AZIENDA OSPEDALIERO - UNIVERSITARIA
Città della Salute e della Scienza di Torino

Dipartimento di Diagnostica per Immagini e
Radiologia Interventistica
Radiologia 1 Universitaria

UNIVERSITÀ DEGLI STUDI DI TORINO
Scuola di Medicina
Dipartimento di Discipline Medico-Chirurgiche
Sezione di Radiodiagnostica

Big Data e intelligenza artificiale: la rivoluzione della diagnostica.

Paolo Fonio, Manuela Durando

Roma, 19 Maggio 2023

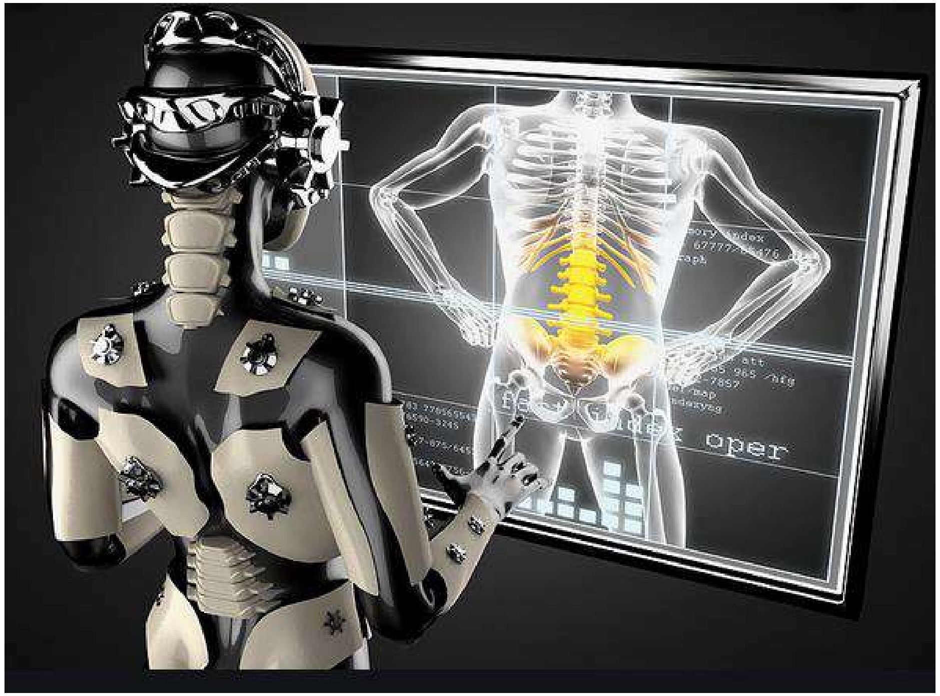
OUTLINE

- WHAT ABOUT **BIG DATA**?

- INTELLIGENZA ARTIFICIALE (**AI**)
    - MACHINE LEARNING
    - DEEP LEARNING
    - RETI NEURALI

- **AI** E APPLICAZIONI IN **DIAGNOSTICA (PER IMMAGINI)**
    - RADIOMICA
    - RADIOGENOMICA

- **AI** E APPLICAZIONI NELL'**IMAGING SENOLOGICO**



40° CONGRESSO NAZIONALE A.N.D.O.S. ROMA
18•19•20 MAGGIO 2023

L'ARTE DELLA CURA PERSONALIZZATA

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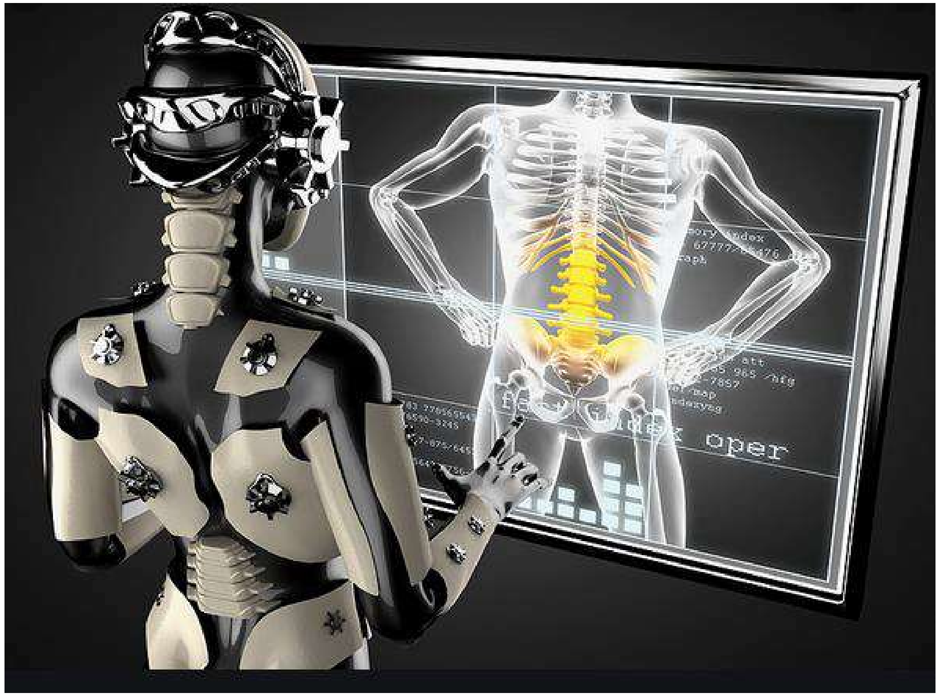

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I Big Data sono associati alle enormi risorse computazionali necessarie a far fronte all’aumento del volume e della complessità dei dati provenienti da molte fonti, come Internet e remote sensor networks.

I Big Data includono:

- informazioni strutturate
- semi-strutturate
- non strutturate
- con interrelazioni complesse (sintattiche, semantiche, sociali, culturali, economiche, e di natura organizzativa).

La cultura dei Big Data abbraccia i sistemi cyber-fisici, il cloud computing e l'Internet of Things (IoT) ovvero Industria 4.0.
Questi enormi sistemi di elaborazione dei dati spesso coinvolgono livelli significativi di automazione dei processi.

I Big Data sono spesso associati a macrosistemi su larga scala, con elaborazione distribuita dei dati che va oltre le capacità dei computer desktop locali e dei software tradizionali, a causa di vincoli imposti dalla velocità e dai volumi di elaborazione.

L'elaborazione delle informazioni è diversificata e può includere streaming di messaggi di testo, immagini, video e file musicali.

5 «V» caratteristiche dei **BIG DATA:**

- **Volume** (enorme mole di dati);
- **Varietà** (di formati e di sorgenti);
- **Velocità** (di trasmissione ed elaborazione dei dati);
- **Variabilità** (mancanza di struttura, coerenza e contesto);
- **Veridicità** (accuratezza e qualità nei dati).

BIG DATA – HEALTH CARE

Stanford MEDICINE

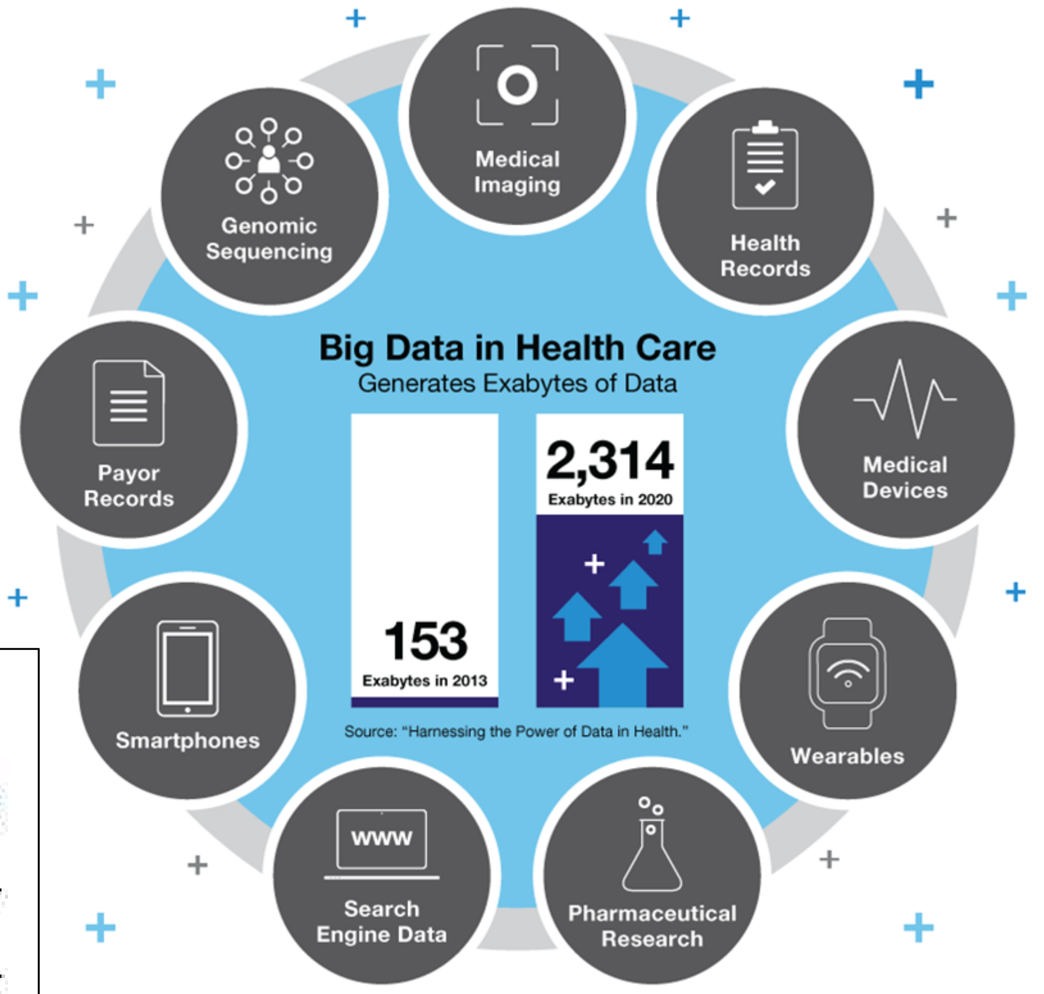
Stanford Medicine 2017 Health Trends Report

