Artificial Intelligence in Medicine

Multi-algorithm approach for real-life clinical applications

Francesco Sensi
next_AIM annual meeting
14.02.2023, Milano

DORIAN TECHNOLOGIES srl (Diagnosis ORIented ANalysis)

DORIAN delivers a fast and reliable tool for the **quantification** of medical imaging to support the early and differential diagnosis of neurodegenerative disorders. It provides clinicians and researchers with state-of-the-art robust, rater-independent and reproducible quantitative biomarkers to **better evaluate** dementias stage and progression, **complementing** their ability to write informed medical reports and improve on the early detection and diagnosis of neurodegenerative diseases.

Dorian recent activity

> Fondazione spin-off	[May 2020]
> Lab sessions @ Nucl. Med. school in Neurology	[Sep. 2021]
> EBAN finalist	[Mar.2022]
> Unicredit StartLab 3rd classified	[May 2022]
>> Amazon AWS academy invitation	[Sep. 2022]
> Lab sessions @ Nucl. Med. school in Neurology	[Oct. 2022]
> First fulfilled contract	[Dec. 2022]


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Near future diagnostics

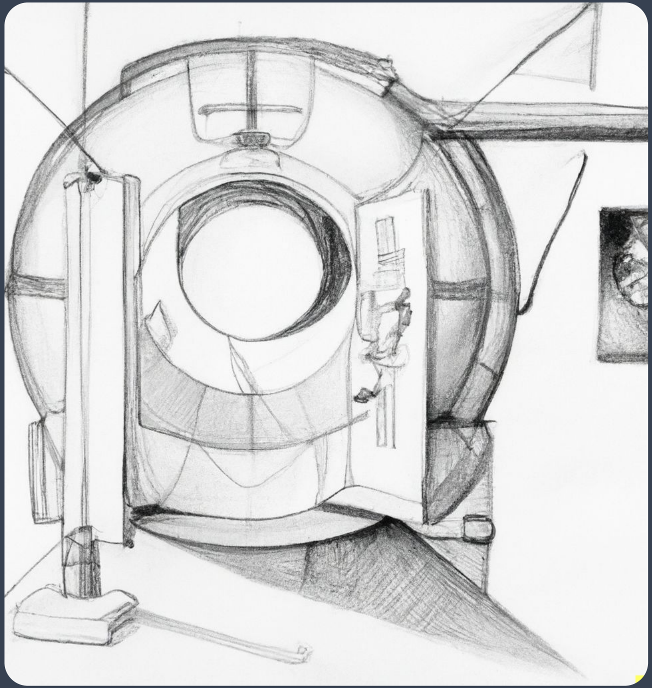
Increasing flow of information...

New acquisition technologies (Ultra-high efficiency PET/SPECT, multi-technology PET/SPECT/CT/MRI integration, software-driven spatial resolution) will raise the number of scans/time unit

Ever evolving radioligands and off-label uses will strain the health systems and demand constantly training experts

Increasing pressure to use advanced processing systems to complement and sometimes replace the diagnostic process

...shift to data-driven medicine



AI..*Hype or Hope?*

Technical issues

- Data heterogeneity
- big data in medicine are never that “big”
- the gold standard uncertainty
- clinical validation ≠ algorithm validation
- interpretability

“Social” issues

The impressive advances in other application fields

- suggest that the same can happen in any field
- spun the belief in the golden age of AI
- fosters the blind trust in what comes out

Fosso Wamba, S. (2022). Impact of artificial intelligence assimilation on firm performance: The mediating effects of organizational agility and customer agility. IJIM

Adam, H.,et al., (2022). Mitigating the impact of biased artificial intelligence in emergency decision-making. Communications Medicine

Kordzadeh, N. et al., (2022). Algorithmic bias: review, synthesis, and future research directions. European Journal of Information Systems

The Ethics of Artificial Intelligence in Healthcare and Research NordFosk Event (DK) (2021)

Ahmad, Z. et al., (2021). Artificial intelligence (AI) in medicine, current applications and future role with special emphasis on its potential and promise in pathology: present and future impact, obstacles including costs and acceptance among pathologists, practical and philosophical considerations. A comprehensive review. Diagnostic Pathology

