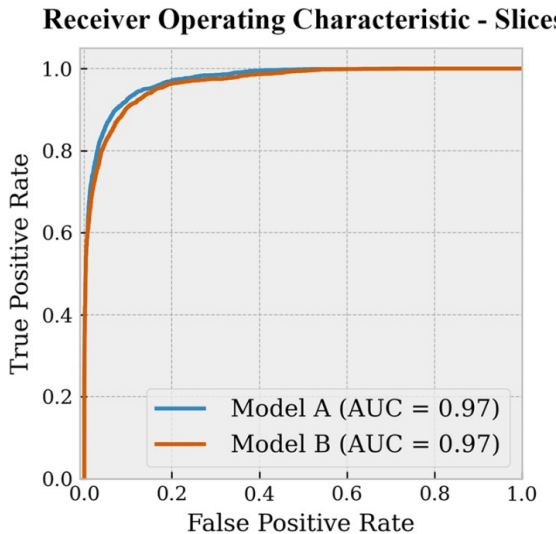
Fig. 3 Confusion matrices for Models A and B on stack- and slice-based classification

Results





= sensitivity = true positive rate



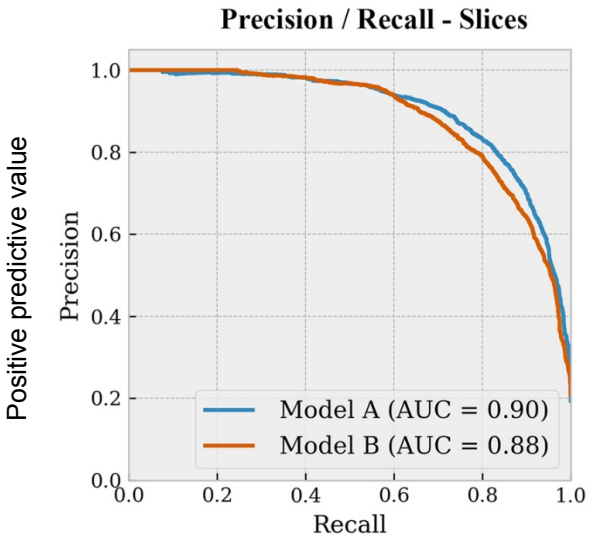


Fig. 2 ROC and PR curves for stack-based and slice-based predictions

Increased sensitivity drops the positive predictive value

Good models yield high sensitivity and positive predictive value at the same time

Results

Discussion

The main contribution of this study is to demonstrate the development of a deep learning model for automated detection of PE from CTPAs, and to show that this is feasible even with limited data annotation resources. We found that our best model (Model A) achieved an ROC AUC of 0.94, sensitivity of 86.6% and specificity of 93.5% in predicting PE from whole CTPA stacks. We showed that these promising results could be achieved using a weakly labelled training dataset consisting of only 600 CTPAs, which is a relatively small dataset for neural networks.

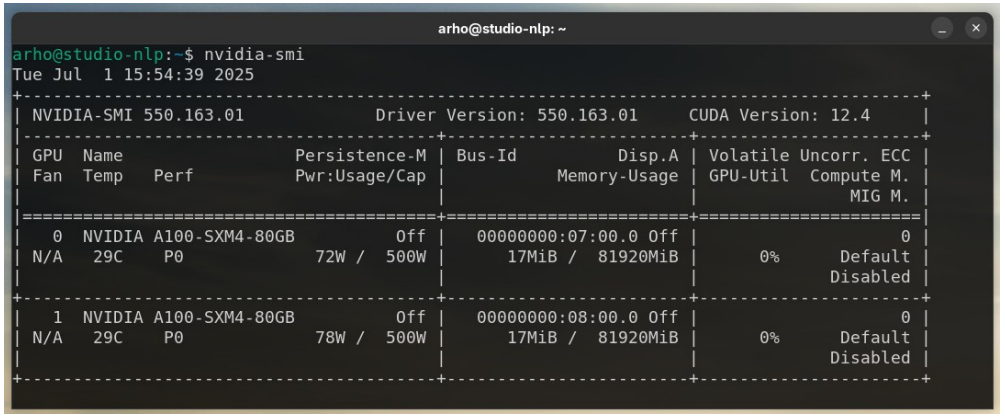
Full article available at
https://doi.org/10.1186/s12880-022-00763-z

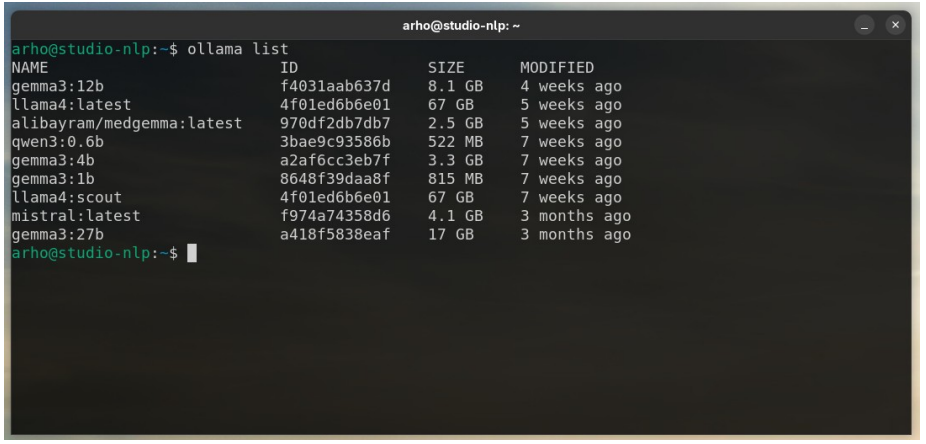
Hot Topics in 2025, Second Half

Application of open source'd in-house LLM's for

- Automated detection and reporting of adverse events
- Automated computation of quality metrics, e.g. clavien-dindo classification of surgical complications
- Confidential discussions with LLM's with augmented organizatorial or patient data
- …

State of art LLM's could not be run in house in December 2024.
But now, in July 2025, Local FOSS LLM's compete with cloud computing.





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Discussion

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