Harnessing the Power of Data in Health

The Road Ahead

The opportunities presented by data in health care are immense, but so are the obstacles the sector faces as it evolves. To move forward, the following challenges must be addressed:

- Rising costs
- Data sharing and security
- Policy and legislation



International Journal of *Environmental Research and Public Health*

MDPI

Commentary

Artificial Intelligence and Big Data in Public Health

Kurt Benke [1,2,*] and Geza Benke [3]

Int. J. Environ. Res. Public Health **2018**, *15*, 2796; doi:10.3390/ijerph15122796

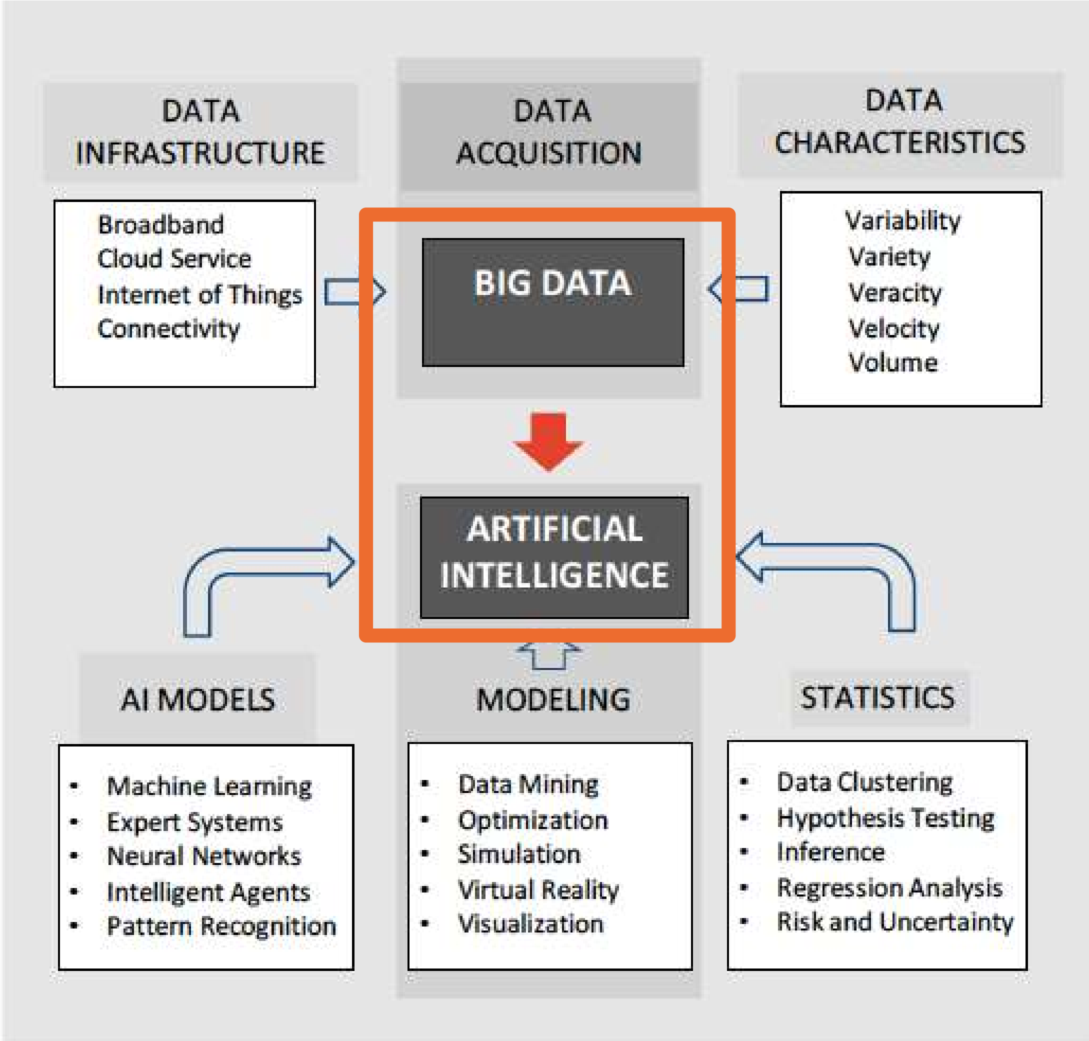
ELSEVIER

Seminars in NUCLEAR MEDICINE

Emergence of "Big Data" and its Potential and Current Limitations in Medical Imaging

Martin J. Yaffe, PhD, CM

https://doi.org/10.1053/j.semnuclmed.2018.11.010



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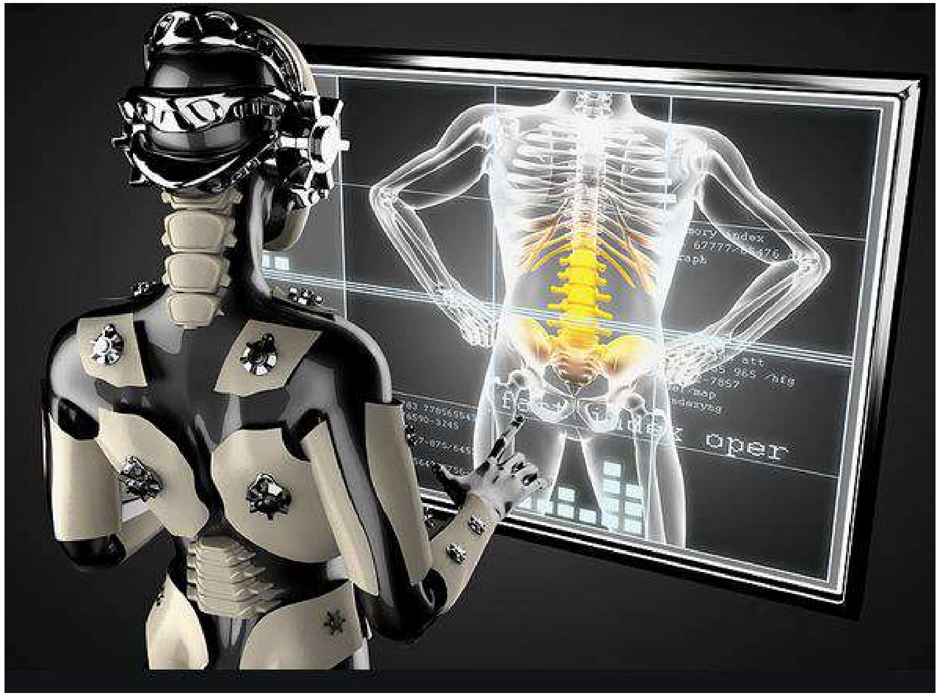

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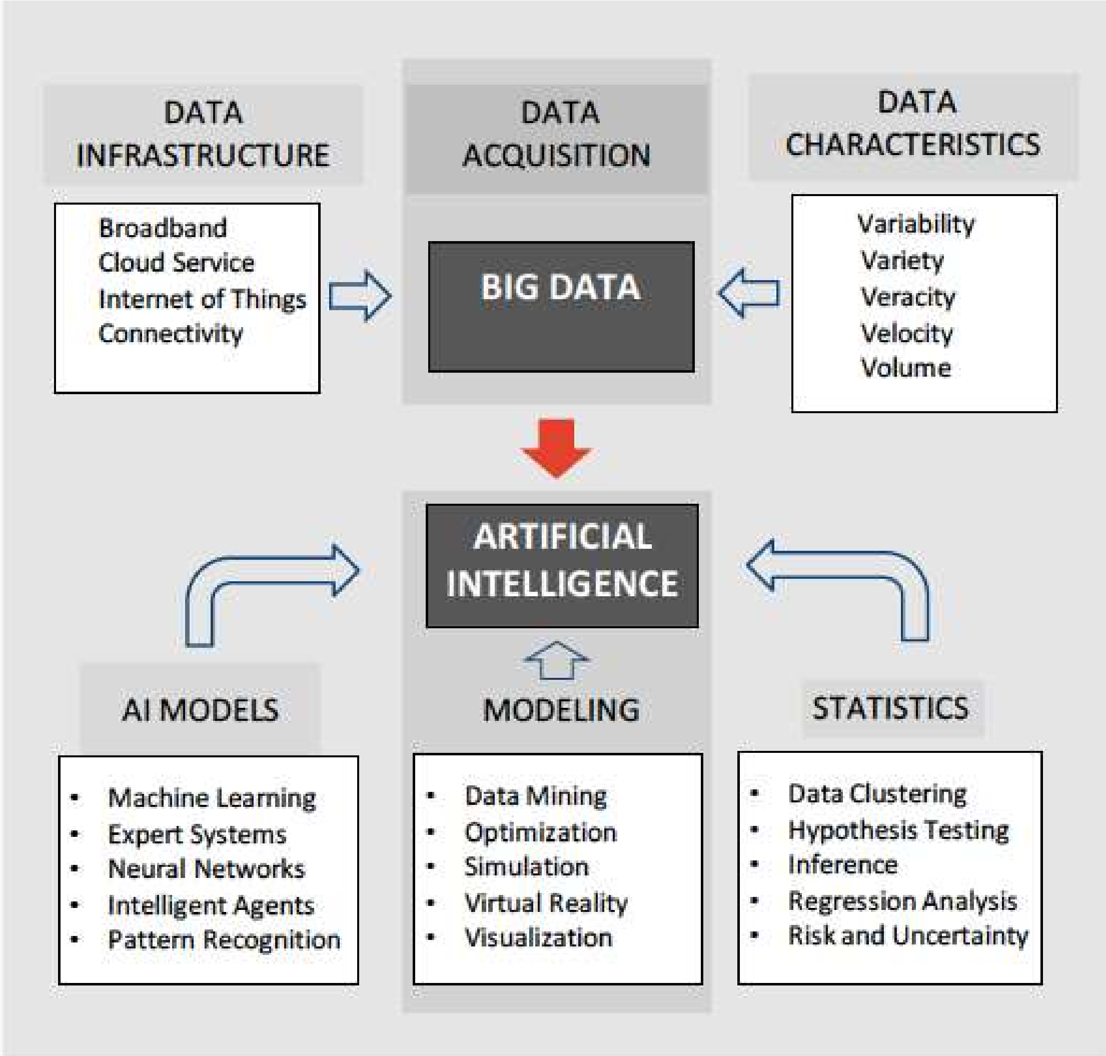
L'ARTE DELLA CURA PERSONALIZZATA