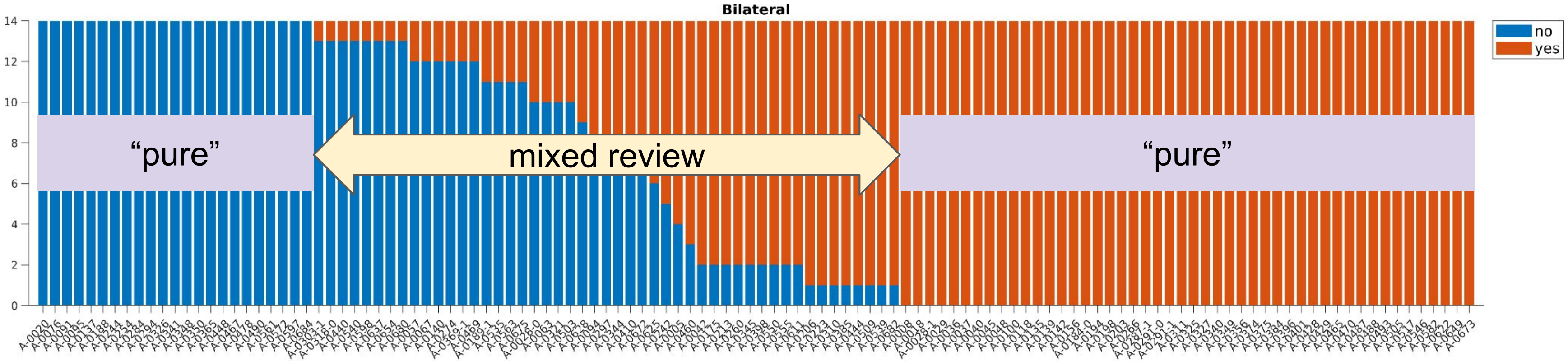
Keris, M. P. (2020). Artificial intelligence in medicine creates real risk management and litigation issues. Journal of Healthcare Risk Management

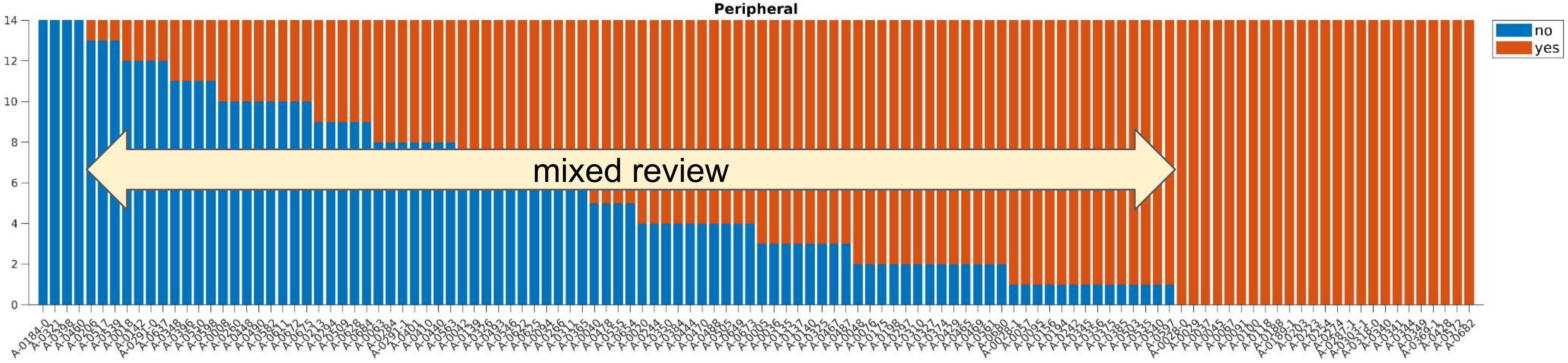
Jung, C. L. (2019). The perils of artificial intelligence in healthcare: Disease diagnosis and treatment. Journal of Computational Biology and Bioinformatics Research

Kabir, M. (2019). Does artificial intelligence (AI) constitute an opportunity or a threat to the future of medicine as we know it? Future Healthcare Journal

