دانشگاه علوم پزشکی و خدمات بهداشتی، درمانی ایران

Artificial Intelligence in Cardiology

دکتر نسیبه رادی راز

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بسم الله الرحمن الرحیم

دانشگاه علوم پزشکی و خدمات بهداشتی، درمانی ایران

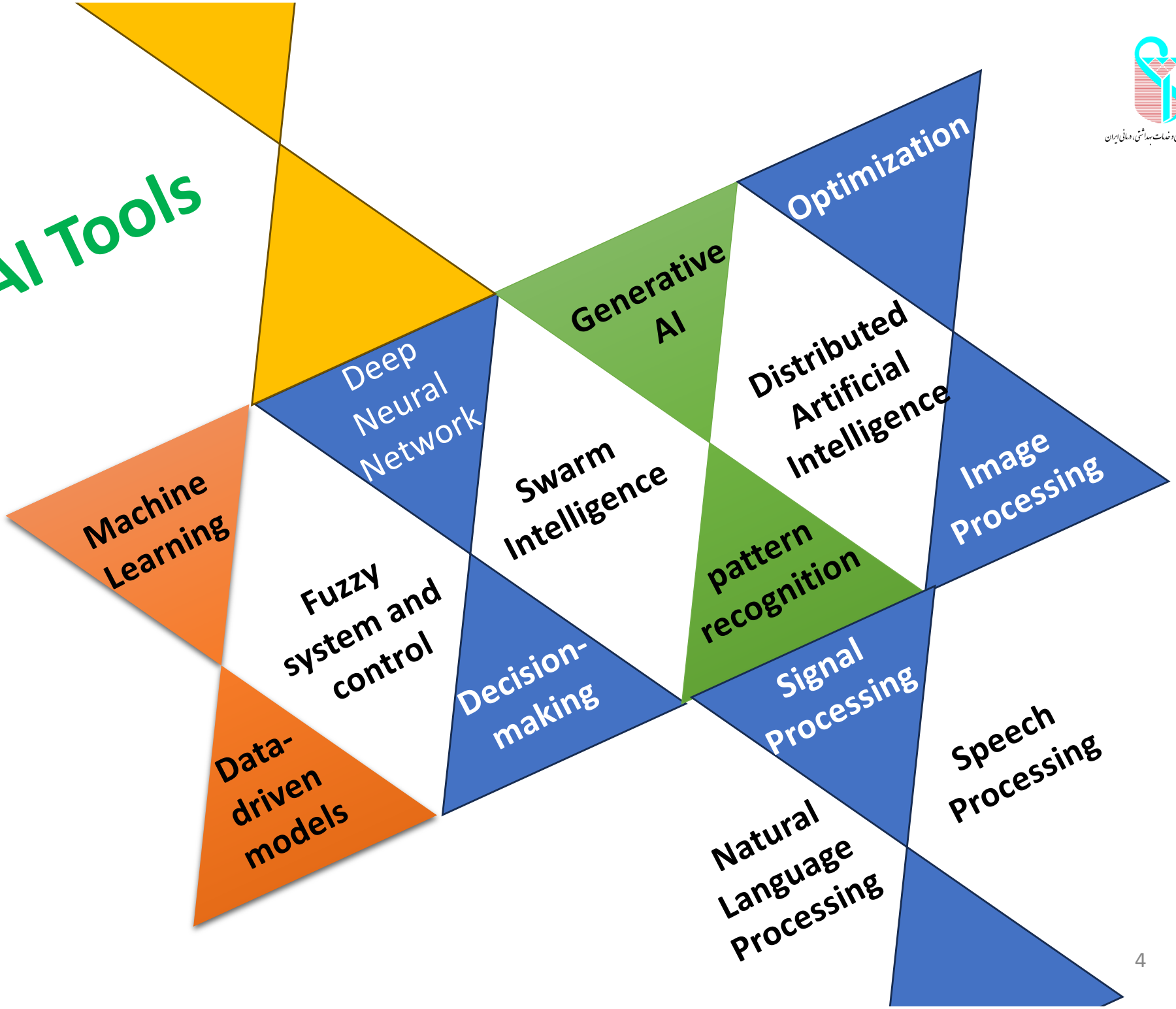
عنوان دوره آنلاین:

هوش مصنوعی در پزشکی با رویکرد بالینی

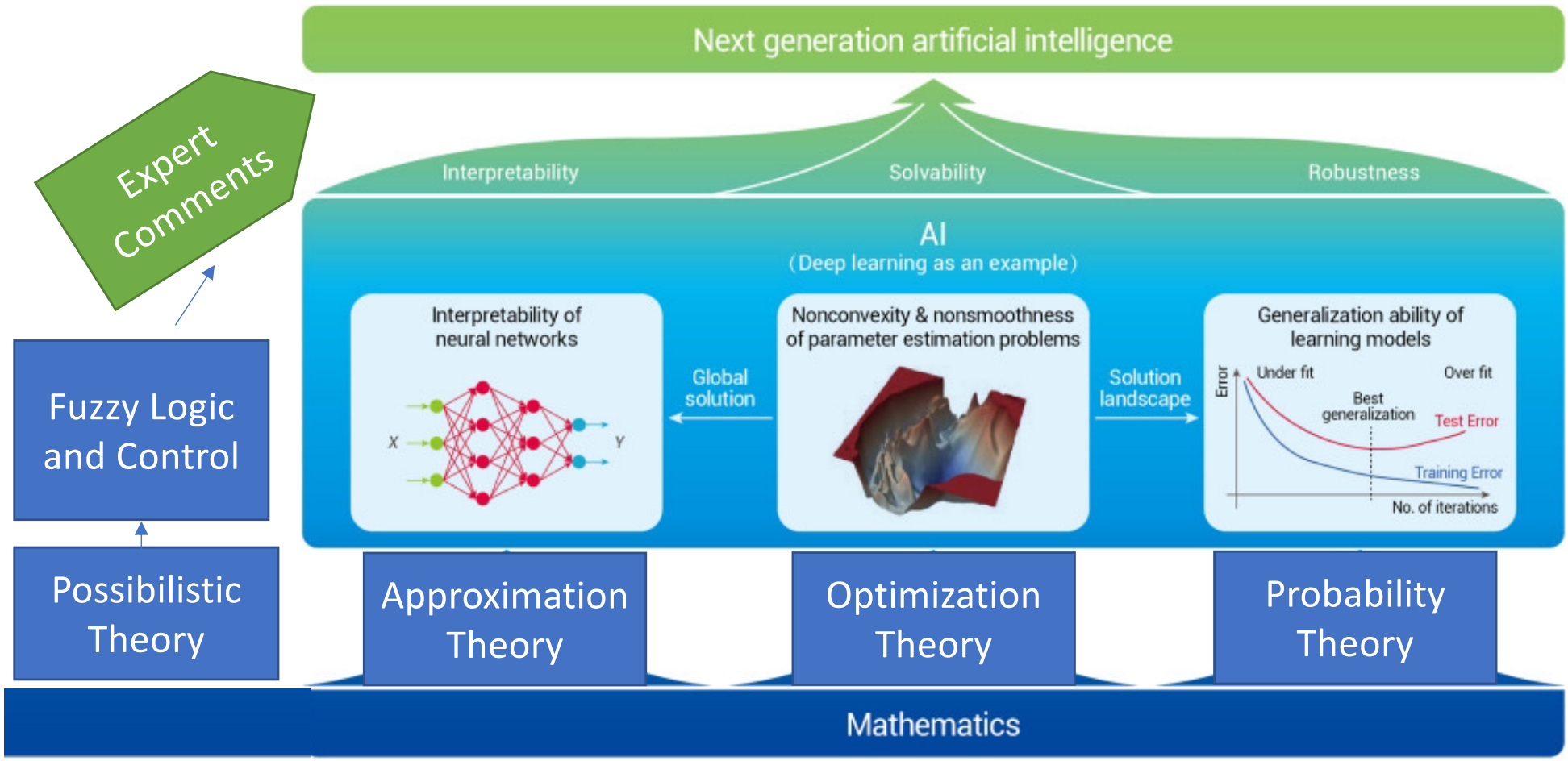
Online Course: Artificial Intelligence in Medicine with Clinical Approach

Course Topics	عناوین بیست و چهار جلسه	تاریخ جلسات
Artificial Intelligence (AI) in medicine	معرفی هوش مصنوعی در پزشکی	۲۸ بهمن ۱۴۰۲
AI and Fuzzy systems and its applications in medicine	هوش مصنوعی و سیستم های فازی در پزشکی	۵ اسفند ۱۴۰۲
Machine Learning and its applications in medicine	یادگیری ماشین و کاربردهای آن در پزشکی	۱۲اسفند۱۴۰۲
Evolutionary systems and its applications in medicine	الگوریتم های بهینه سازی تکاملی و کاربردهای آن در پزشکی	۱۹اسفند ۱۴۰۲
Neural networks and deep neural networks in medicine	شبکه های عصبی و شبکه های عصبی عمیق در پزشکی	۲۵فروردین ۱۴۰۳
Application of AI in Early Detection of Disease	کاربرد هوش مصنوعی در تشخیص زودهنگام بیماری ها	۱ اردیبهشت ۱۴۰۳
Swarm Intelligence and multi-agent/swarm in medicine	هوش ازدحامی، سیستم های چند عامله/ازدحامی در پزشکی	۸اردیبهشت ۱۴۰۳
Application of AI in Cancer	کاربردهای هوش مصنوعی در سرطان	۲۲اردیبهشت ۱۴۰۳
Application of AI in surgery	کاربردهای هوش مصنوعی در جراحی	۲۹ اردیبهشت ۱۴۰۳
Applications of AI in Neurology	کاربردهای هوش مصنوعی در مغز و اعصاب	۵ خرداد ۱۴۰۳
Application of AI in Internal Medicine	کاربردهای هوش مصنوعی در پزشکی داخلی	۱۲ خرداد ۱۴۰۳
Applications of AI in cardiovascular	کاربردهای هوش مصنوعی در قلب و عروق	۱۹ خرداد ۱۴۰۳
Applications of AI in Breast Disease	کاربردهای هوش مصنوعی در بیماری های پستان	۲۶ خرداد ۱۴۰۳
Application of AI in Ophthalmology	کاربردهای هوش مصنوعی در چشم پزشکی	۲ تیر ۱۴۰۳
Application of AI in Nephrology	کاربردهای هوش مصنوعی در نفرولوژی	۹ تیر ۱۴۰۳
Application of AI in Otorhinolaryngology	کاربردهای هوش مصنوعی در گوش و حلق و بینی	۱۶ تیر ۱۴۰۳
Application of AI in Gynecology and obstetrics	کاربردهای هوش مصنوعی در زنان و مامایی	۲۳ تیر ۱۴۰۳
Application of AI in pediatric medicine	کاربردهای هوش مصنوعی در پزشکی اطفال	۳۰ تیر ۱۴۰۳
Application of AI in anesthesia	کاربردهای هوش مصنوعی در بیهوشی	۶ مرداد ۱۴۰۳
Application of AI in emergency medicine	کاربردهای هوش مصنوعی در پزشکی اورژانس	۱۳ مرداد ۱۴۰۳
Applications of artificial intelligence in orthopedics	کاربردهای هوش مصنوعی در ارتوپدی	۲۰ مرداد ۱۴۰۳
Application of AI in pain management	کاربردهای هوش مصنوعی در مدیریت درد	۲۷ مرداد ۱۴۰۳
Application of AI in pharmacology	کاربردهای هوش مصنوعی در داروسازی	۳ شهریور ۱۴۰۳
Application of AI in dentistry	کاربردهای هوش مصنوعی در دندان پزشکی	۱۰ شهریور ۱۴۰۳