Intelligenza artificiale (AI)

È una branca della scienza informatica che ha lo scopo di dare ai computer o alle macchine alcune abilità che possano simulare l'intelligenza umana, come ad esempio imparare, risolvere problemi e assumere decisioni

"la capacità, da parte di un computer, di svolgere compiti o ragionamenti che vengono comunemente attribuiti all'intelligenza umana

"imitazione dell'intelligenza o del pattern di comportamento umani o di altre entità viventi"



Intelligenza artificiale (AI)

- Aumentare la produttività e l'efficienza dell'erogazione delle cure
- Migliorare l'attività quotidiana dei professionisti sanitari
- Incrementare l'accuratezza della diagnosi e la personalizzazione delle cure
- Velocizzare l'arrivo sul mercato di terapie efficaci
- Impatto su pazienti, professionisti e sistema sanitaria
- *Potenziali rischi*
- *Questioni etiche relative all'uso dell'AI*

Areas of impact of AI in health care

Intelligenza artificiale (AI)

- Aumentare la produttività e l'efficienza dell'erogazione delle cure
- Migliorare l'attività quotidiana dei professionisti sanitari
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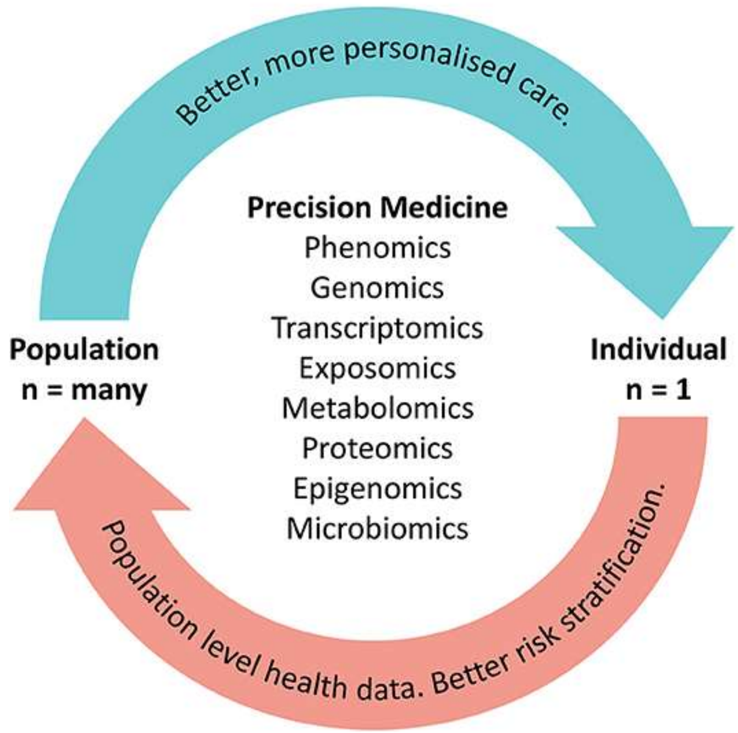
Areas of impact of AI in health care

What is precision medicine?

Precision medicine is "an emerging approach for disease treatment and prevention that takes into account individual variability in genes, environment, and lifestyle for each person." This approach will allow doctors and researchers to predict more accurately which treatment and prevention strategies for a particular disease will work in which groups of people. It is in contrast to a one-size-fits-all approach, in which disease treatment and prevention strategies are developed for the average person, with less consideration for the differences between individuals.



Bilkey GA, Burns BL, Coles EP, Mahede T, Baynam G, Nowak KJ. Optimizing Precision Medicine for Public Health. Front Public Health. 2019 Mar 7;7:42.

Intelligenza artificiale (AI)

- Aumentare la produttività e l'efficienza dell'erogazione delle cure
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Areas of impact of AI in health care

European Parliament

Manuscript completed in October 2016

LEGAL AFFAIRS

Artificial Intelligence: Potential Be Ethical Considerations

KEY FINDINGS

- The ability of AI systems to transform vast amounts of c information into insight has the potential to reveal long-held se some of the world's most enduring problems.
- However, like all powerful technologies, great care must be take and deployment. To reap the societal benefits of AI systems, we v them and make sure that they follow the same ethical princ professional codes, and social norms that we humans would follow in the same scenario. Research and educational efforts, as well as carefully designed regulations, must be put in
- International Bu as well as with make AI ethic

But trust will also require a system of best practices that can help guide the safe and ethical management of AI systems including alignment with social norms and values; algorithmic responsibility; compliance with existing legislation and policy; assurance of the integrity of the data, algorithms and systems; and protection of privacy and personal information.

BIG DATA IN BIG TROUBLE?

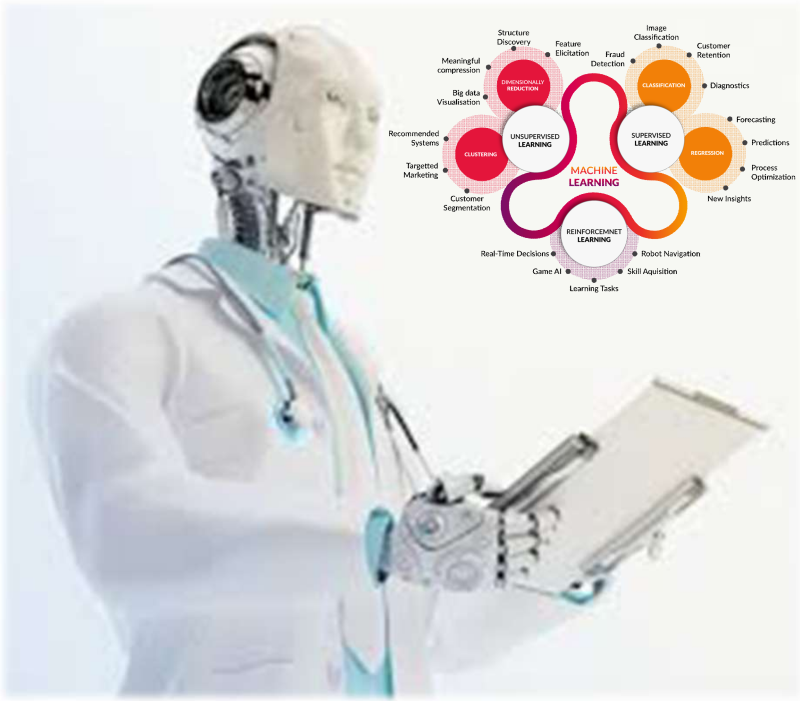
Using big data comes with its own caveats. There is still a need to establish policies to protect the data of individuals in terms of confidentiality, privacy and security, while still ensuring that advancements in science can take advantage of the vast availability and open use of data.

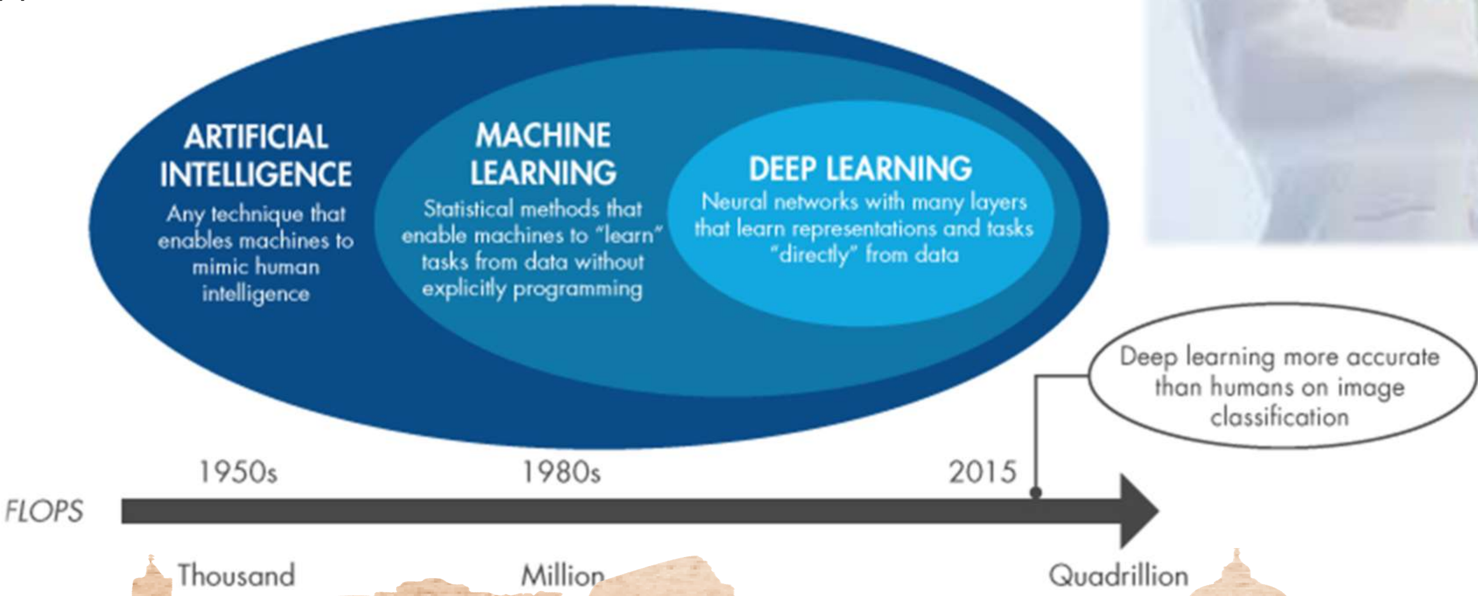
1) **the risk of inadvertent disclosure of personally identifying information**;
2) the potential for increasing dimensionality of data to make it difficult to determine if a **dataset is sufficiently de-identified** to prevent 'deductive disclosure' of personally identifying information;
3) the challenge of identifying and maintaining standards of ethical research in the face of emerging technologies that may shift the generally accepted norms regarding **privacy**