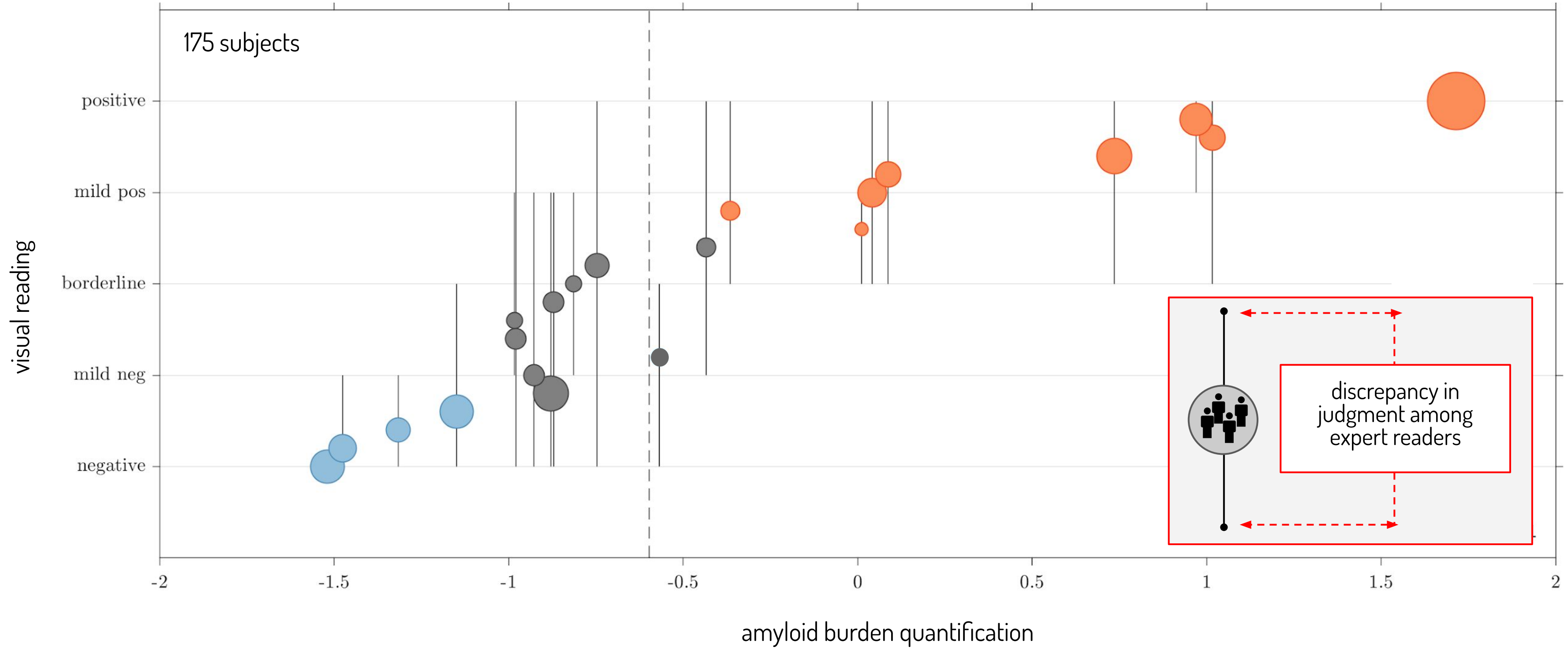
McCartney, M. (2018). Margaret McCartney: AI in medicine must be rigorously tested. BMJ, k1752

Gold standard uncertainty





Gold standard uncertainty



Chincarini et al.. "Semi-quantification and grading of amyloid PET: A project of the European Alzheimer's Disease Consortium (EADC)". Neuroimage: Clinical. 2019

An alternative approach

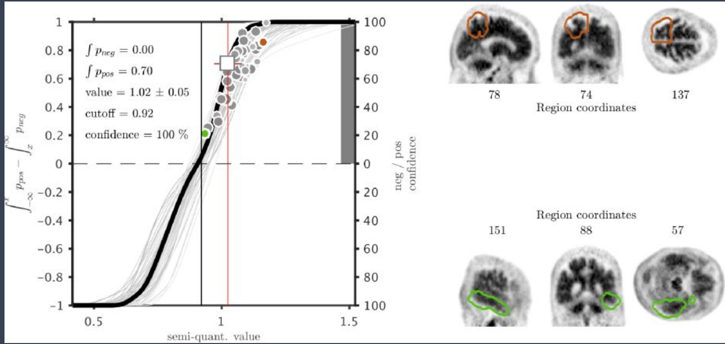
1. **include** clinicians/NM experts in the process from the beginning
2. do not trust AI only, but **integrate** with standard methodologies
3. aim at **quantification** (i.e. a direct product of the exam, open to interpretation) rather than at the diagnostic label (the outcome of a more complex process often involving several experts, difficult to challenge)
4. train users & **explain** algorithms
5. keep implementation **simple** (do not rely on local computational resources)