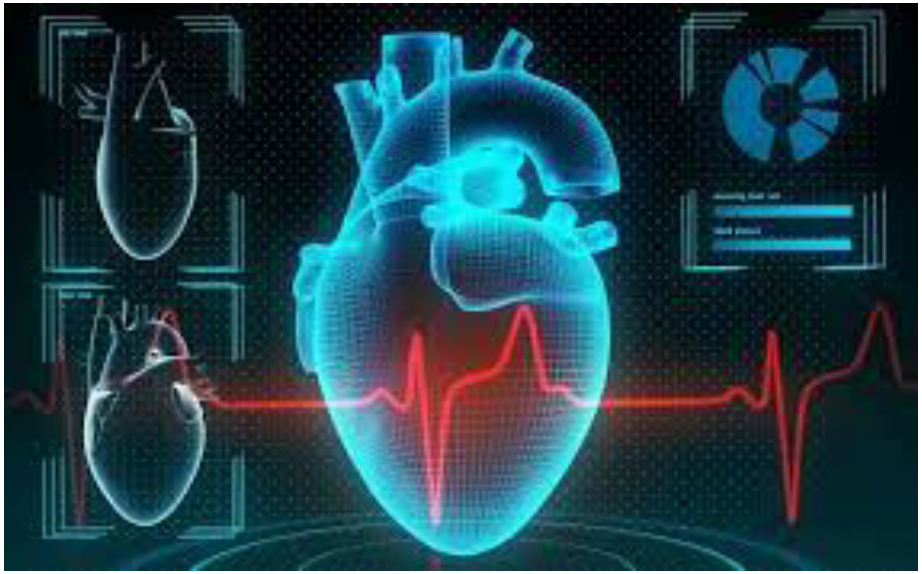
AI Tools


Machine Learning
Deep Neural Network
Generative AI
Optimization
Fuzzy system and control
Swarm Intelligence
Distributed Artificial Intelligence
Image Processing
Data-driven models
Decision-making
pattern recognition
Signal Processing
Speech Processing
Natural Language Processing

Artificial Intelligence



Artificial Intelligence in Cardiology



You

require to interpret data

make clinical decisions

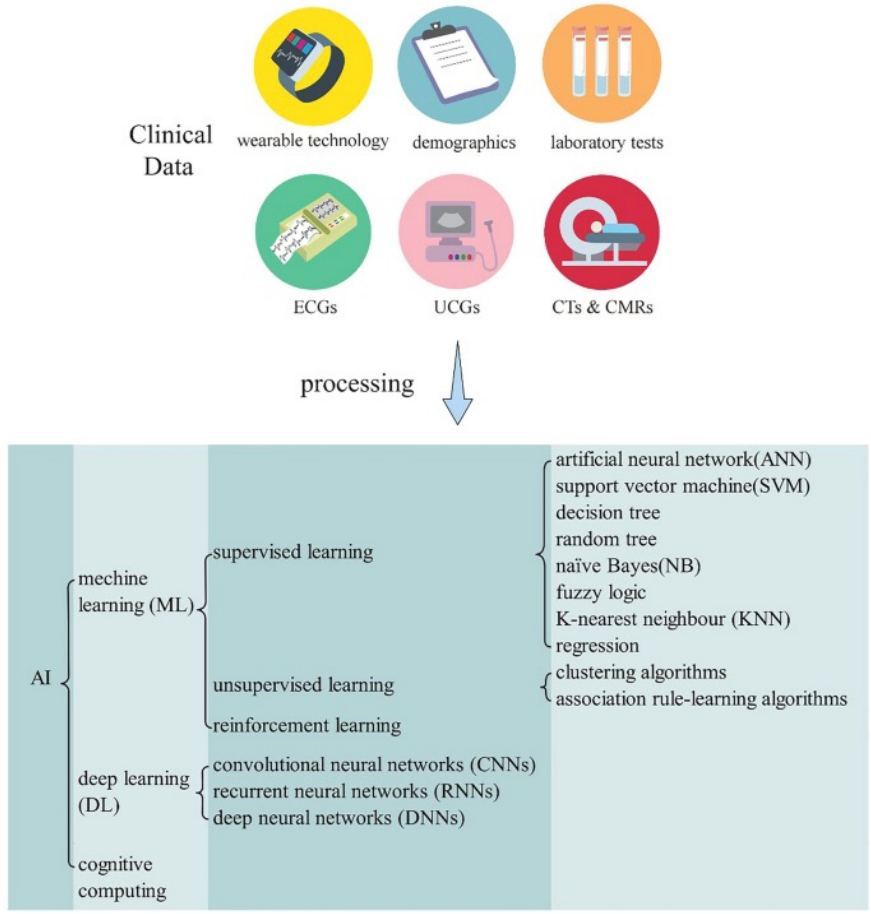
operational efficiencies are important

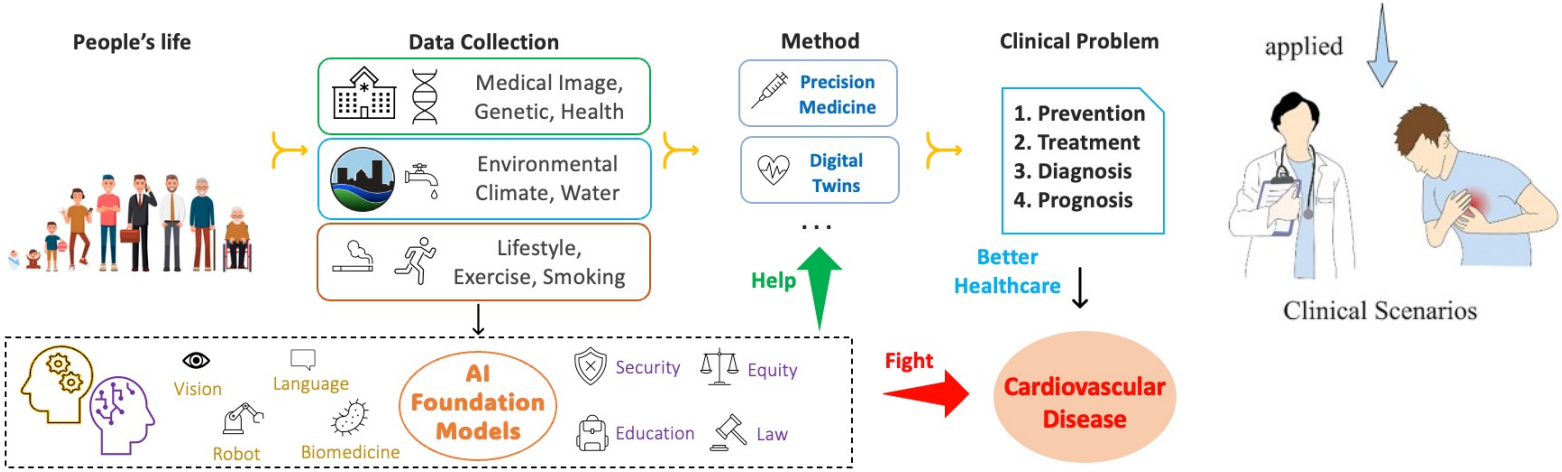
want information faster

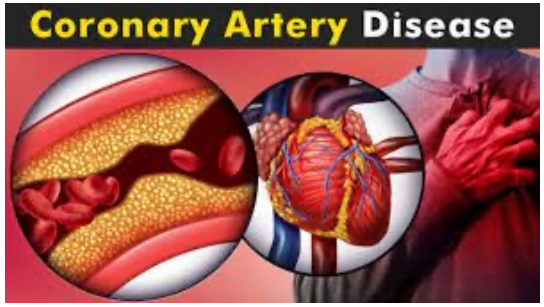
want more personalized care

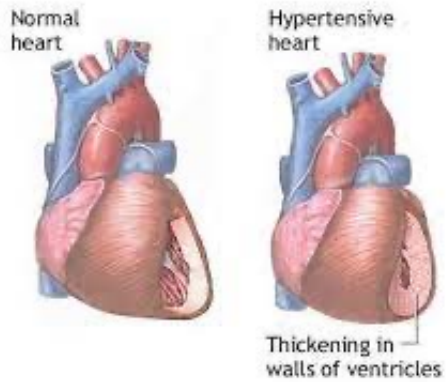
patients

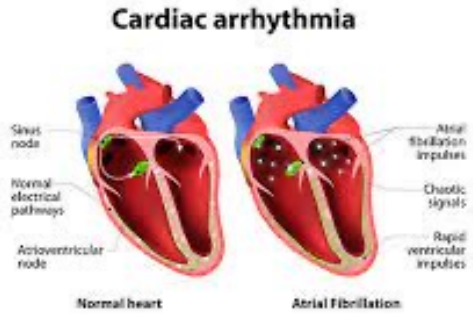
Example


Clinical Data
wearable technology
demographics
laboratory tests
ECGs
UCGs
CTs & CMRs
processing
AI
mechine learning (ML)
supervised learning
artificial neural network(ANN)
support vector machine(SVM)
decision tree
random tree
naïve Bayes(NB)
fuzzy logic
K-nearest neighbour (KNN)
regression
unsupervised learning
clustering algorithms
association rule-learning algorithms
reinforcement learning
deep learning (DL)
convolutional neural networks (CNNs)
recurrent neural networks (RNNs)
deep neural networks (DNNs)
cognitive computing