Big Data in Public Health: Terminology, Machine Learning, and Privacy. *Mooney et al, Annu Rev Public Health. 2018.*

AI E MACHINE LEARNING

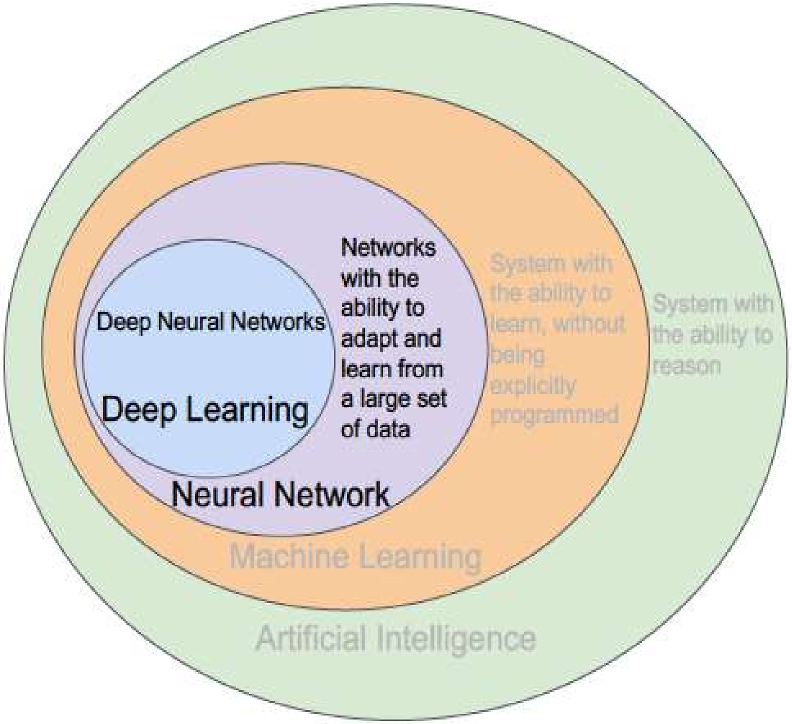
Il **Machine learning** è un’ applicazione dell’intelligenza artificiale (AI) che fornisce l’abilità dell’apprendimento automatico e del miglioramento attraverso l’esperienza, senza una programmazione esplicita. Il Machine learning si focalizza sullo sviluppo dei programmi computerizzati che possono accedere a dati ed utilizzarli per l’apprendimento.

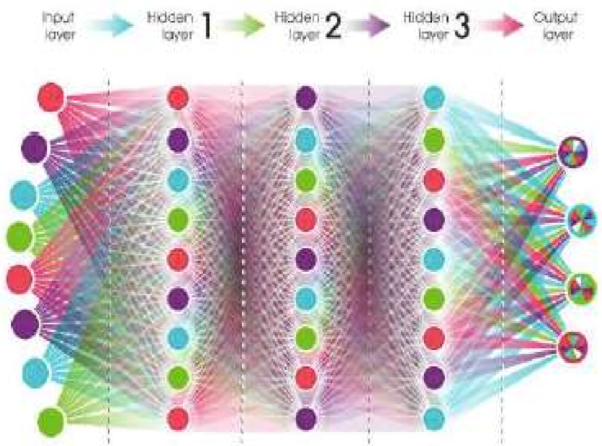


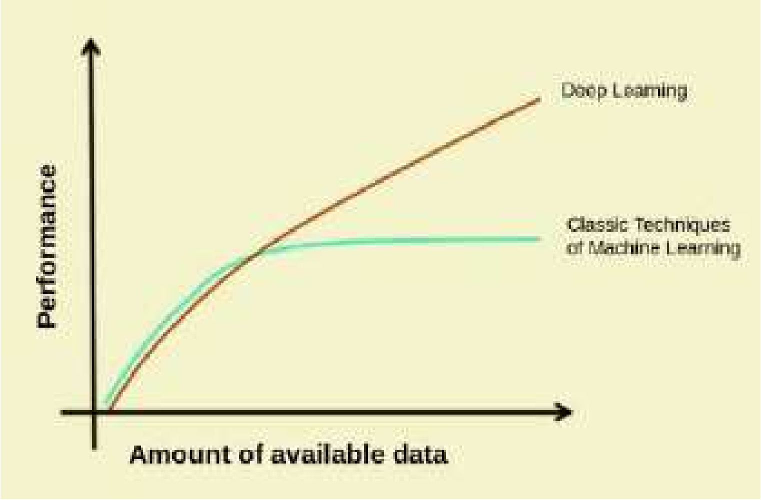


AI E DEEP LEARNING

Il Deep learning è un sottoinsieme degli algoritmi del machine learning che utilizza multiple tecniche per estrarre progressivamente features di livello sempre più alto da un input di dati grezzi.







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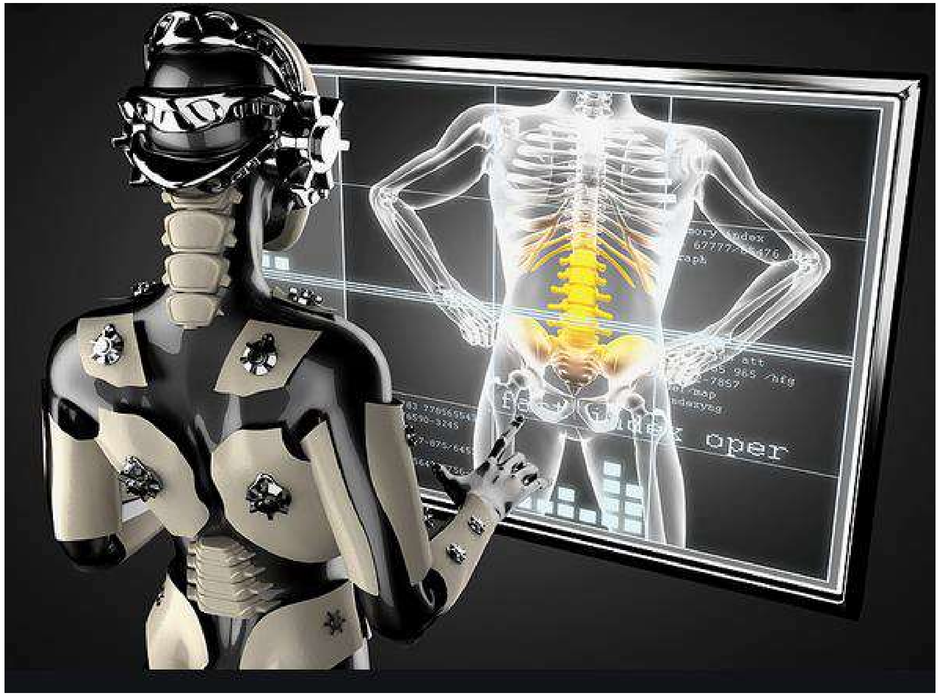


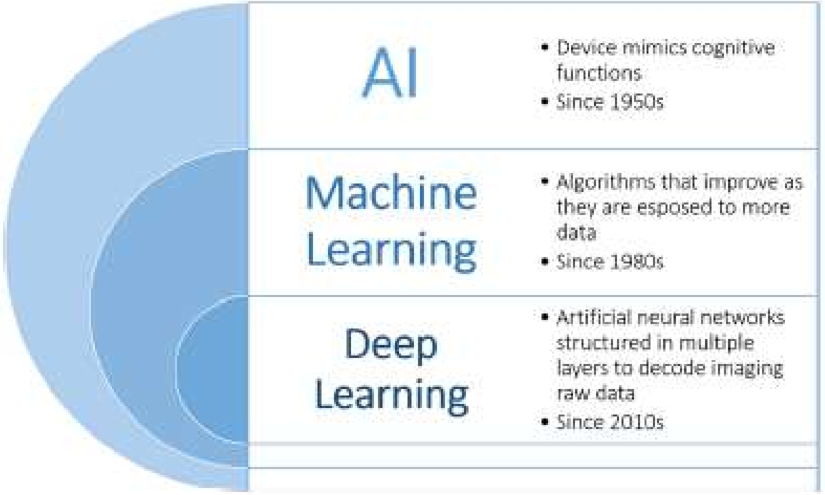
Pesapane *et al. European Radiology Experimental* (2018) 2:35
https://doi.org/10.1186/s41747-018-0061-6

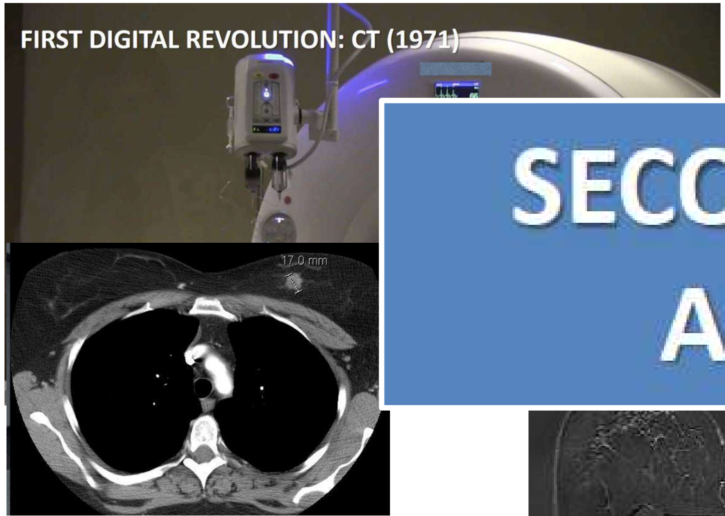
European Radiology Experimental

NARRATIVE REVIEW — Open Access

Artificial intelligence in medical imaging: threat or opportunity? Radiologists again at the forefront of innovation in medicine

Filippo Pesapane[1†], Marina Codari[2*†] and Francesco Sardanelli[2,3]