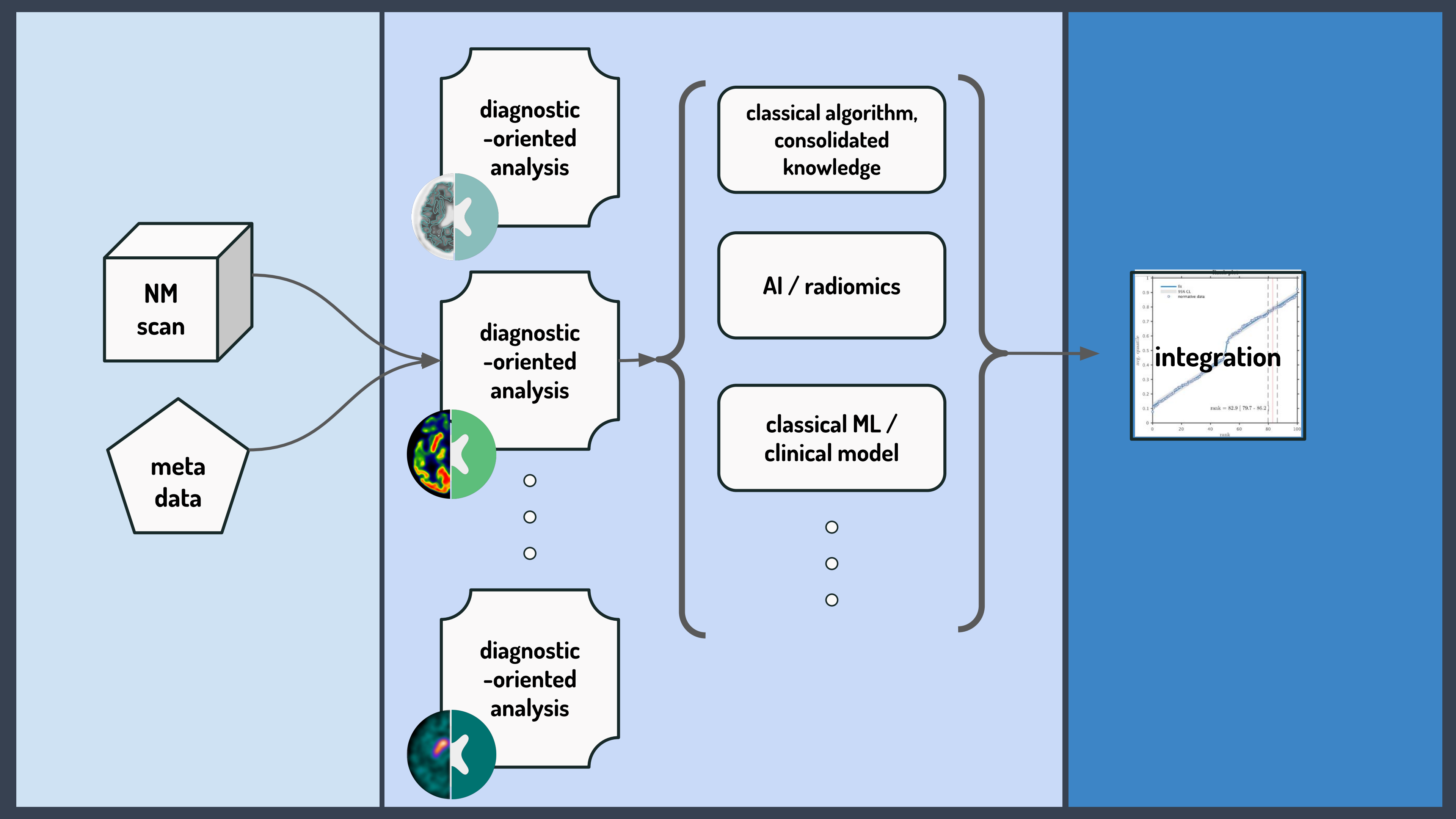
DOlab framework

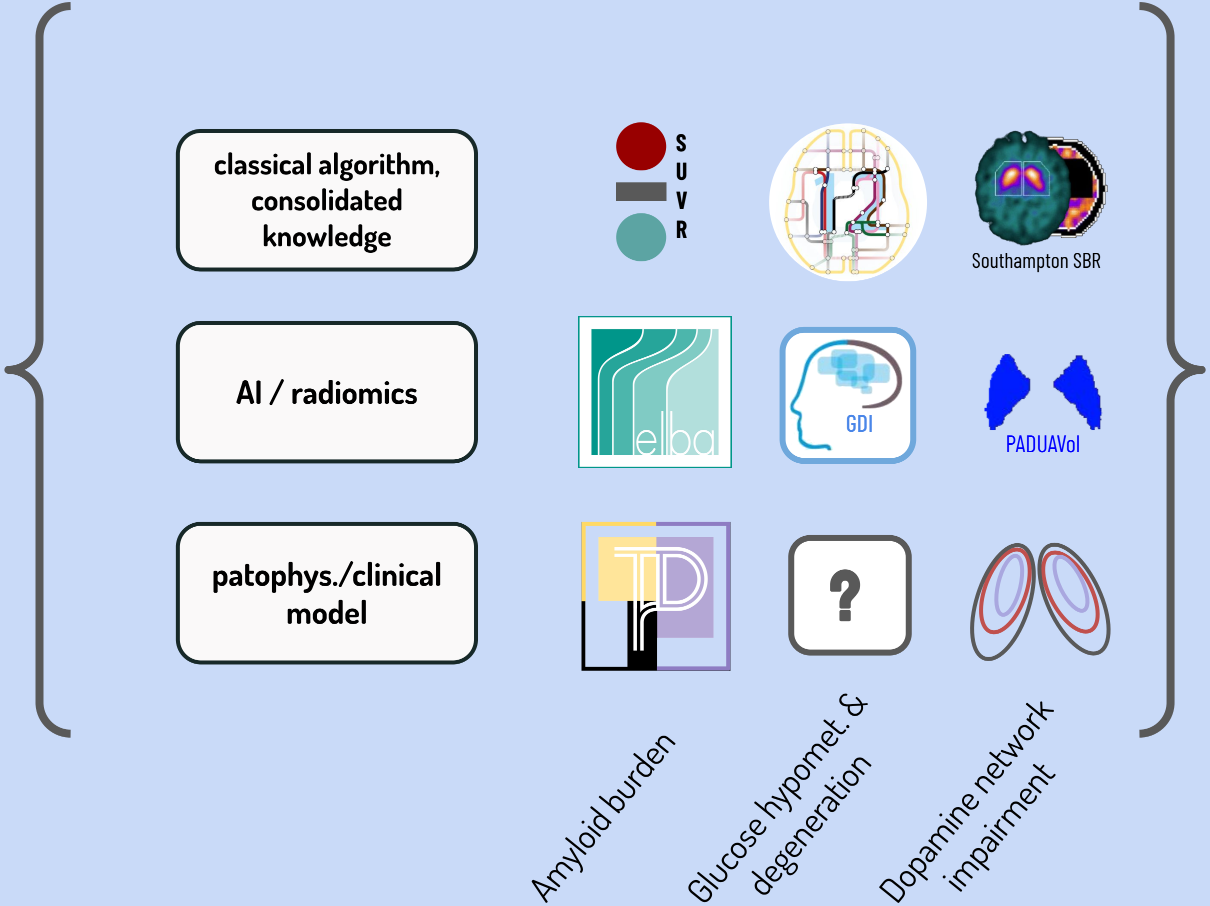
The framework consists of:

- Analysis pipeline with
  - at least one **standard**, non-AI analysis method based on solid clinical evidence and rooted in the consolidated practice;
  - a **fully data-driven** approach using AI, radiomics and sophisticated algorithms;
  - an algorithm that encapsulates **clinical or physiological models** as part of the analysis.

- Model validation on multi-center dataset (~1000 clinically validated cases) → real world/generalizable
- A-posteriori validation by a set of expert clinicians in a consensus round
- Comprehensive model and graphical representation to ensure that any conclusion is robust, trustworthy, and ethical




NM
scan
meta
data
diagnostic
-oriented
analysis
diagnostic
-oriented
analysis
diagnostic
-oriented
analysis
classical algorithm,
consolidated
knowledge
AI / radiomics
classical ML /
clinical model
integration



classical algorithm, consolidated knowledge
AI / radiomics
patophys./clinical model
SUVR
Southampton SBR
elba
GDI
PADUAVol
?
Amyloid burden
Glucose hypomet. & degeneration
Dopamine network impairment