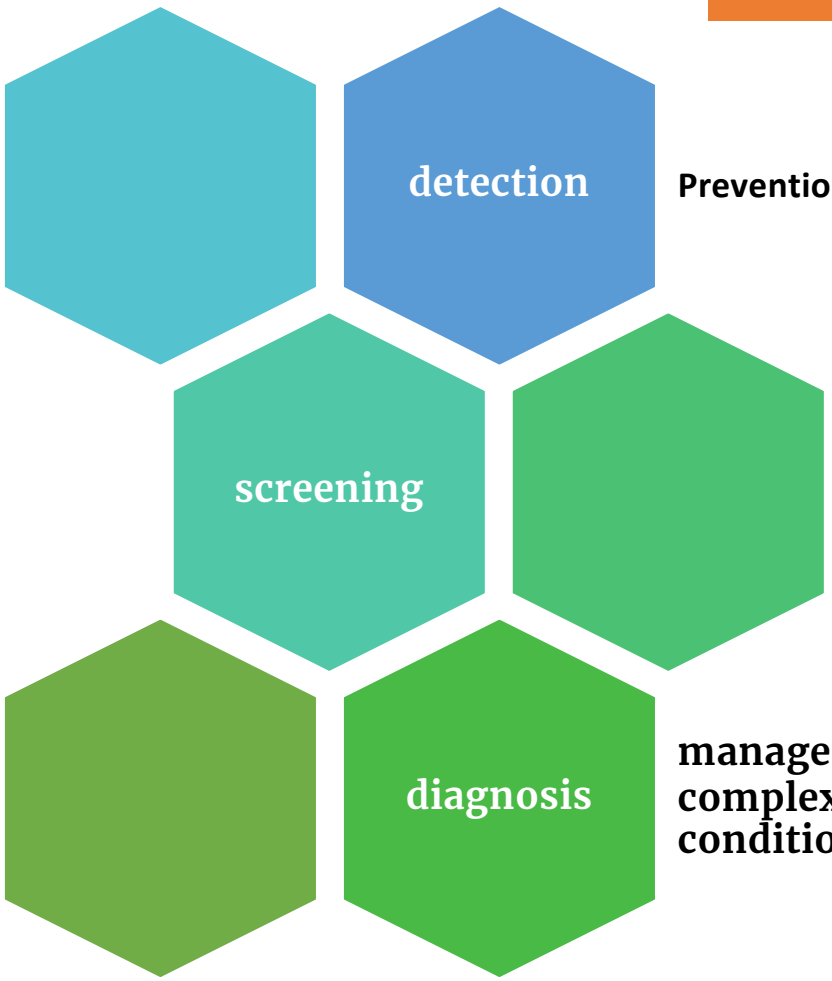

People's life
Data Collection
Medical Image, Genetic, Health
Environmental Climate, Water
Lifestyle, Exercise, Smoking
Method
Precision Medicine
Digital Twins
...
Help
Clinical Problem
1. Prevention
2. Treatment
3. Diagnosis
4. Prognosis
Better Healthcare
applied
Clinical Scenarios
Vision
Language
Robot
Biomedicine
AI Foundation Models
Security
Equity
Education
Law
Fight
Cardiovascular Disease







imaging cardiologist
interventional cardiologist
electrophysiologist



Prevention

management of complex conditions

Predicting and preventing these conditions is the true benefit of AI

Artificial Intelligence in Cardiology

- Monitoring to detect signs of severe heart failure or cardiac arrest
- Diagnosis of Pathology
- Heart Monitoring and Self-Care
- Treatment Selection
- Predicting Cardiac Risk
- Cardiac Events Detection and Monitoring
- Cardiovascular risk reduction
- Cardiac rehabilitation
- Decision support systems for exercise prescription

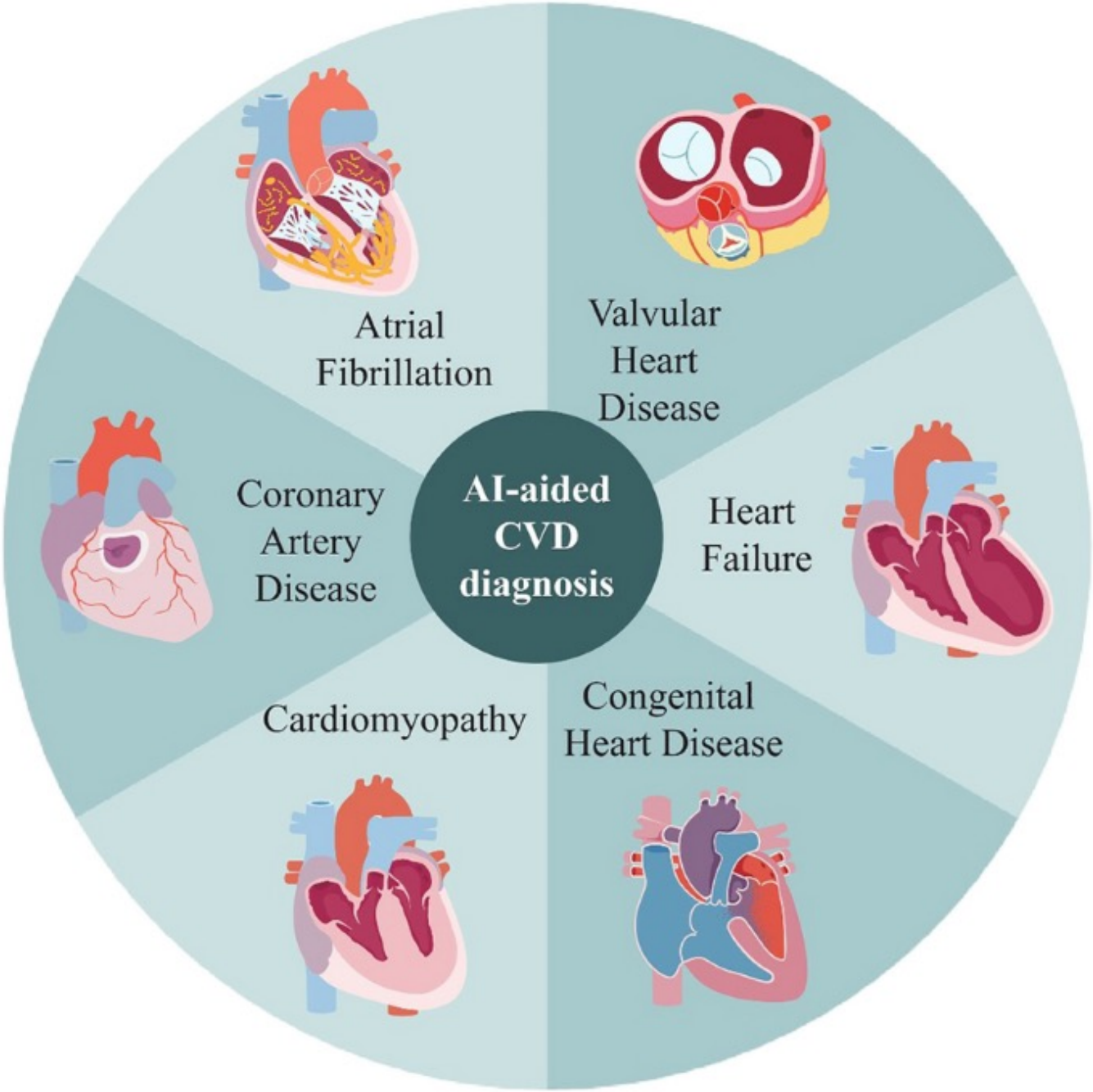
[1] Karim Bayoumy Et al., “Smart wearable devices in cardiovascular care: where we are and how to move forward,“ *Nature Reviews Cardiology,* vol. 18, pp. 581–599, 2021.

Role of AI in preventive cardiology

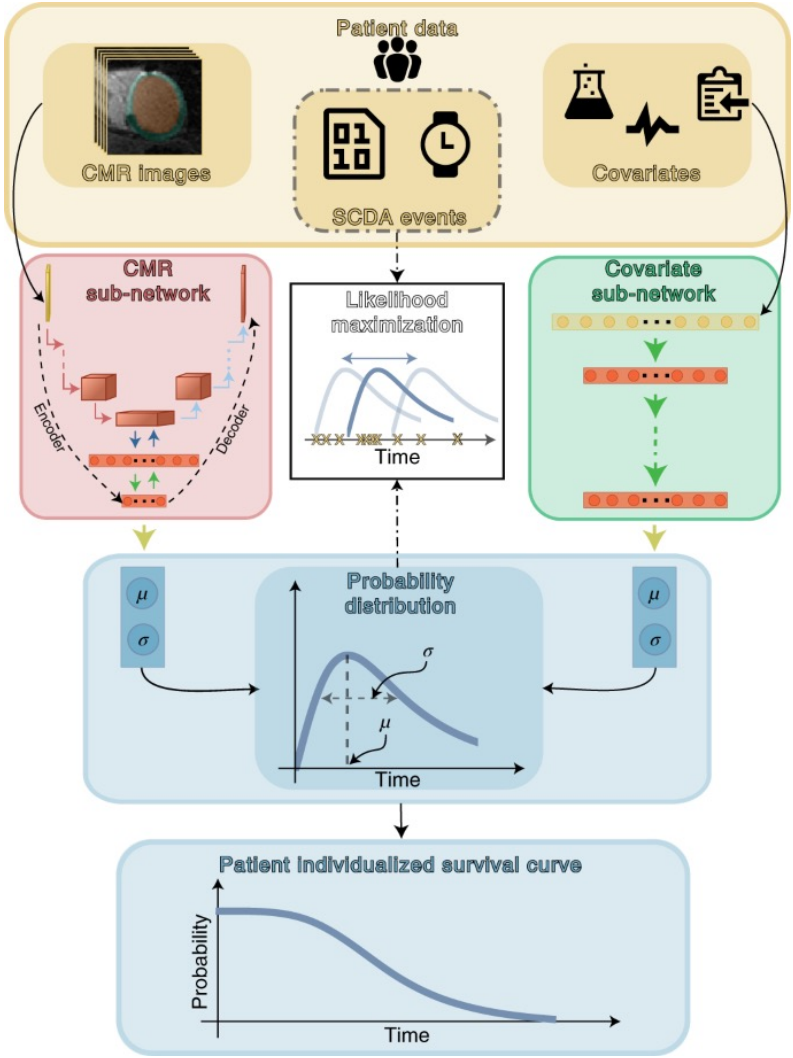
- Risk Reduction
- AI based Cardiac rehabilitation
- Personalized exercise prescription
- Enable cardiologists to make better decisions
- Improve the accuracy of human readers
- Reduce variability between readers
- Give more confidence in findings.
- Preventing heart problems