SECOND DIGITAL REVOLUTION: AI: ML/DL & RADIOMICS

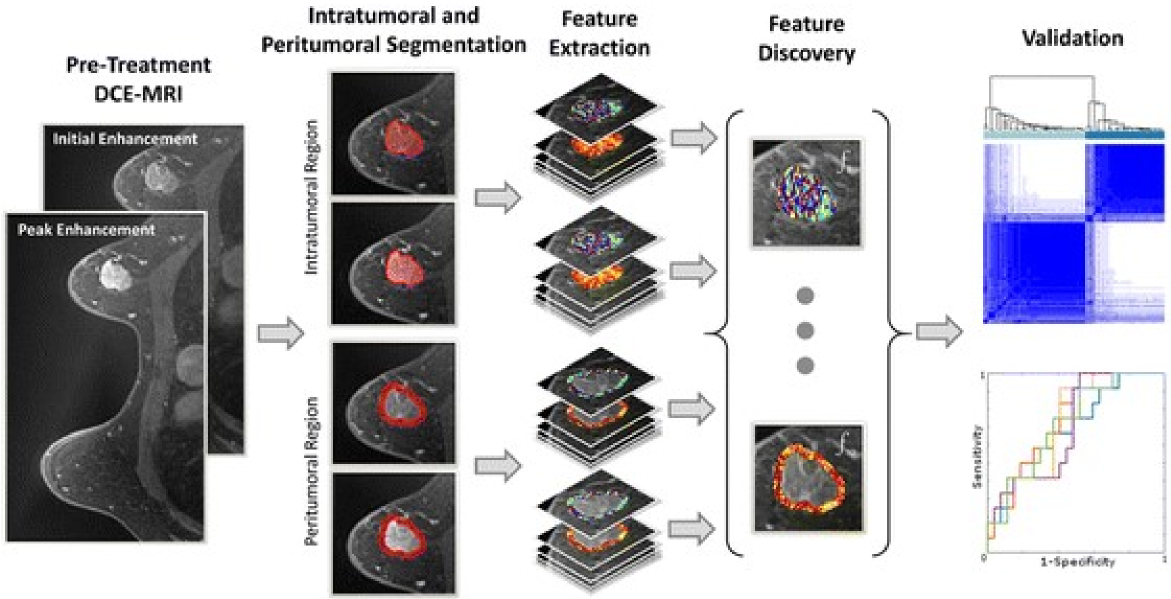
RADIOMICA

Oltre alle immagini …..

Metodi matematici e statistici per valutare:

- Intensità dei livelli di grigio
- Posizione dei pixel all'interno dell'immagine

Ricavandone <u>descrittori complessi</u>

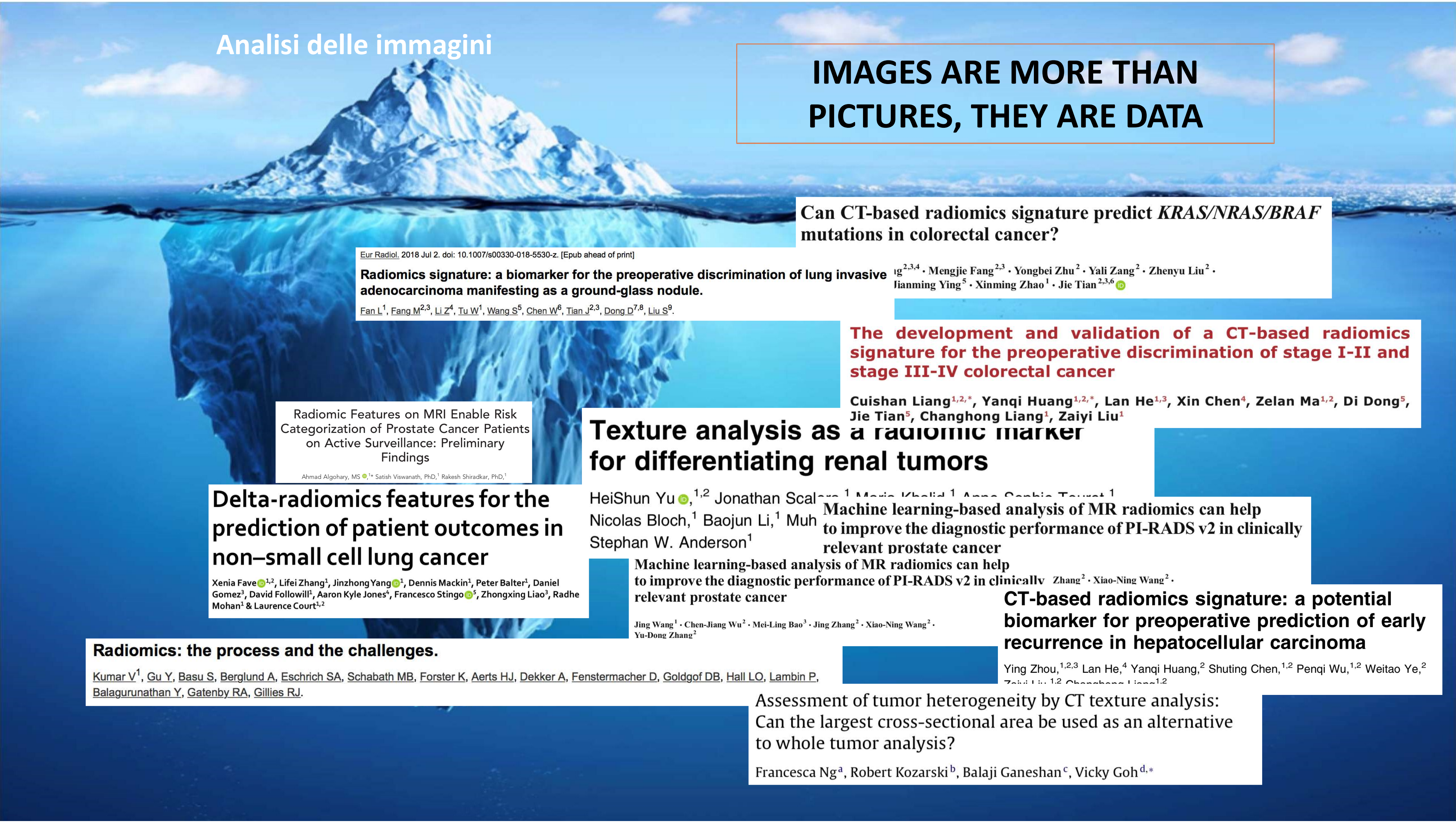


> Radiology. 2016 Feb;278(2):563-77. doi: 10.1148/radiol.2015151169. Epub 2015 Nov 18.

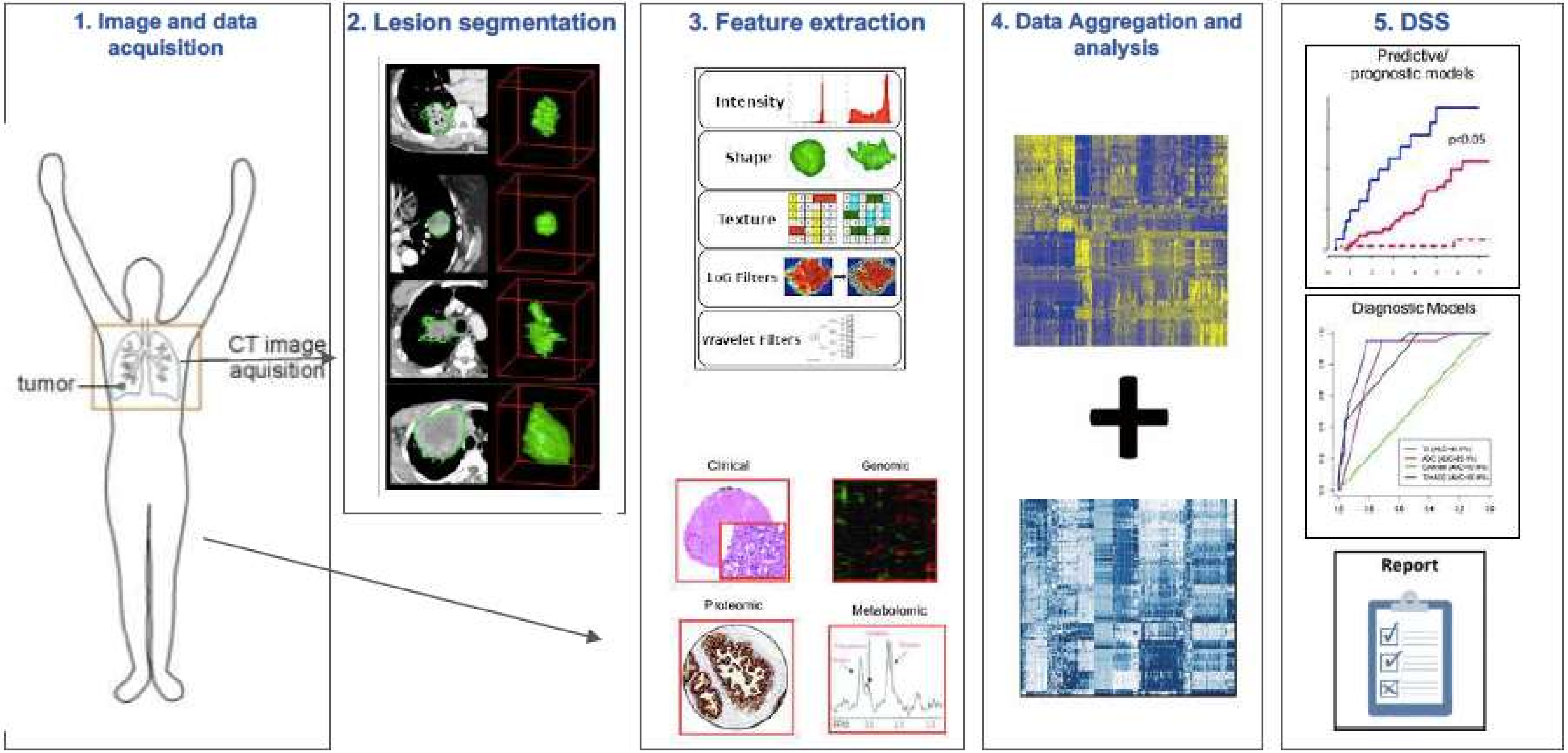
Radiomics: Images Are More than Pictures, They Are Data