Measures integration

European Journal of Nuclear Medicine and Molecular Imaging (2022) 49:4097–4108
https://doi.org/10.1007/s00259-022-05846-1

ORIGINAL ARTICLE

A comparison of advanced semi-quantitative amyloid PET analysis methods

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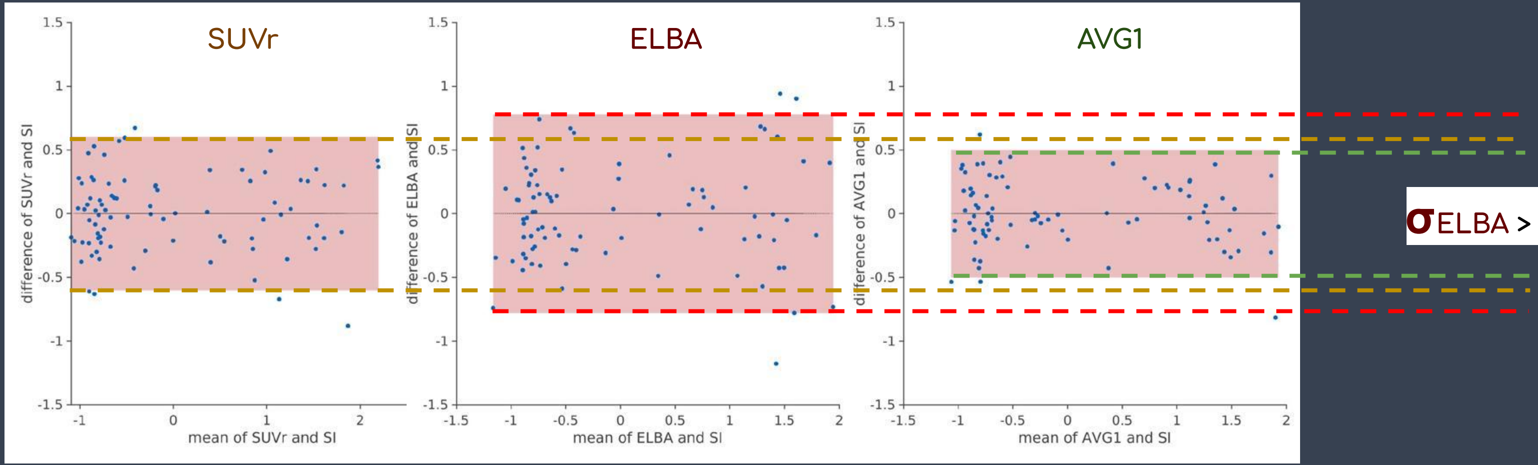
Abstract
Purpose To date, there is no consensus on how to semi-quantitatively assess brain amyloid PET. Some approaches use late acquisition alone (e.g., ELBA, based on radiomic features), others integrate the early scan (e.g., TDr, which targets the area of maximum perfusion) and structural imaging (e.g., WMR, that compares kinetic behaviour of white and grey matter, or SI based on the kinetic characteristics of the grey matter alone). In this study SUVr, ELBA, TDr, WMR, and SI were compared. The latter — the most complete one — provided the reference measure for amyloid burden allowing to assess the efficacy and feasibility in clinical setting of the other approaches.
Methods We used data from 85 patients (aged 44–87) who underwent dual time-point PET/MRI acquisitions. The correlations



σ ELBA > σ SUVr > σ AVG1

AVG1 : SUVr, ELBA

AVG2 : SUVr, ELBA, TDr

AVG3 : SUVr, ELBA, TDr, WMR

Peira, E., et al (2022), A comparison of advanced semi-quantitative amyloid-PET analysis methods

Quantifiers vs *Gold-standard measurement* correlation

Quantifiers vs Visual reading agreement (AUC)