Role of AI in detection

- Detecting atrial fibrillation (a-fib) sooner
- Predicting risk early in conditions such as embolic stroke
- Occult cardiac disease
- Hypertrophic cardiomyopathy
- Cardiac arrhythmias
- Valvular Heart Disease
- Coronary Artery Disease
- Predicting heart attack
- Analyzing blood pressure

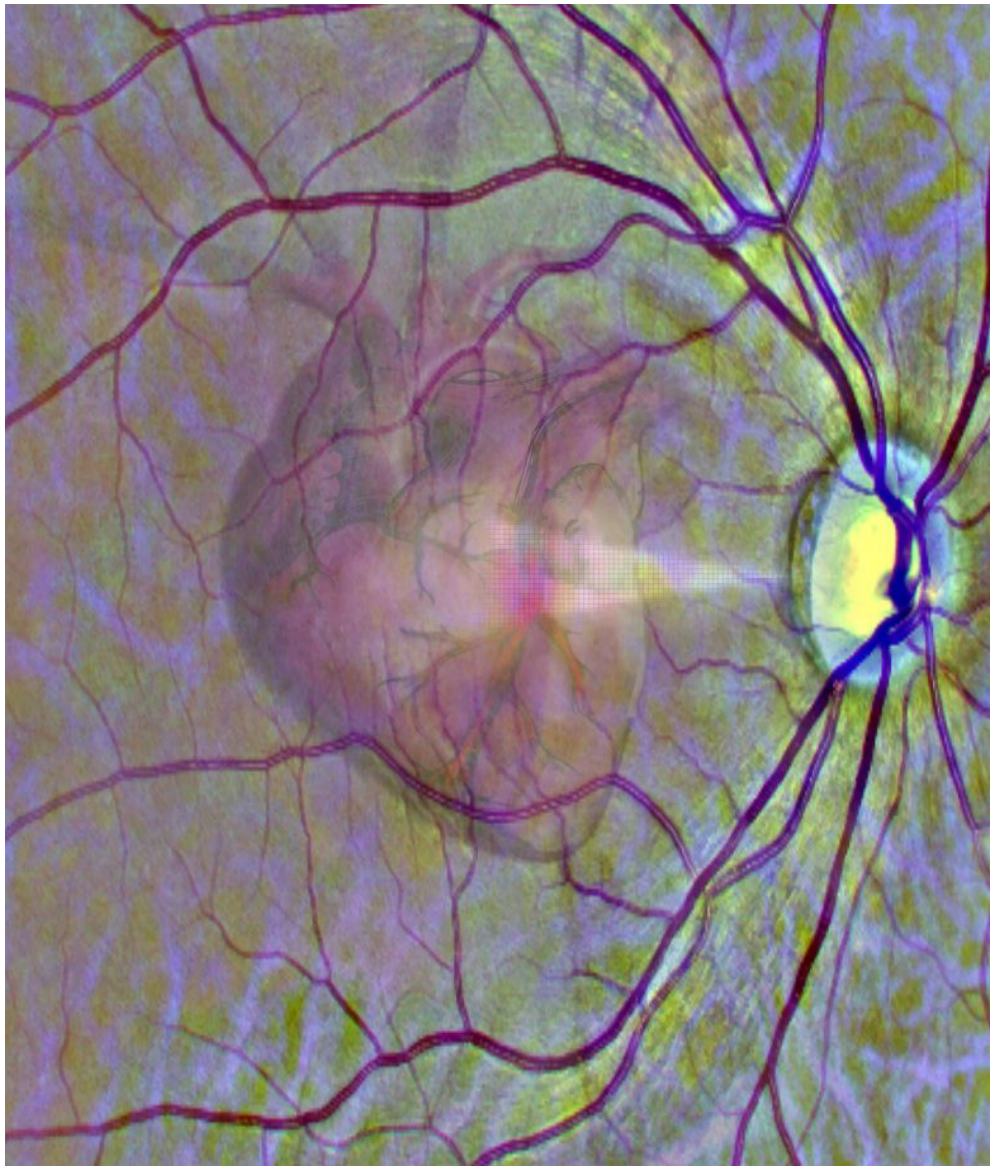

AI-aided CVD diagnosis
Atrial Fibrillation
Valvular Heart Disease
Heart Failure
Congenital Heart Disease
Cardiomyopathy
Coronary Artery Disease

Arrhythmic sudden death survival prediction using deep learning analysis of scarring in the heart



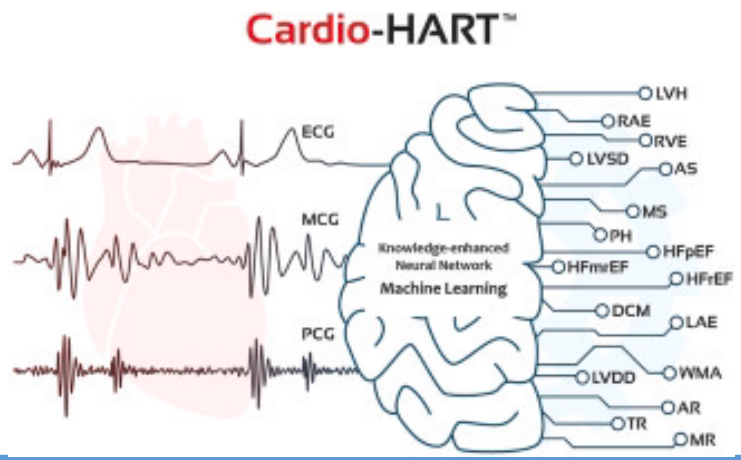
Nature Cardiovascular Research **volume 1**, pages334–343 (2022)

Artificial Intelligence Can Analyze Eye Scans To Identify Patients at High Risk of Heart Attack



https://scitechdaily.com/artificial-intelligence-can-analyze-eye-scans-to-identify-patients-at-high-risk-of-heart-attack/

AI in Arrythmia



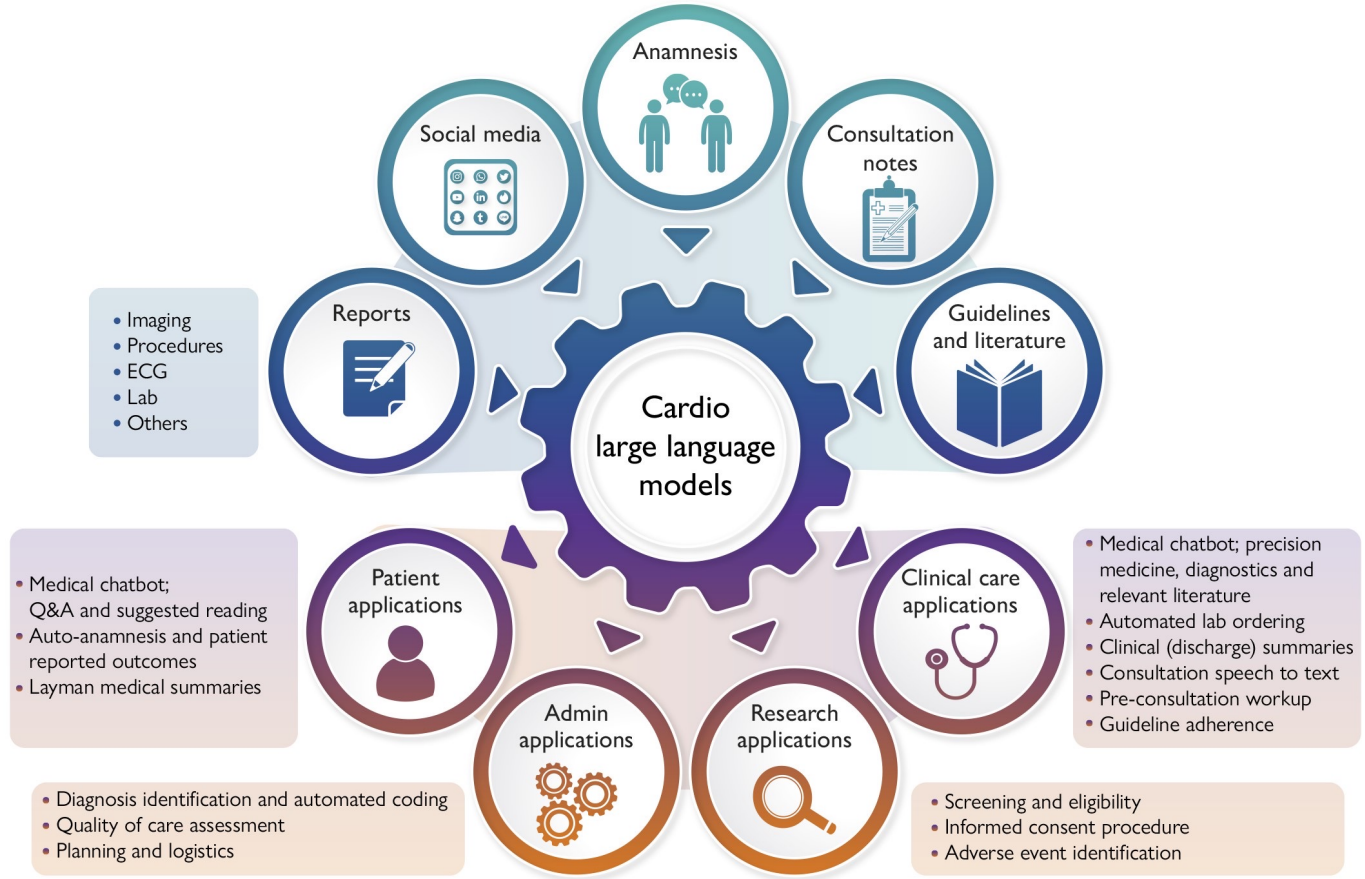
ECG—Electro-physiological abnormalities: arrhythmias, premature beats, atrioventricular blocks, bundle-branch blocks, etc.;