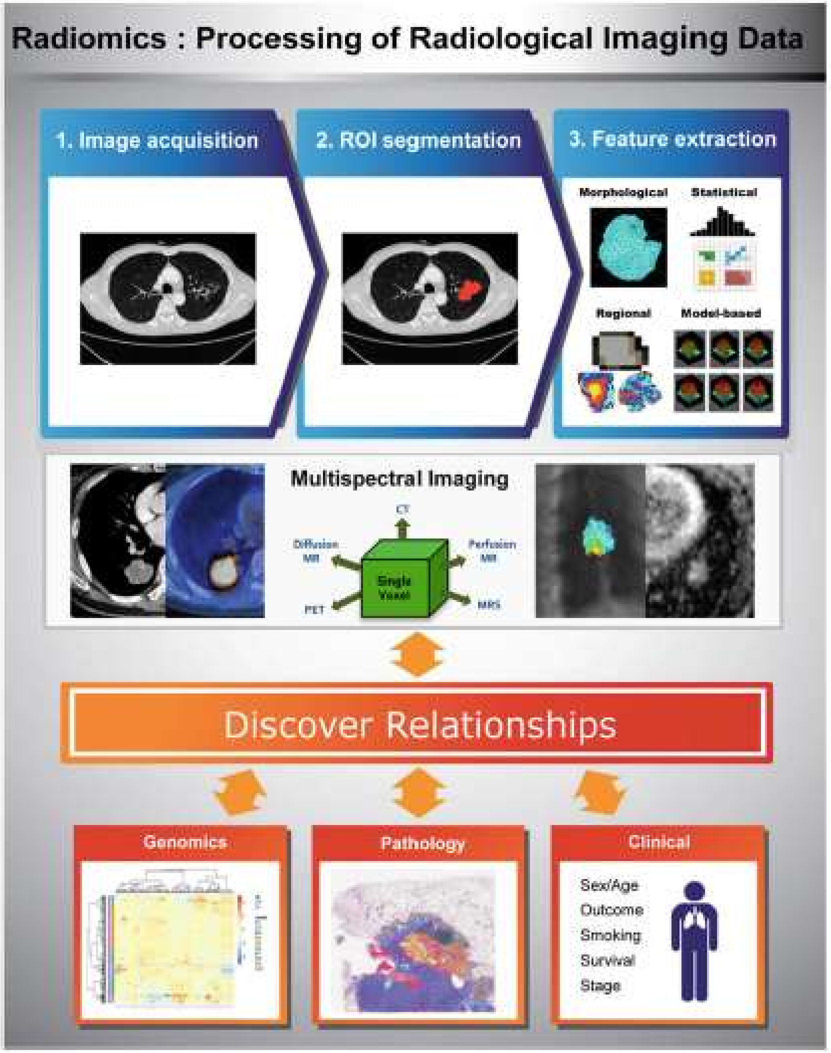
Robert J Gillies [1], Paul E Kinahan [1], Hedvig Hricak [1]

Le features estratte possono essere correlate con dati clinico-radiologici e utilizzati in nell'evidence-based decision making. La Radiomica offre un ventaglio molto ampio di biomarker di imaging che possono avere potenzialità nel riconoscimento di lesioni neoplastiche, definire la prognosi, predire la risposta al trattamento e monitorare lo stato della malattia.


Analisi delle immagini
IMAGES ARE MORE THAN PICTURES, THEY ARE DATA
Can CT-based radiomics signature predict KRAS/NRAS/BRAF mutations in colorectal cancer?
g2,3,4 · Mengjie Fang2,3 · Yongbei Zhu2 · Yali Zang2 · Zhenyu Liu2 · Jianming Ying5 · Xinming Zhao1 · Jie Tian2,3,6
Eur Radiol. 2018 Jul 2. doi: 10.1007/s00330-018-5530-z. [Epub ahead of print]
Radiomics signature: a biomarker for the preoperative discrimination of lung invasive adenocarcinoma manifesting as a ground-glass nodule.
Fan L1, Fang M2,3, Li Z4, Tu W1, Wang S5, Chen W6, Tian J2,3, Dong D7,8, Liu S9.
The development and validation of a CT-based radiomics signature for the preoperative discrimination of stage I-II and stage III-IV colorectal cancer
Cuishan Liang1,2,*, Yanqi Huang1,2,*, Lan He1,3, Xin Chen4, Zelan Ma1,2, Di Dong5, Jie Tian5, Changhong Liang1, Zaiyi Liu1
Radiomic Features on MRI Enable Risk Categorization of Prostate Cancer Patients on Active Surveillance: Preliminary Findings
Texture analysis as a radiomic marker for differentiating renal tumors
HeiShun Yu 1,2 Jonathan Scal
Nicolas Bloch,1 Baojun Li,1 Muh
Stephan W. Anderson1
Delta-radiomics features for the prediction of patient outcomes in non–small cell lung cancer
Xenia Fave1,2, Lifei Zhang1, Jinzhong Yang1, Dennis Mackin1, Peter Balter1, Daniel Gomez3, David Followill1, Aaron Kyle Jones4, Francesco Stingo5, Zhongxing Liao3, Radhe Mohan1 & Laurence Court1,2
Machine learning-based analysis of MR radiomics can help to improve the diagnostic performance of PI-RADS v2 in clinically relevant prostate cancer
Machine learning-based analysis of MR radiomics can help to improve the diagnostic performance of PI-RADS v2 in clinically relevant prostate cancer
Jing Wang1 · Chen-Jiang Wu2 · Mei-Ling Bao3 · Jing Zhang2 · Xiao-Ning Wang2 · Yu-Dong Zhang2
CT-based radiomics signature: a potential biomarker for preoperative prediction of early recurrence in hepatocellular carcinoma
Ying Zhou,1,2,3 Lan He,4 Yanqi Huang,2 Shuting Chen,1,2 Penqi Wu,1,2 Weitao Ye,2
Radiomics: the process and the challenges.
Kumar V1, Gu Y, Basu S, Berglund A, Eschrich SA, Schabath MB, Forster K, Aerts HJ, Dekker A, Fenstermacher D, Goldgof DB, Hall LO, Lambin P, Balagurunathan Y, Gatenby RA, Gillies RJ.
Assessment of tumor heterogeneity by CT texture analysis: Can the largest cross-sectional area be used as an alternative to whole tumor analysis?
Francesca Nga, Robert Kozarskib, Balaji Ganeshanc, Vicky Gohd,*

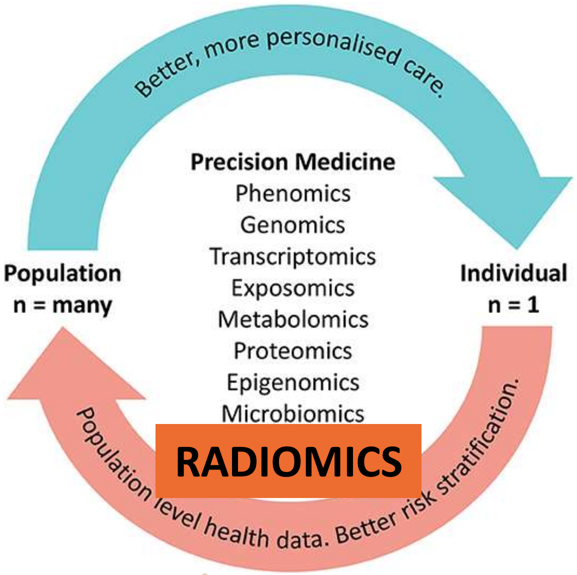
RADIOMICA


1. Image and data acquisition
tumor
CT image aquisition
2. Lesion segmentation
3. Feature extraction
Intensity
Shape
Texture
LoG Filters
Wavelet Filters
Clinical
Genomic
Proteomic
Metabolomic
4. Data Aggregation and analysis
5. DSS
Predictive/ prognostic models
p<0.05
Diagnostic Models
Report