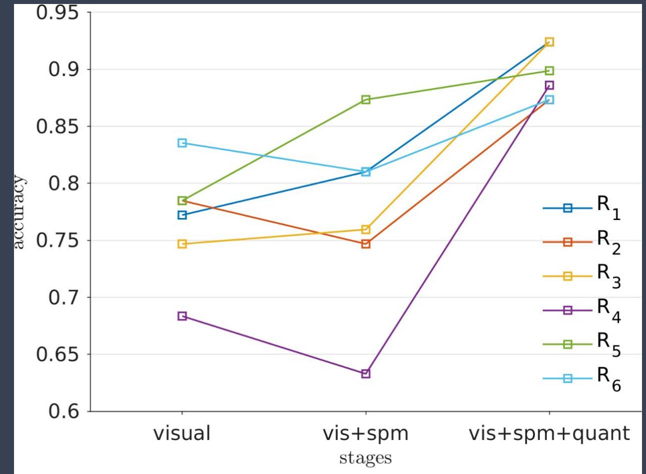
Choosing quantification

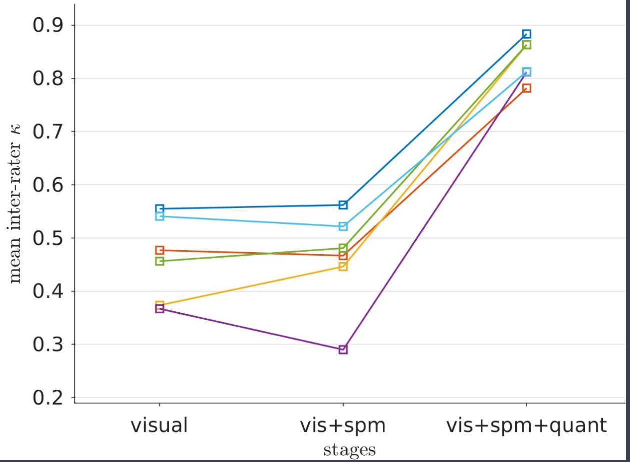
The key ingredient is to use the algorithm not to deliver a definite answer in terms of patient condition or disease probability, but to provide robust and reliable quantification.

Quantification is the mean to leverage standard and more sophisticated Ai-driven approaches without overstepping the boundary between the clinician expertise and its duty to interpret and deliver the diagnosis:

- quantification enables practitioners to visualize and measure data more accurately, allowing for greater precision in diagnosis and treatment decisions;
- it allows physicians to identify subtle differences between healthy and unhealthy tissue, leading to better disease management and earlier intervention;
- it can help reduce radiation exposure by enabling doctors to limit the amount of time they spend performing scans;
- with quantification, it is possible to track changes over time, making long-term monitoring easier;
- quantification also facilitates patient education about their condition and helps improve communication between healthcare providers and patients.