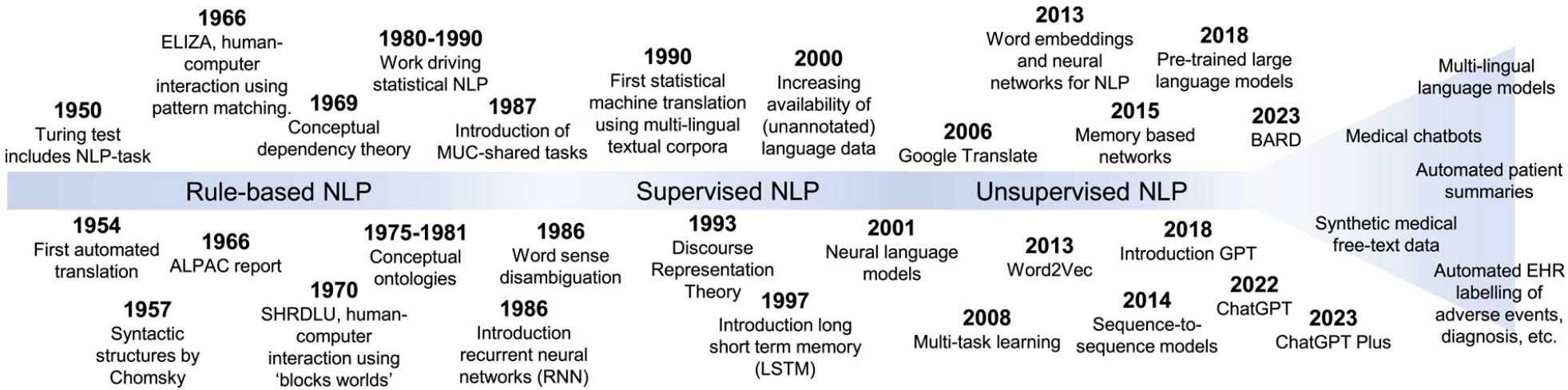
PCG—Hemodynamical diseases: valve stenosis, valve regurgitation, hypertension (arterial or pulmonary hypertension);

MCG—Mechano-physiological abnormalities: cardiomyopathy, myocarditis, myocardial infarction, ischemia, hypertrophies, atrial enlargements, systolic or diastolic dysfunction, or other wall motion problems;

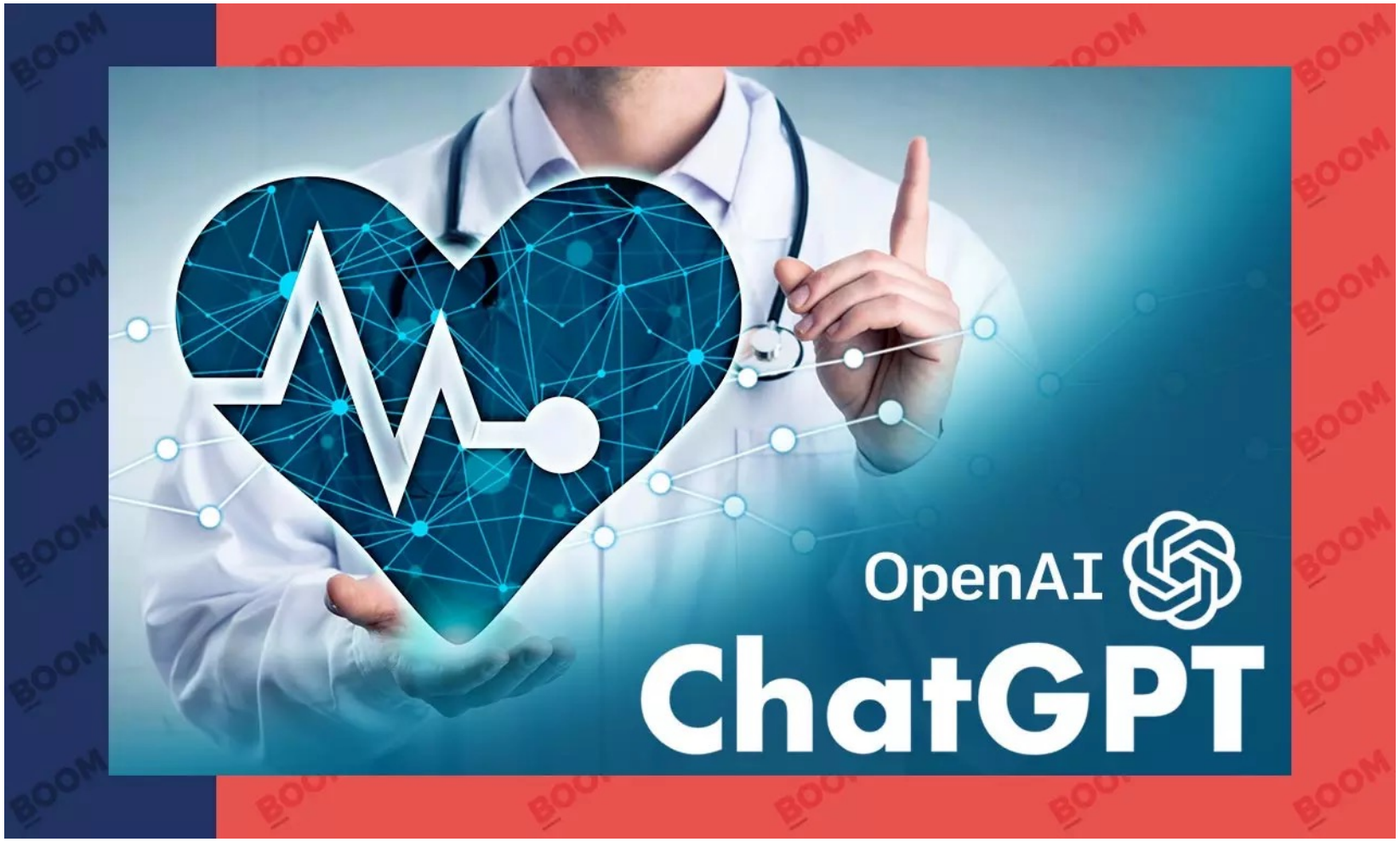
Computers in Biology and Medicine Volume 154, March 2023, 106547

LLM

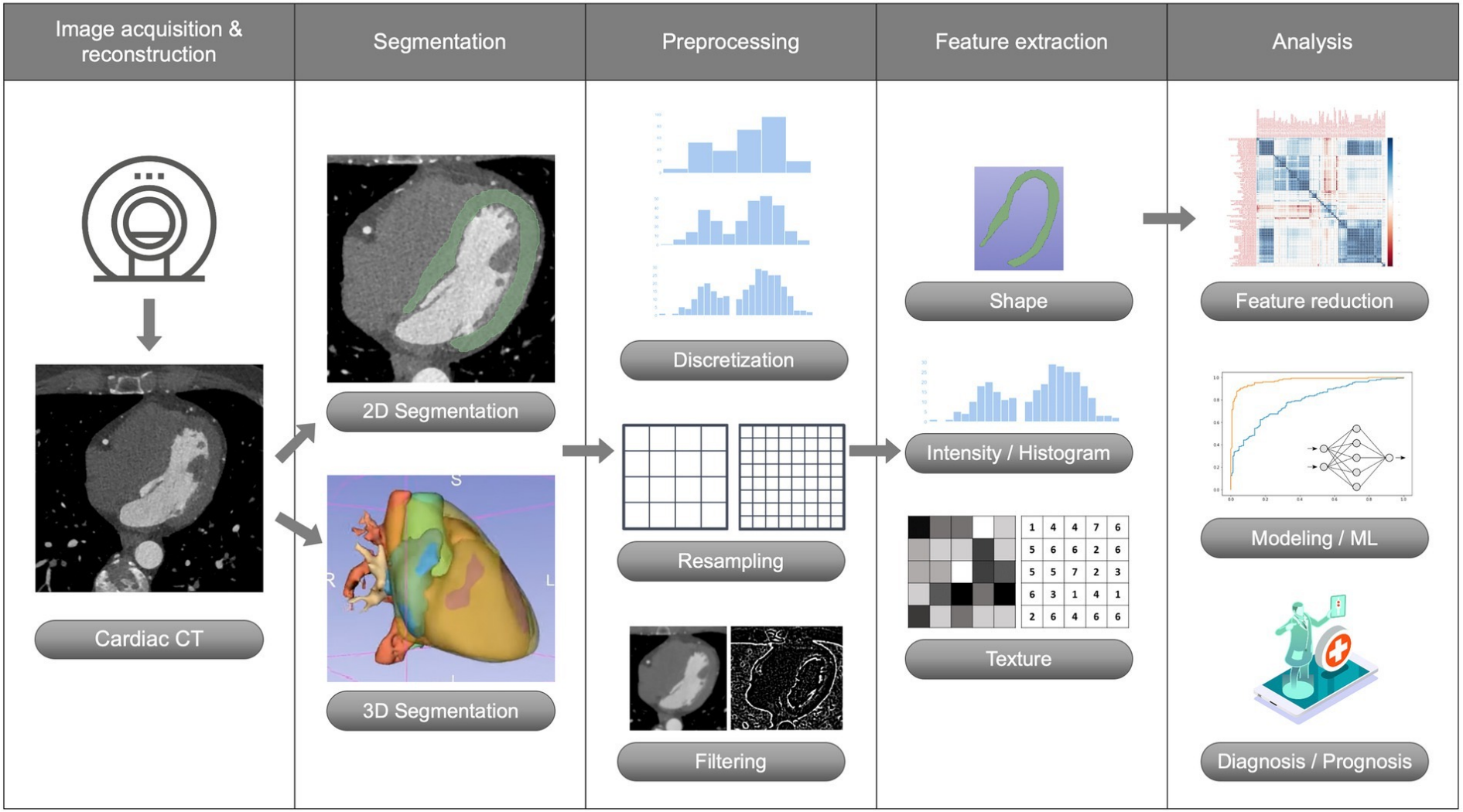

Anamnesis
Social media
Consultation notes
Reports
Guidelines and literature
Cardio large language models
Patient applications
Clinical care applications
Admin applications
Research applications
• Imaging
• Procedures
• ECG
• Lab
• Others
• Medical chatbot; Q&A and suggested reading
• Auto-anamnesis and patient reported outcomes
• Layman medical summaries
• Medical chatbot; precision medicine, diagnostics and relevant literature
• Automated lab ordering
• Clinical (discharge) summaries
• Consultation speech to text
• Pre-consultation workup
• Guideline adherence
• Diagnosis identification and automated coding
• Quality of care assessment
• Planning and logistics
• Screening and eligibility
• Informed consent procedure
• Adverse event identification