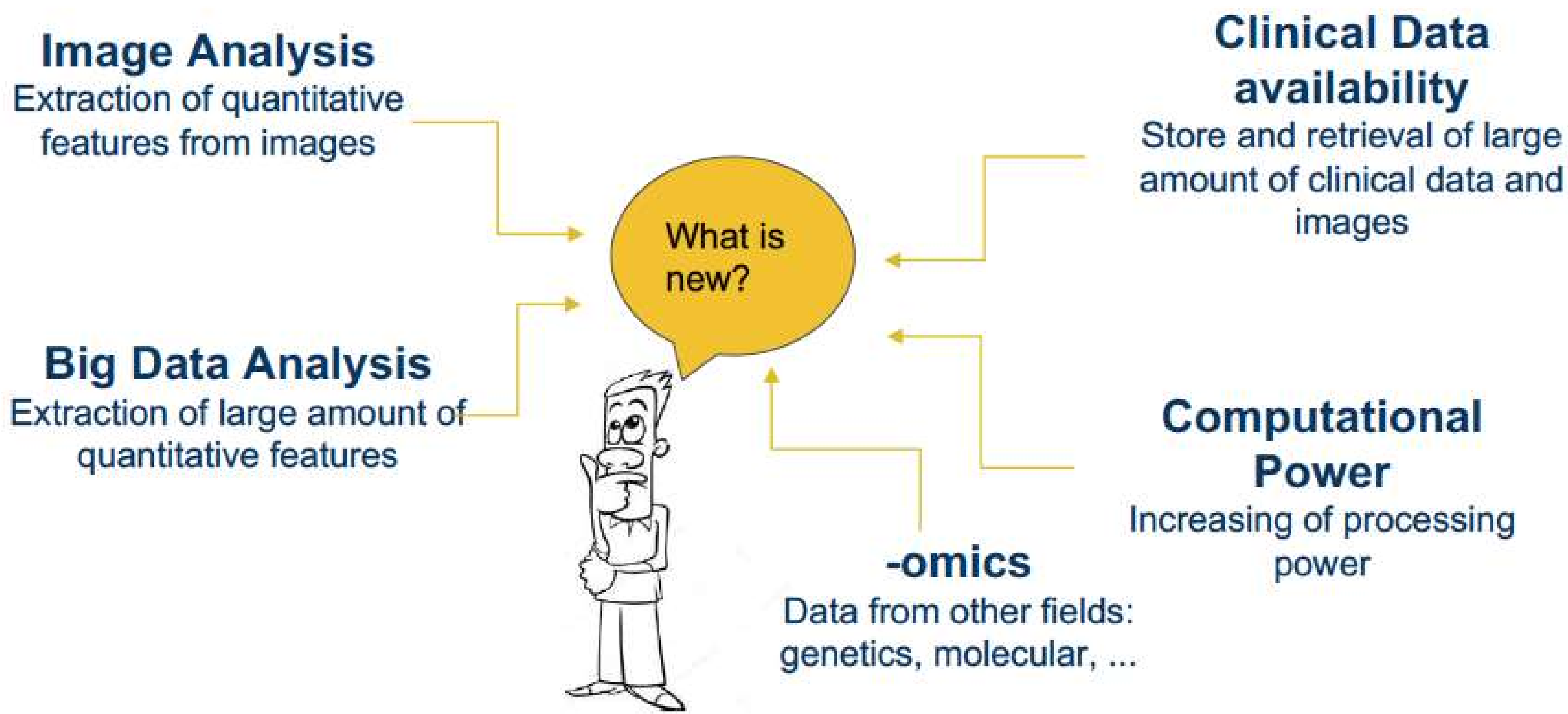


RADIOMICA

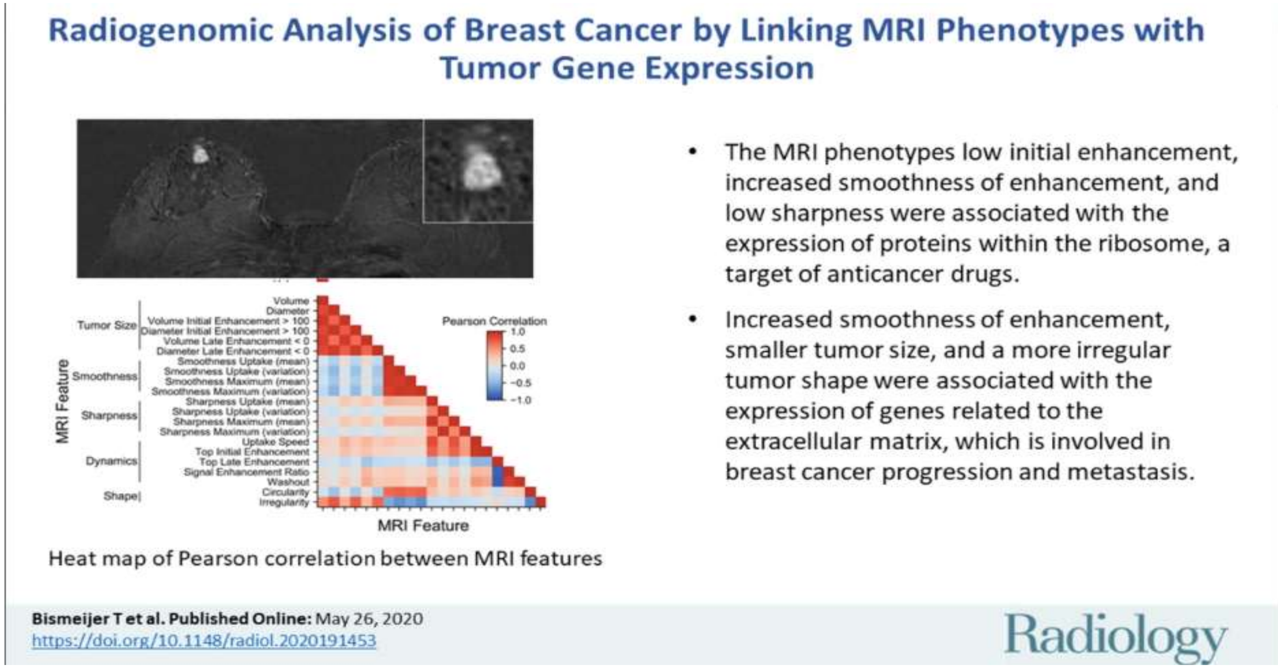
L'ipotesi della radiomica è che le caratteristiche distintive di imaging tra le forme di malattia possano essere utili per **prevedere la prognosi e la risposta terapeutica** per varie condizioni, fornendo così preziose informazioni per una terapia personalizzata.



Radiomics and Precision Medicine



RADIOGENOMICA



Approccio non invasivo con lo scopo di associare i reperti di imaging con i sottotipi molecolari, le mutazioni genetiche e altre caratteristiche correlate con i geni dei tumori.

Nell'ambito del tumore mammario (soprattutto utilizzando dati RM), si è focalizzata nel correlare dati genomici derivanti dai sottotipi molecolari, espressione genomiche individuali e score clinici di rischio di recidiva (OncotypeDx, MammaPrint, Mammostrat, PAM50/Prosigna).

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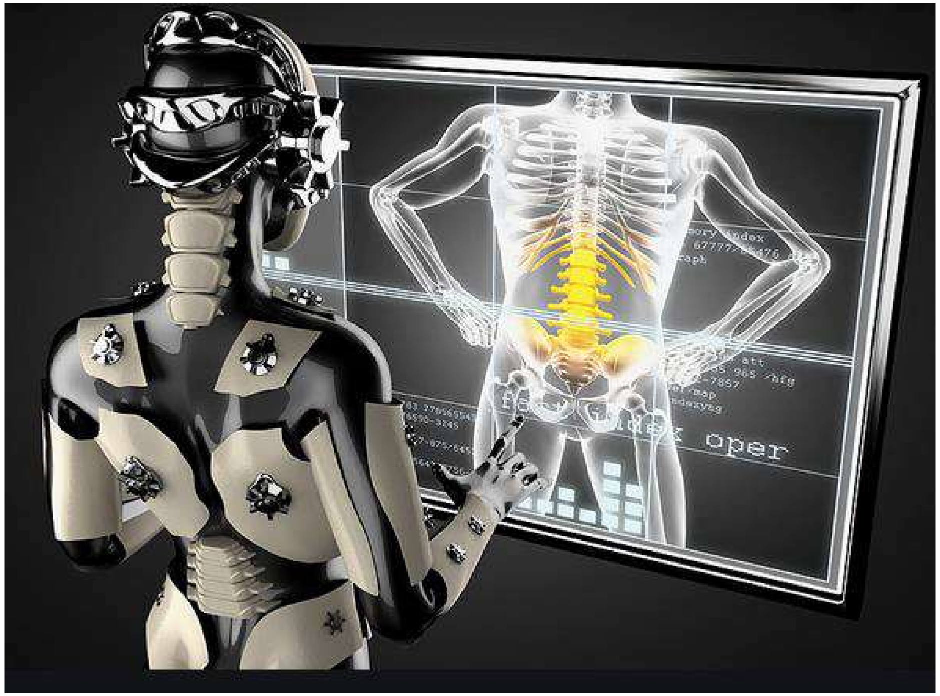

Artificial Intelligence: Is It Armageddon for Breast Radiologists?

Chiwome L, Okojie O M, Rahman A, et al. (June 30, 2020) Cureus 12(6): e8923.

Review

The Application of Radiomics

Technology in Cancer Research & Treatment
Volume 19: 1-16

Table 1. Studies on Di

First Author, Year	Study Desig
Bahreini *et al* (2010)[6]	Retrospecti
Bickelhaupt *et al* (2108)[7]	Retrospecti
Bickelhaupt *et al* (2017)[8]	Prospective
Holli *et al* (2010)[9]	Retrospecti
Hu *et al* (2018)[10]	Retrospecti
Jiang *et al* (2018)[11]	Retrospecti
Karahaliou *et al* (2010)[12]	Not mentione
Nie *et al* (2008)[13]	Retrospecti
Whitney *et al* (2019)[14]	Retrospecti
Gibbs and Turnbull (2003)[15]	Retrospecti

Table 2. Studies on

First Author, Year	Study De
Chai *et al* (2019)[16]	Retrospec
Cui *et al* (2019)[17]	Retrospec
Dong *et al* (2018)[18]	Retrospec
Han *et al* (2019)[19]	Retrospec
Liu *et al* (2019)[20]	Retrospec
Liu *et al* (2019)[21]	Prospecti

Table 3. Studies on Predicting Molecular Subtypes of B

First Author, Year	Study Design	Number of Patients	MRI Mod
Kirsi Holli-Helenius *et al* (2017)[22]	Nc		
Fan *et al*, (2018)[23]	Re		
Fan *et al* (2017)[24]	Re		
Fan *et al* (2019)[25]	Re		
Grimm *et al* (2015)[26]	Re		
Juan *et al* (2018)[27]	Re		
Ko *et al* (2016)[28]	Nc		
Liang *et al* (2018)[29]	Re		
Ma *et al* (2018)[30]	Re		
Monti *et al* (2018)[31]	Nc		
Saha *et al* (2018)[32]	Nc		

Table 4. Studies on Prediction of Tumor Response to Chemotherapy in Breast Cancer.

First Author, Year	Study Design	Number of Patients	MRI Modality	Magnetic Field	Radiomics Features	Studies Directions	Outcomes

Table 5. Studies on Prediction of Survival Outcomes in Patients With Breast Cancer.

