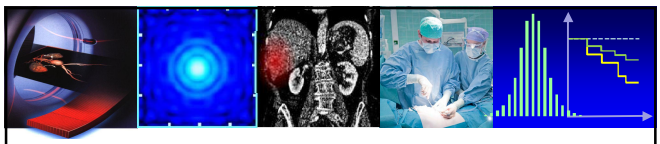


From image quality to care outcome

NSFS

Helsinki – 12.6.2019

vMar-2019

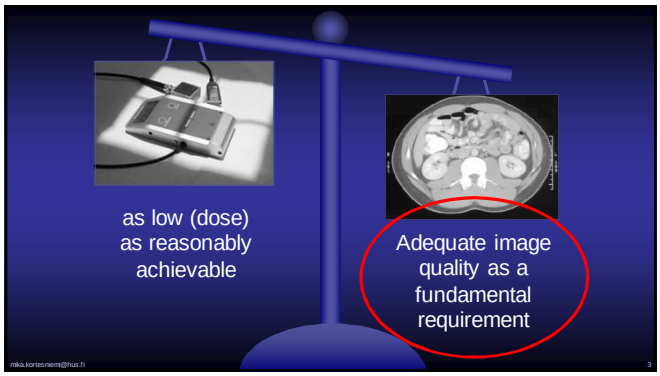
HELSINKI UNIVERSITY
DEPARTMENT OF PHYSICS

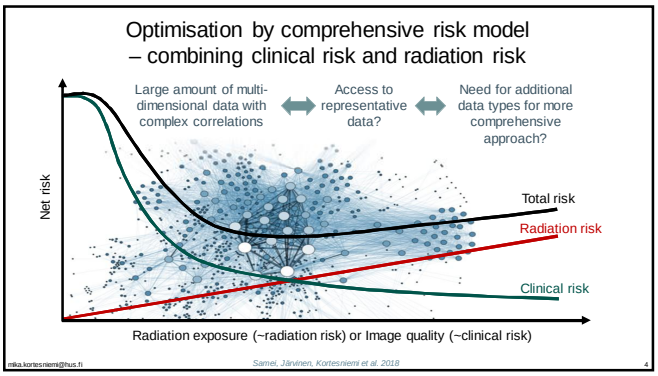
HUS Medical Imaging Center

Mika Kortesniemi
Adjunct Professor, Chief Physicist, PhD
HUS Medical Imaging Center
University of Helsinki
Meilahti Hospital, Dept. of Radiology

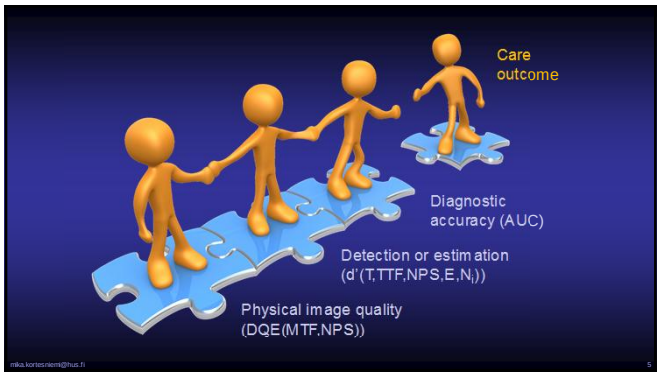
Outline

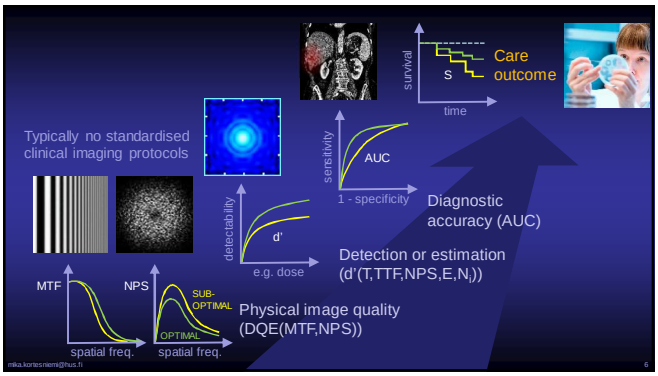
- Developing optimisation process
- Quantification from measurable physics parameters towards more comprehensive and effective clinical parameters
- Radiomics and machine-learning – providing tools for quantification

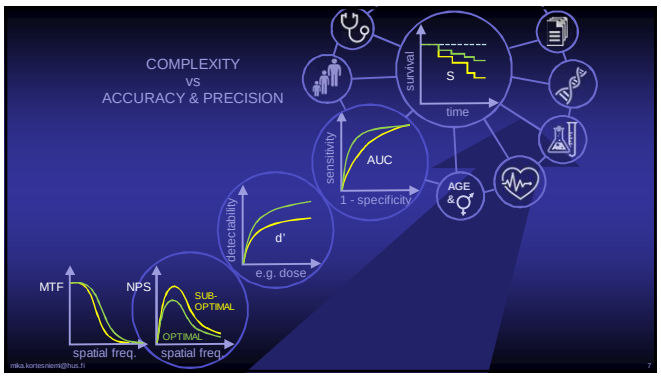




Samei, Järvinen, Kortesniemi et al. 2018







Radiomics – method for quantification

Radiomics = field of medical study that aims to extract large amount of quantitative features from medical images using data-characterisation algorithms.