Benefits of quantification



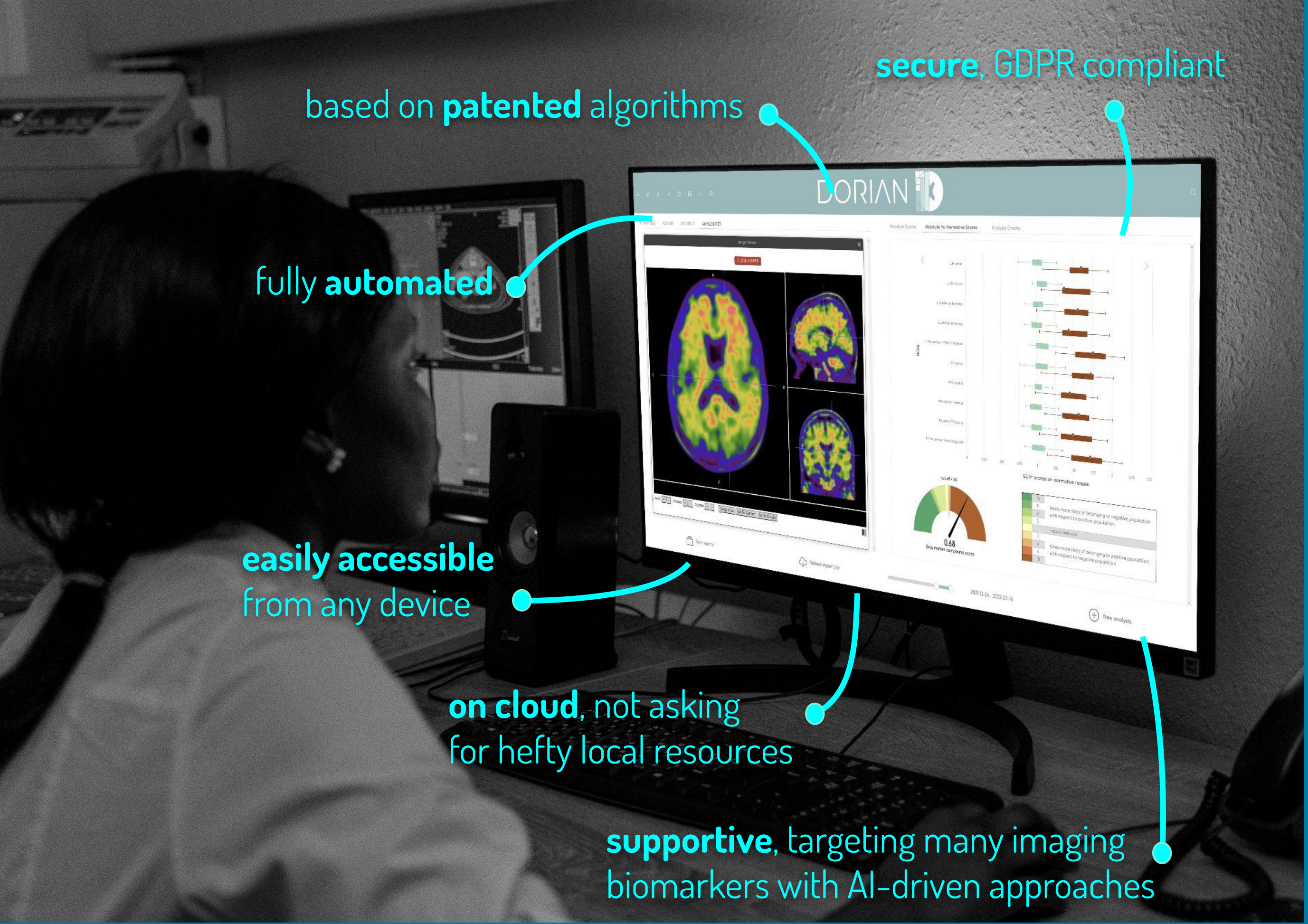


Inter-rater agreement of 6 expert clinicians in the differential assessment of 100 FDG-PET cases, which have been confirmed with a diagnosis of MCI-LB or MCI-AD.

The accuracy and agreement (w Cohen's *k*) of each clinician is plotted with respect to 3 different diagnostic settings:

1. "visual": PET data is presented as acquired,
2. "vis+spm" where the PET data is presented together with a consolidated semi-quantification algorithm
3. "vis+spm+quant" where the PET data and semi-quantification are complemented with a third machine learning-based method, and a comprehensive analysis is presented to the clinician.

The added information and its synthesis not only **improves the accuracy** of the single clinician with respect to the true diagnosis, but it also delivers a much **higher intra-rater agreement**.



Our **one-stop shop solution** for **everyday quantitative diagnostic** imaging

REDUCE <

misdiagnosis from 30% to 1%

IMPROVE <

accuracy in patient monitoring by 20%

SPEED UP <

the image analysis time by 90%

DOlab system

Data flow in DOlab

Keys are generated inside client and handled / stored as SHA256 of SHA256
Credentials can be copied locally and exported

Metadata are encrypted with AES key

User

User Hospital/..

login

registration

desktop

Metadata are always seen as cleartext inside client

Workflow selection

metadata

imaging

analysis

biomarker report

Report are saved locally / remotely, are searchable, editable and printable

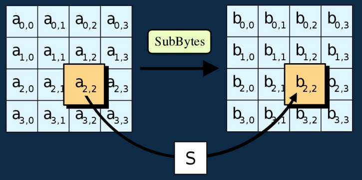
authentication

cloud/farm

Getting ready for dockerized submission

GE-INFN farm
~150 cpu cores
2Gb RAM / core
10Tb shared storage

user privKey
user pubKey



AES key

- recover lost data
- update certificates

“master” pubKey

Closing statements

"DON'T EVER GET TOO COMFORTABLE, YOU CAN BE REPLACED."
— ANONYMOUS

AI has the potential to revolutionize medical imaging analysis, but it is important to remember that it should be used as a tool in conjunction with, not in place of, qualified clinicians.

Over-reliance (use of software alene) on AI can lead to missed or incorrect diagnoses, ultimately resulting in negative consequences for patients and the healthcare system.

Additionally, AI-based software in medical imaging is still in the early stages and it is not yet clear how well these systems will perform in practice, especially in cases where the images are not clear or have abnormalities that are not common.

It is essential to use a multi-disciplinary approach in medical imaging analysis, which includes both human expertise and AI algorithms to ensure reliability, transparency, and accuracy in the diagnostic process.

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Thank you

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