First Author, Year	Study Design	Number of Patients	MRI Modality	Magnetic Field	Radiomics Features	Studies Directions	Outcomes
Kim *et al* (2017)[48]	Retrospective	203	DCE-MRI	1.5 T	Texture features	To determine the relationship between tumor heterogeneity assessed by means of MRI texture analysis and survival outcomes in patients with primary breast cancer.	In multivariate analysis, a higher N stage (RFS hazard ratio, 11.15 (N3 stage); *P* = .002, Bonferroni adjusted a = 0.0167), triple-negative subtype (RFS hazard ratio, 16.91; *P* = .001, Bonferroni adjusted a = 0.0167), high risk of T1 entropy (less than the cutoff values (mean, 5.057; range, 5.022-5.167], RFS hazard ratio, 4.55; *P* = .018), and T2 entropy (equal to or higher than the cutoff values (mean, 6.013; range: 6.004-6.035), RFS hazard ratio = 9.84; *P* = .001) were associated with worse outcomes.
Chan *et al* (2017)[49]	Retrospective	563	DCE-MRI	1.5 T	Not mentioned	We present a radiomics model to discriminate between patients at low risk and those at high risk of treatment failure at long-term follow-up based on eigentumors.	The ROC curves of the model yielded AUC values of 0.88, 0.77 and 0.73, for the training, leave-one-out cross-validated and bootstrapped performances, respectively.
Drukker *et al* (2018)[50]	Not mentioned	162	DCE-MRI	1.5 T	Not mentioned	To predict recurrence-free survival "early on" in breast cancer neoadjuvant chemotherapy.	The C-statistics for the association of METV with recurrence-free survival were 0.69 with 95% confidence interval of 0.58-0.80 at pretreatment and 0.72 (0.60-0.84) at early treatment. The hazard ratios calculated from Kaplan-Meier curves were 2.28 (1.08-4.61), 3.43 (1.83-6.75), and 4.81 (2.16-10.72) for the lowest quartile, median quartile, and upper quartile cutpoints for METV at early treatment.
Park *et al* (2018)[51]	Retrospective	294	DCE-MRI	1.5T	Morphological, histogram-based features, and higher-order texture features.	To develop a radiomics signature to estimate DFS in patients with invasive breast cancer and to establish a radiomics nomogram that incorporates the radiomics signature and MRI and clinicopathological findings.	The radiomics nomogram estimated DFS (C-index, 0.76; 95% confidence interval (CI): 0.74-0.77) better than the clinicopathological (C-index, 0.72; 95% CI: 0.70-0.74) or Rad-score only nomograms (C-index, 0.67; 95% CI, 0.65-0.69).
Pickles *et al* (2016)[52]	Retrospective	112	DCE-MRI	3.0 T	Texture, shape features	To determine if associations exist between pretreatment DCE-MRI and survival intervals and compare the prognostic value of DCE-MRI parameters against traditional pretreatment survival indicators.	Accuracy of risk stratification based on either traditional (59%) or DCE-MRI (65%) survival indicators performed to a similar level. However, combined traditional and MR risk stratification resulted in the highest accuracy (86%).

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Opportunities in Breast Imaging: Clinical needs and possible AI solutions

CLINICAL NEEDS	AI ROLE
1. Personalized screening	BC risk stratification
2. More efficient screening	AI reader, reduced human time
3. Reducing biopsy rate of benign lesions	Lesion classification (mal vs. ben)
4. Personalized therapy	Cancer "molecular" characterization
5. Prediction of response to NAC	Advanced image analysis

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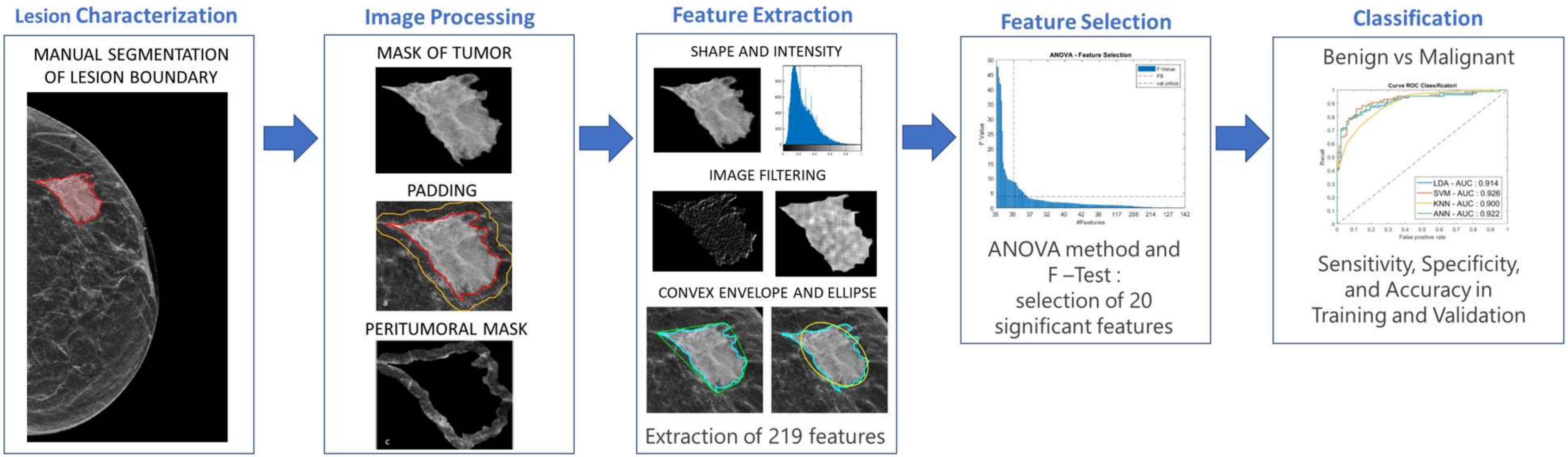
ECR 2022 / C-21877

Machine Learning Algorithm in Tomosynthesis and Synthetic Mammography Images: a Decision Support System for the characterization of breast masses lesions



AI E APPLICAZIONI NELL'**IMAGING SENOLOGICO**

AZIENDA OSPEDALIERO - UNIVERSITARIA
Città della Salute e della Scienza di Torino

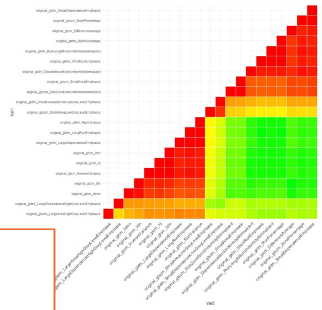
ANALYSIS OF RADIOMIC FEATURES IN THE MRI ASSESSMENT OF THE RESPONSE TO NEOADJUVANT CHEMOTHERAPY IN PATIENTS WITH TRIPLE-NEGATIVE BREAST CANCER

N. **Damiani**, F. Galioto, M. Durando, G. Bartoli, V. Rossetti, E. Regini, I. Landolfi, P. Fonio, O. Rampado.

Department of Diagnostic Imaging and Interventional Radiology
University of Turin, Turin/IT

Results – *pCR (multivariate analysis)*

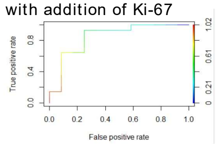
- Radiomic features correlation in the **subtraction images.**



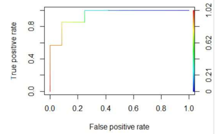
a) Predictive model obtained with 3 Radiomic features (glcm_Id, glrlm_LongRunEmphasis e glszm_SmallAreaLowGrayLevelEmphasis);

b) Predictive model obtained with addition of Ki-67 index.

a) AUC = 0,84



b) AUC = 0,94



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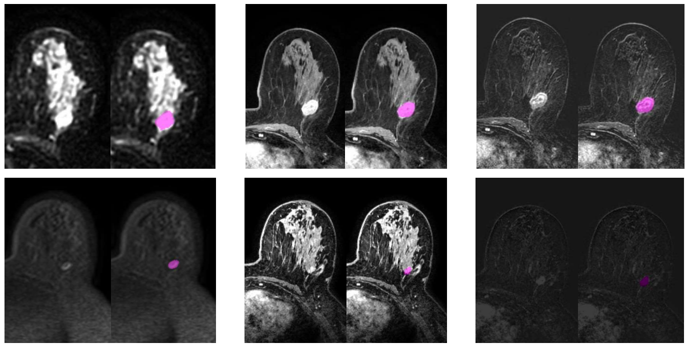
Methods – *Lesions Segmentation*

- *Pre*Treatment
- *Post*Treatment



- Manually drawn ROI on the lesions in DWI and DCE (5th acquisition after mdc injection and the 3rd subtraction images) with software LIFEX 7.1, analysed with Py-Radiomics (Python package).

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AI as an opportunity….

Pesapane *et al. European Radiology Experimental* (2018) 2:35
https://doi.org/10.1186/s41747-018-0061-6

European Radiology Experimental

NARRATIVE REVIEW Open Access

Artificial intelligence in medical imaging: threat or opportunity? Radiologists again at the forefront of innovation in medicine

Filippo Pesapane[1†], Marina Codari[2*†] and Francesco Sardanelli[2,3]

AI will not replace radiologists.
Yes, those radiologists who take advantage of the potential of AI will replace the ones who refuse this crucial challenge

Grazie per l'attenzione

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Grazie Comitato Torino

40 CONGRESSO NAZIONALE A.N.D.O.S. ROMA

18•19•20 MAGGIO 2023

L'ARTE DELLA CURA PERSONALIZZATA

Radiomics role in the clinics

- Imaging is routinely performed for oncological patients:
  - diagnosis
  - treatment planning
  - follow-up

  - large amount of retrospective data
  - database continuously updated
  - no additional cost

- Imaging is not invasive and minimally detrimental:
  - invasive alternative: biopsy or blood sampling

  no additional patient discomfort

- Radiomics quantifies the properties of the whole volume:
  - reduce risk of under -sampling as compared to e.g. biopsy

  more complete information

- Differentiate malignant/benign tissue
- Tumor staging: differentiate between early and advanced stage disease
- Prognostic models: correlation with survival
- Predictive models: predict treatment response (chemoterapy, radiation therapy)
- Assessment of metastatic potential of tumors
- Assessment of cancer genetics / biological or histopathological properties (biological basis of clinical application of radiomics)
- Improve predictivity of models based on clinical, biological, genetic data

Radiomics challenges

- Volume segmentation
- Dimension of volume
- Rigorous methodology
- Standardization
- Redundancy