1950 Turing test includes NLP-task
1954 First automated translation
1957 Syntactic structures by Chomsky
1966 ELIZA, human-computer interaction using pattern matching.
1966 ALPAC report
1969 Conceptual dependency theory
1970 SHRDLU, human-computer interaction using 'blocks worlds'
1975-1981 Conceptual ontologies
1980-1990 Work driving statistical NLP
1986 Word sense disambiguation
1986 Introduction recurrent neural networks (RNN)
1987 Introduction of MUC-shared tasks
1990 First statistical machine translation using multi-lingual textual corpora
1993 Discourse Representation Theory
1997 Introduction long short term memory (LSTM)
2000 Increasing availability of (unannotated) language data
2001 Neural language models
2006 Google Translate
2008 Multi-task learning
2013 Word embeddings and neural networks for NLP
2013 Word2Vec
2014 Sequence-to-sequence models
2015 Memory based networks
2018 Pre-trained large language models
2018 Introduction GPT
2022 ChatGPT
2023 BARD
2023 ChatGPT Plus
Rule-based NLP
Supervised NLP
Unsupervised NLP
Multi-lingual language models
Medical chatbots
Automated patient summaries
Synthetic medical free-text data
Automated EHR labelling of adverse events, diagnosis, etc.

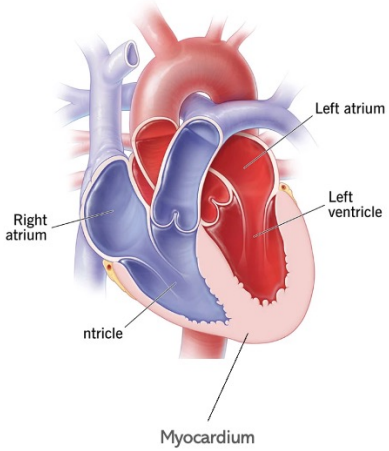
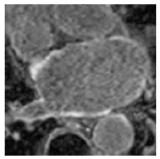
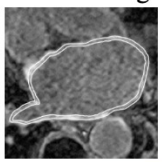
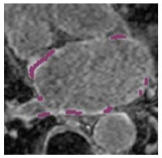
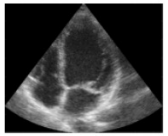
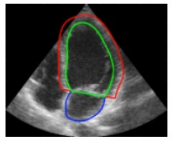
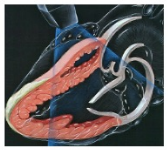
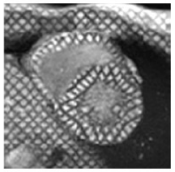
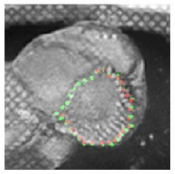
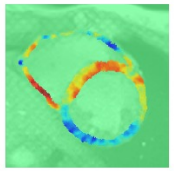
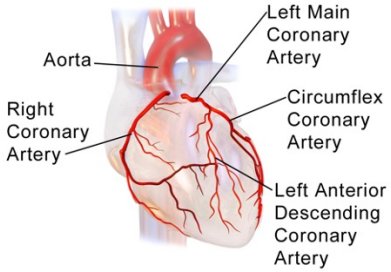
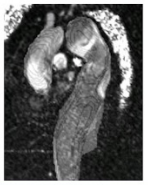
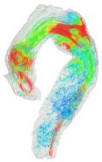
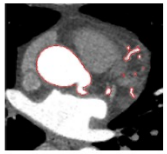
Chat GPT's medical "assistant."