Machine learning = type of artificial intelligence that allows software applications to become more accurate in predicting outcomes without being explicitly programmed.

- **For radiologists:** Chartrand G, Cheng PM, Vorontsov E, Drozdzal M, Turcotte S, Pal CJ, Kadoury S, Tang A. Deep Learning: A Primer for Radiologists. Radiographics. 2017 Nov-Dec;37(7):2113-2131.
- **For physicists:** Sahiner B, Pezeshk A, Hadjiiski LM, Wang X, Drukker K, Cha KH, Summers RM, Giger ML. Deep learning in medical imaging and radiation therapy. Med Phys. 2019 Jan;46(1):e1-e36.

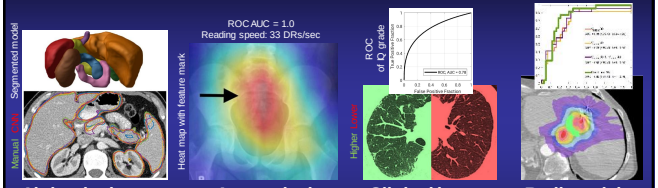
Radiomics – method for quantification

VARIOUS LEVELS OF MACHINE LEARNING TASKS

➡ DETECTION
➡ LOCALISATION
➡ SEGMENTATION
➡ CLASSIFICATION
➡ OUTCOME PREDICTION

- **For radiologists:** Chartrand G, Cheng PM, Vorontsov E, Drozdzal M, Turcotte S, Pal CJ, Kadoury S, Tang A. Deep Learning: A Primer for Radiologists. Radiographics. 2017 Nov-Dec;37(7):2113-2131.
- **For physicists:** Sahiner B, Pezeshk A, Hadjiiski LM, Wang X, Drukker K, Cha KH, Summers RM, Giger ML. Deep learning in medical imaging and radiation therapy. Med Phys. 2019 Jan;46(1):e1-e36.

Examples of machine learning in segmentation, labeling, clinical image quality estimation and outcome prediction



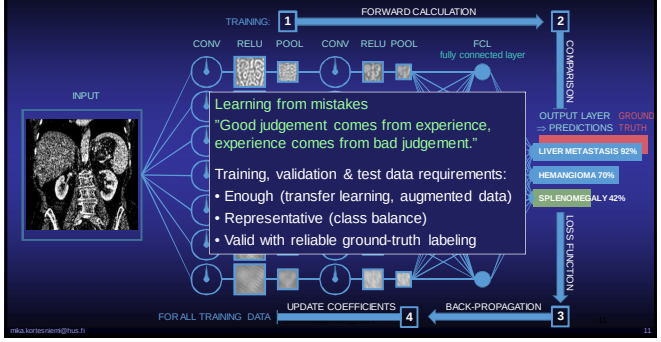
Abdominal organ segmentation
Abd CT data
CNN method
Gibson et al. 2017

Anatomical labeling
Pediatric DR data
CNN method
P.H. Yi et al. 2019

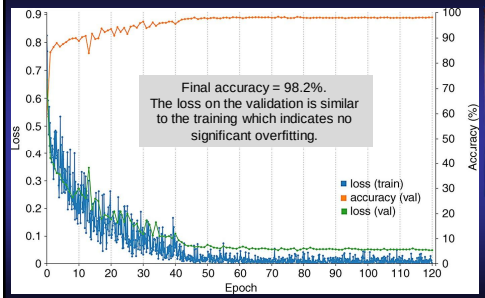
Clinical image quality in lung
Chest CT data
CNN method
Lee et al. 2018