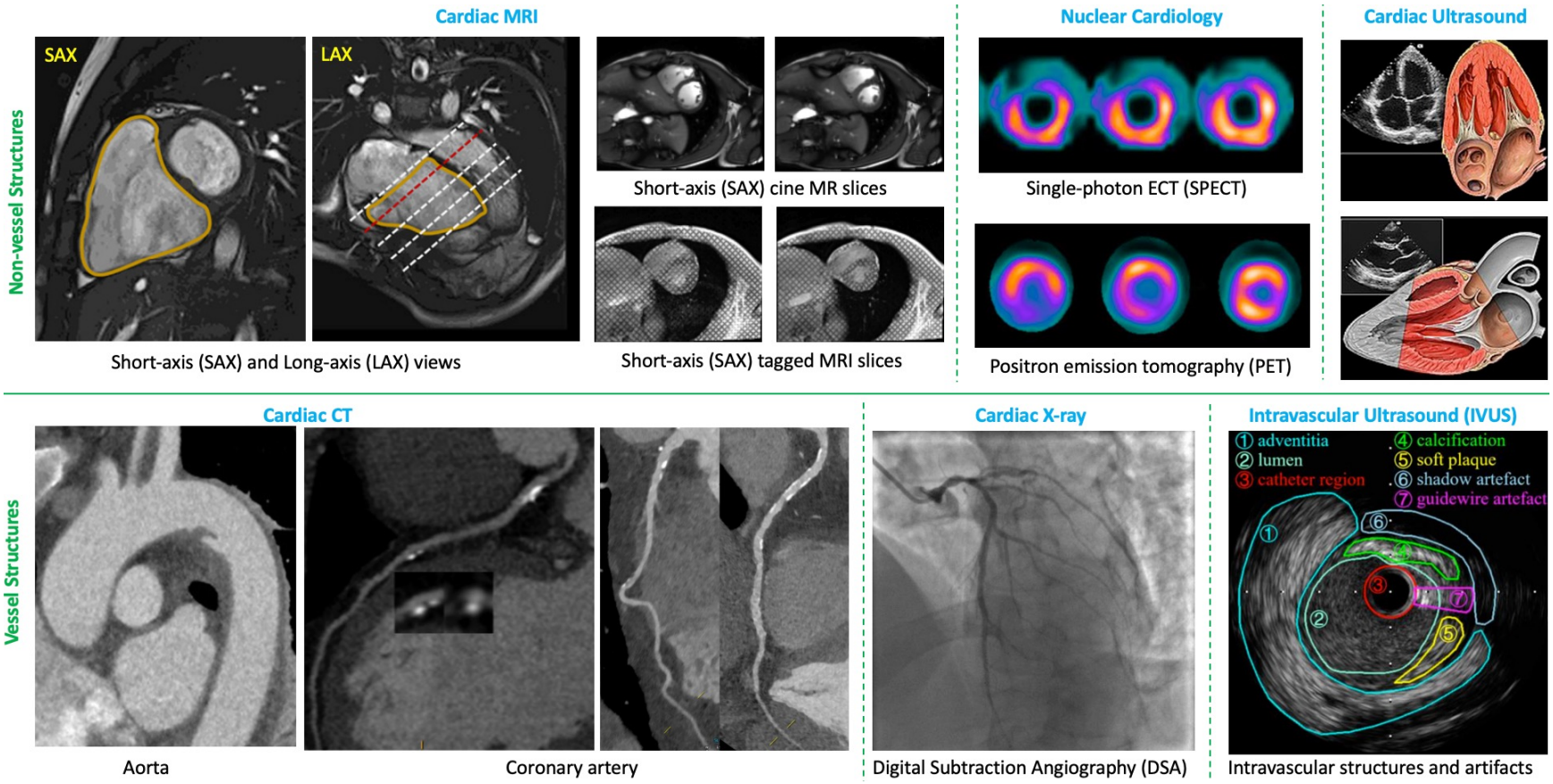
The Radiomics Workflow for Cardiac CT



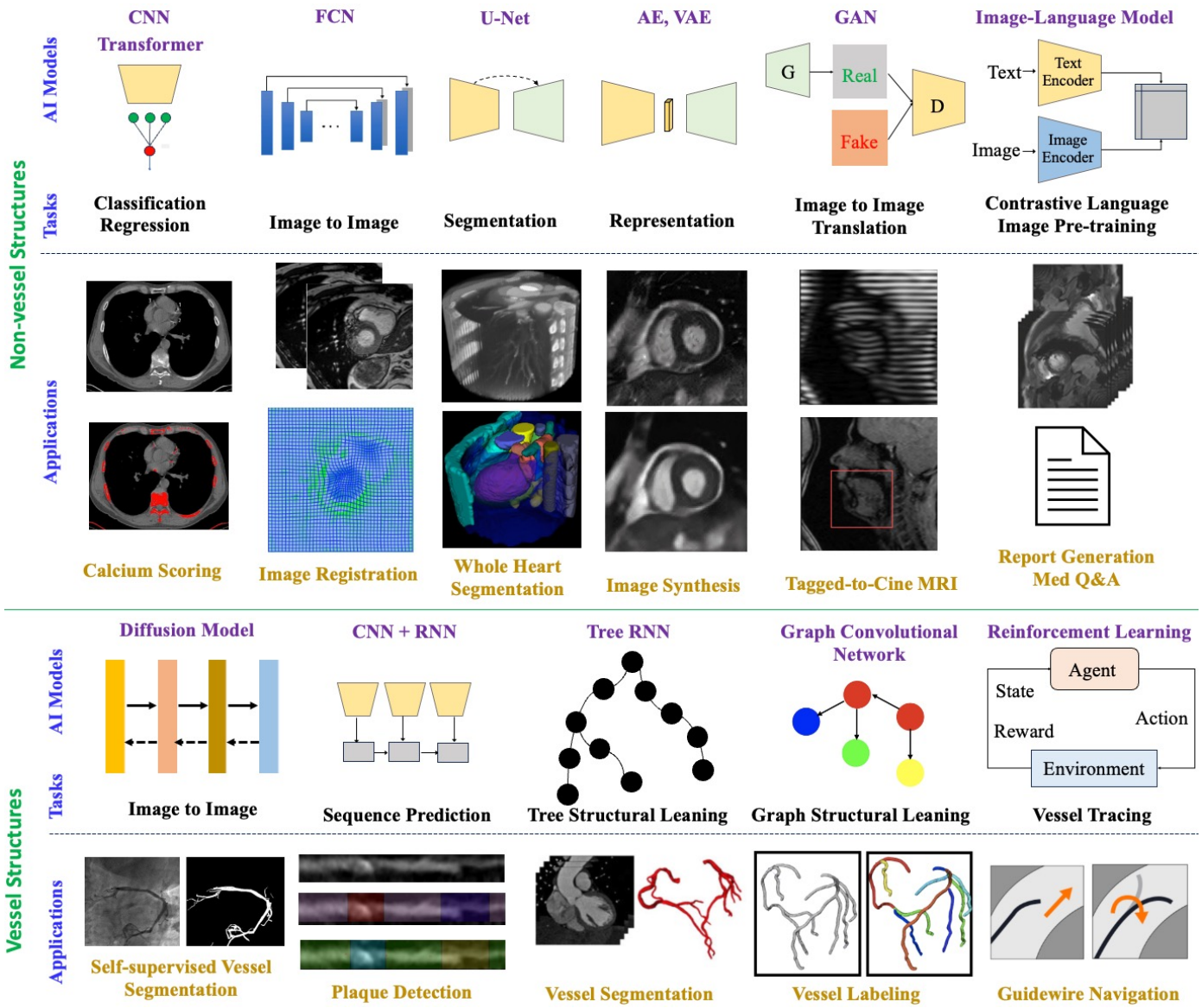
CARDIAC IMAGING

Heart	Target	Modality	Structure	Lesion/Function	Related Disease
Non-vessel 	Atria (a)	LEG MRI 	LA Wall Seg 	LA fibrosis 	Atrial Fibrillation
	Ventricle (b)	Ultrasound 	Ventricle Seg 	Ventricle Function 	Ejection Fraction Estimation
	Myocardium (c)	Cardiac tagging MRI 	Landmarks tracking 	Motion Fields 	Ischemic Heart Disease
Vessel 	Aorta (d)	4D Flow MRI 	Aorta Seg	Aorta Flow 	Aorta Dissections
	Coronary Arteries (e)	CTA 	Coronary Artery Seg	Fractional Flow Reserve	Coronary Artery Disease