Radiotoxicity in liver
Body CT data
CNN method
Ibragimov et al. 2018

Convolutional Neural Network (CNN) – Basic principle

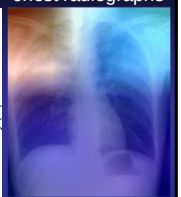


Example training curve of CNN classifier

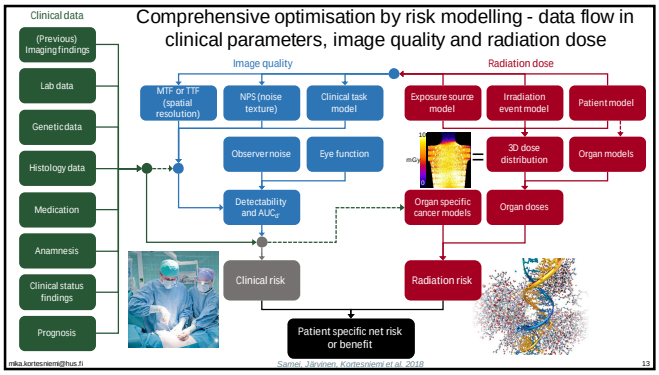


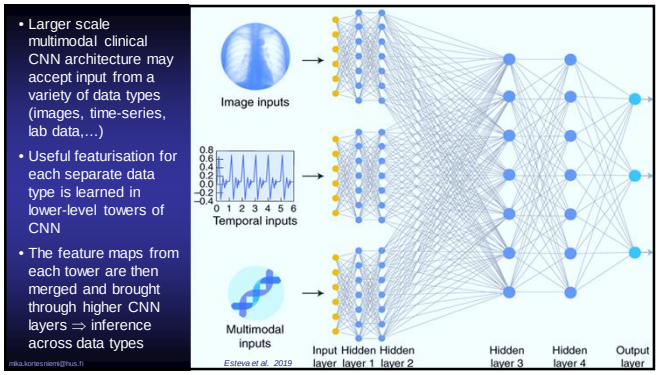
Lakhani et al. 2017

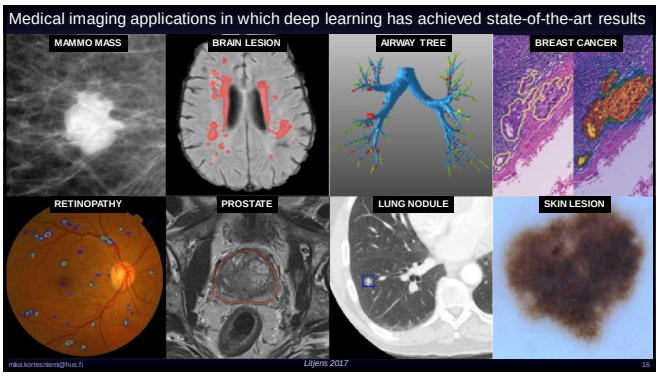
Tuberculosis in chest radiographs

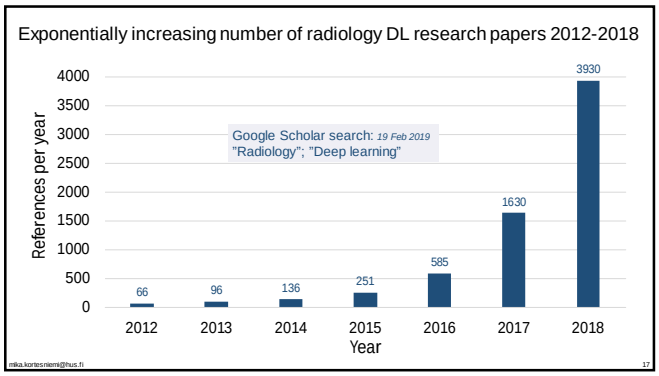


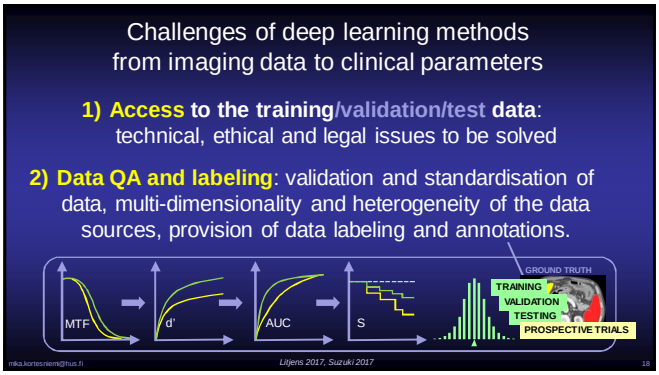
Chest radiograph with a tuberculosis probability heat map overlay

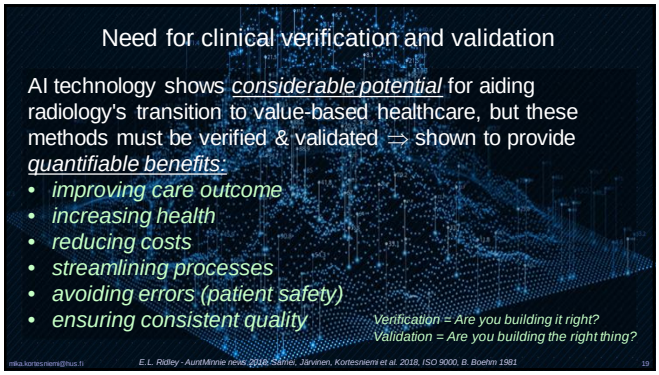

Comprehensive optimisation by risk modelling - data flow in clinical parameters, image quality and radiation dose
Clinical data
(Previous) Imaging findings
Lab data
Genetic data
Histology data
Medication
Anamnesis
Clinical status findings
Prognosis
Image quality
MTF or TTF (spatial resolution)
NPS (noise texture)
Clinical task model
Observer noise
Eye function
Detectability and AUC
Clinical risk
Radiation dose
Exposure source model
Irradiation event model
Patient model
3D dose distribution
Organ models
Organ specific cancer models
Organ doses
Radiation risk
Patient specific net risk or benefit
Sarnet, Järvinen, Kortesniemi et al. 2018


• Larger scale multimodal clinical CNN architecture may accept input from a variety of data types (images, time-series, lab data,…)
• Useful featurisation for each separate data type is learned in lower-level towers of CNN
• The feature maps from each tower are then merged and brought through higher CNN layers ⇒ inference across data types
Image inputs
Temporal inputs
Multimodal inputs
Input layer
Hidden layer 1
Hidden layer 2
Hidden layer 3
Hidden layer 4
Output layer
Esteva et al. 2019


Medical imaging applications in which deep learning has achieved state-of-the-art results
MAMMO MASS
BRAIN LESION
AIRWAY TREE
BREAST CANCER
RETINOPATHY
PROSTATE
LUNG NODULE
SKIN LESION
Litjens 2017


Exponentially increasing number of radiology DL research papers 2012-2018
References per year
Year
Google Scholar search: 19 Feb 2019
"Radiology"; "Deep learning"
66
96
136
251
585
1630
3930
2012
2013
2014
2015
2016
2017
2018


Challenges of deep learning methods from imaging data to clinical parameters
1) Access to the training/validation/test data: technical, ethical and legal issues to be solved
2) Data QA and labeling: validation and standardisation of data, multi-dimensionality and heterogeneity of the data sources, provision of data labeling and annotations.
MTF
d'
AUC
S
GROUND TRUTH
TRAINING
VALIDATION
TESTING
PROSPECTIVE TRIALS
Litjens 2017, Suzuki 2017


Need for clinical verification and validation
AI technology shows considerable potential for aiding radiology's transition to value-based healthcare, but these methods must be verified & validated ⇒ shown to provide quantifiable benefits:
• improving care outcome
• increasing health
• reducing costs
• streamlining processes
• avoiding errors (patient safety)
• ensuring consistent quality
Verification = Are you building it right?
Validation = Are you building the right thing?
E.L. Ridley - AuntMinnie news 2018, Sarnet, Järvinen, Kortesniemi et al. 2018, ISO 9000, B. Boehm 1981

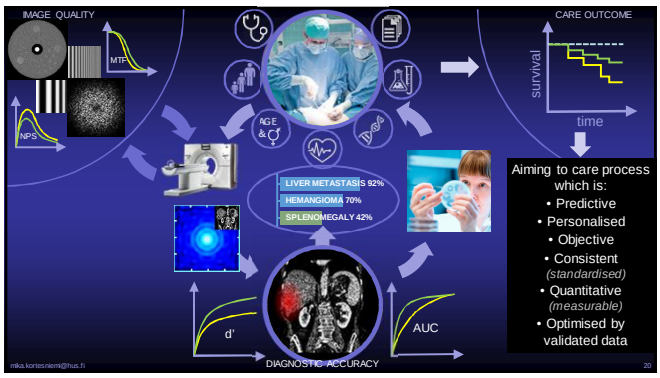


IMAGE QUALITY
MTF
NPS
CARE OUTCOME
survival
time
AGE & ♂
LIVER METASTASIS 92%
HEMANGIOMA 70%
SPLENOMEGALY 42%
Aiming to care process which is:
• Predictive
• Personalised
• Objective
• Consistent
(standardised)
• Quantitative
(measurable)
• Optimised by validated data
d'
AUC
DIAGNOSTIC ACCURACY
mika.kortesniemi@hus.fi
20


Quantified imaging quality chain towards clinical level:
➡ Higher diagnostic accuracy and effectiveness
➡ Provision of imaging biomarkers relevant to care outcome
➡ Support for continual decision-making process in healthcare
- PREDICTIVE • PERSONALISED • PREVENTIVE -
Thank you
Kiitos
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