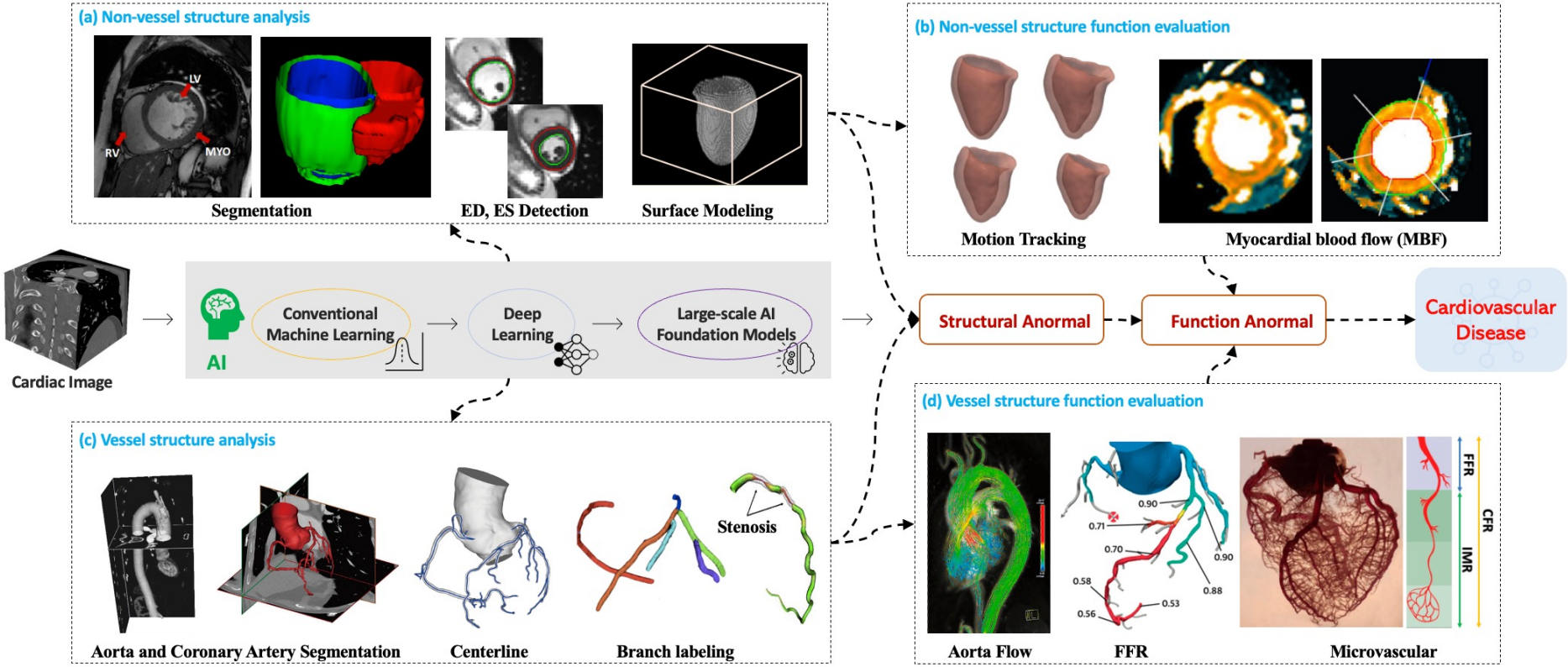
Cardiac Imaging



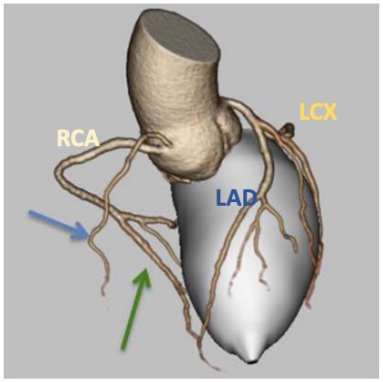
CARDIAC IMAGING

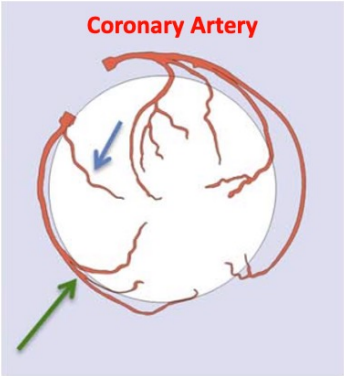


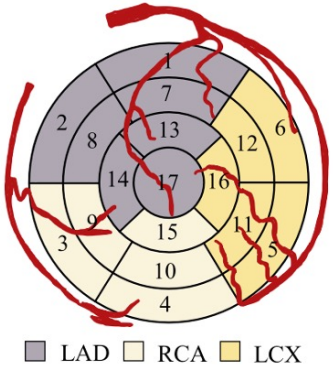
Cardiac Imaging

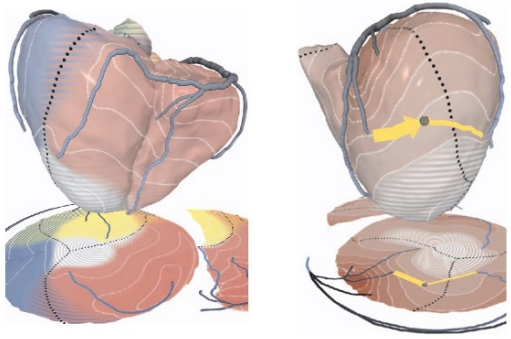


CARDIAC IMAGING

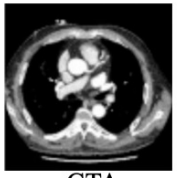






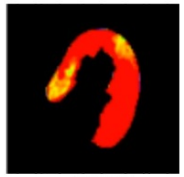


Visualization of Supply from Coronary Artery

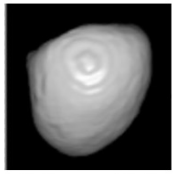


CTA

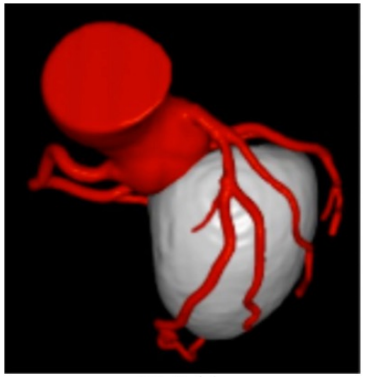
Coronary



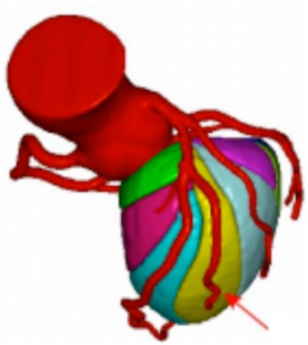
MBF



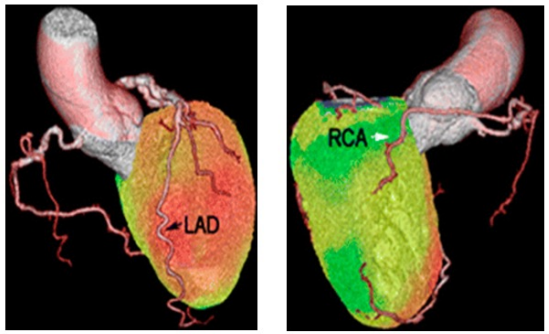
Myocardial



Matching

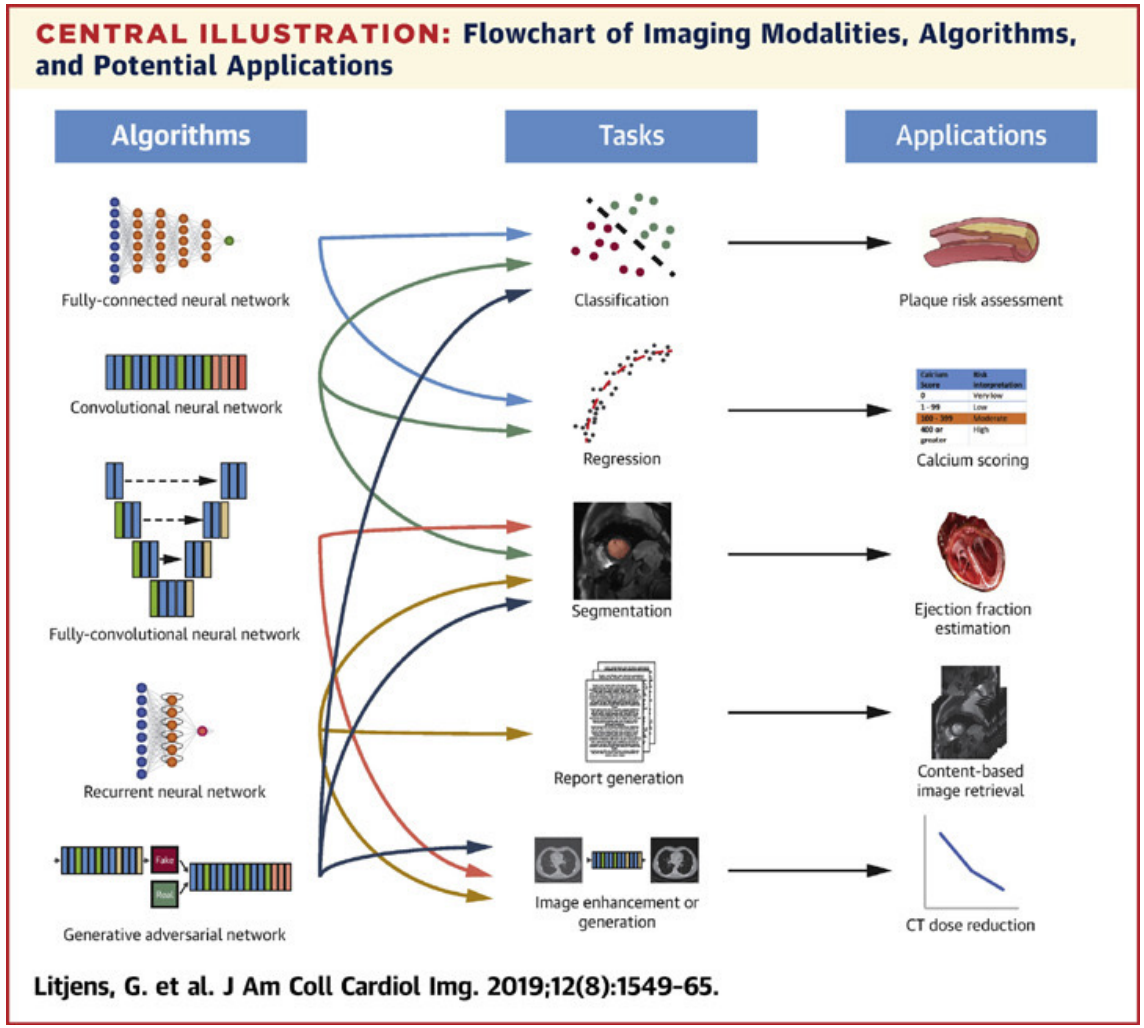


Myocardial Prefusion Area



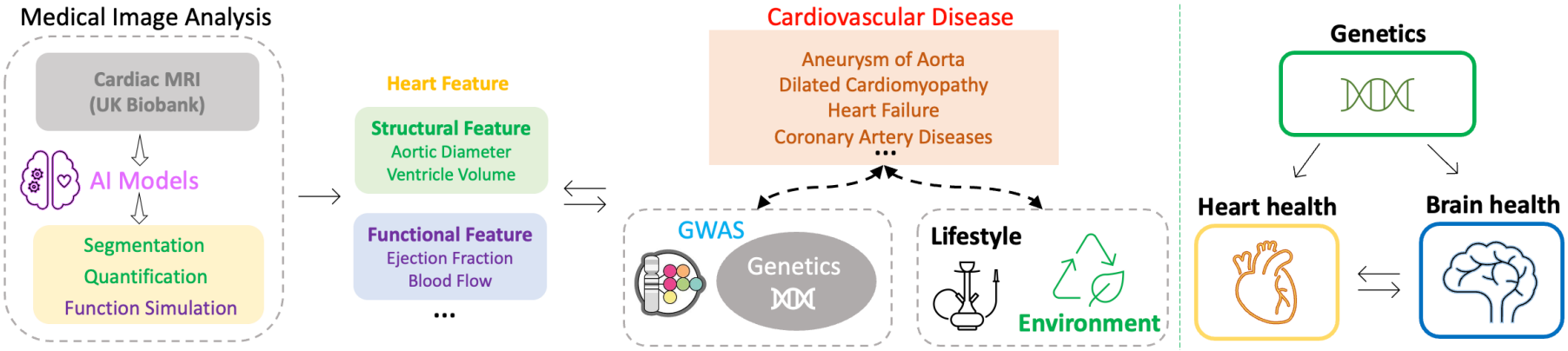
PET/CT Assessing Perfusion

Medical image analysis

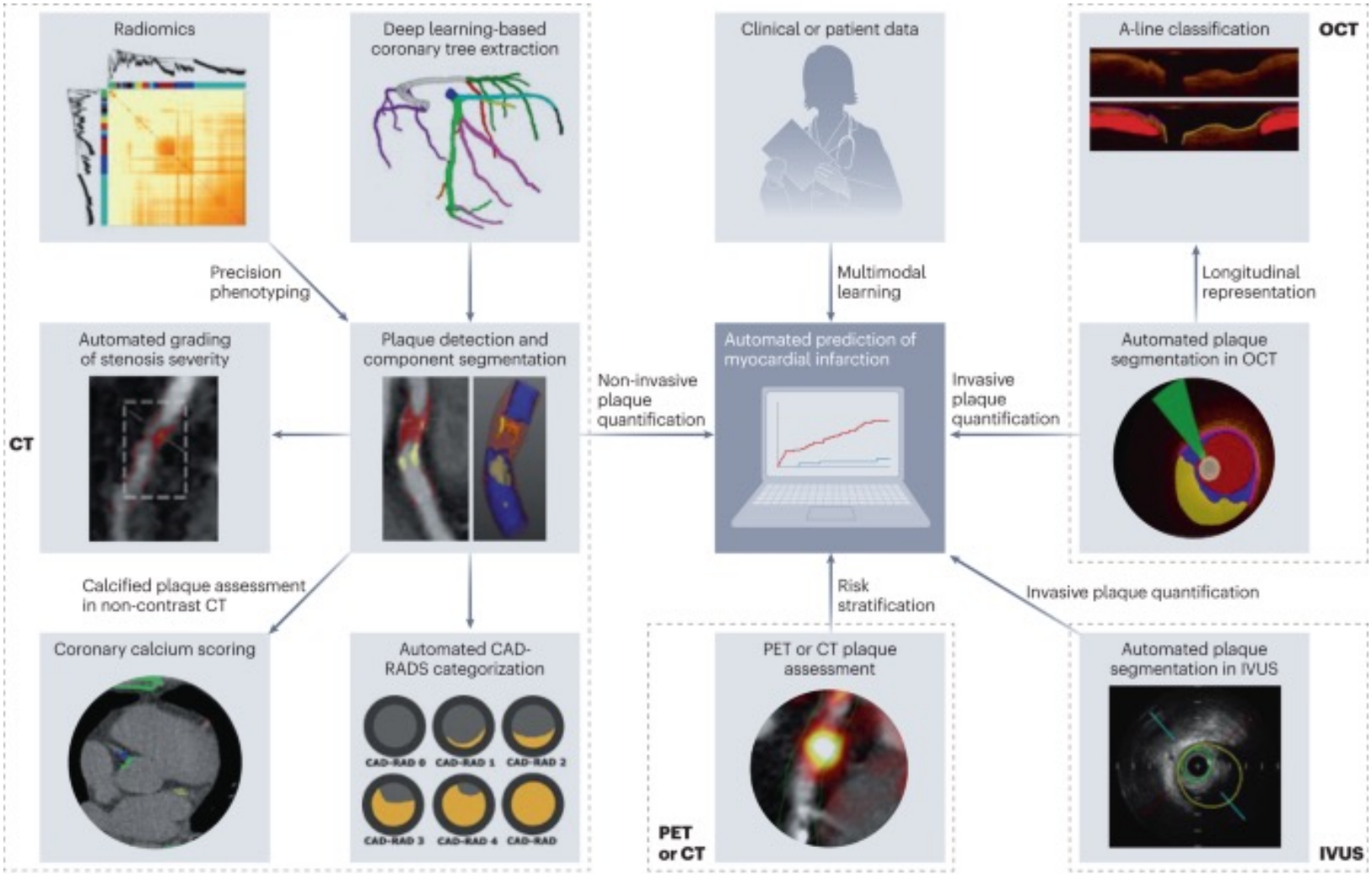


Maxime Sermesant, Hervé Delingette, Hubert Cochet, Pierre Jaïs & Nicholas Ayache," Applications of artificial intelligence in cardiovascular imaging," Nature Reviews Cardiology, 18, pages600–609 (2021)

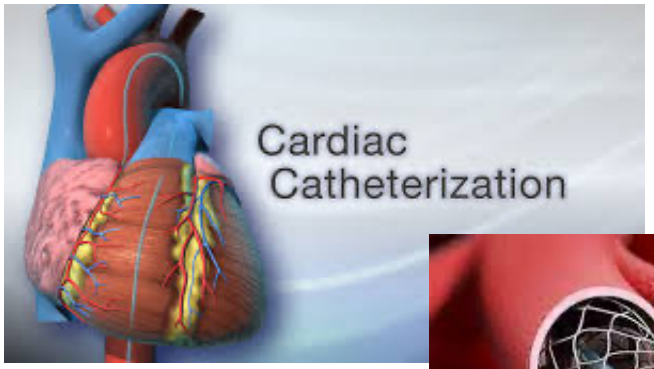
Cardiac Imaging Genetic Analysis Pipeline



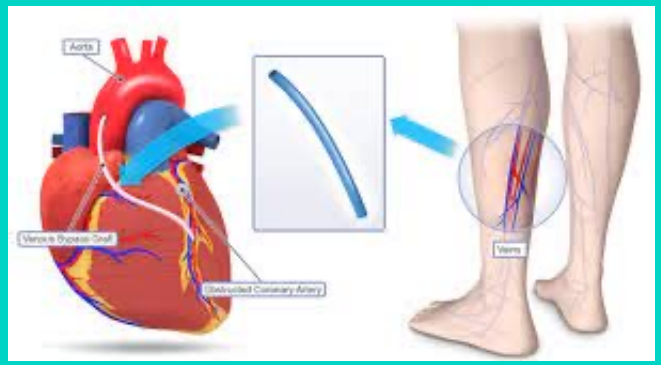
plaque recognition



Catheterization

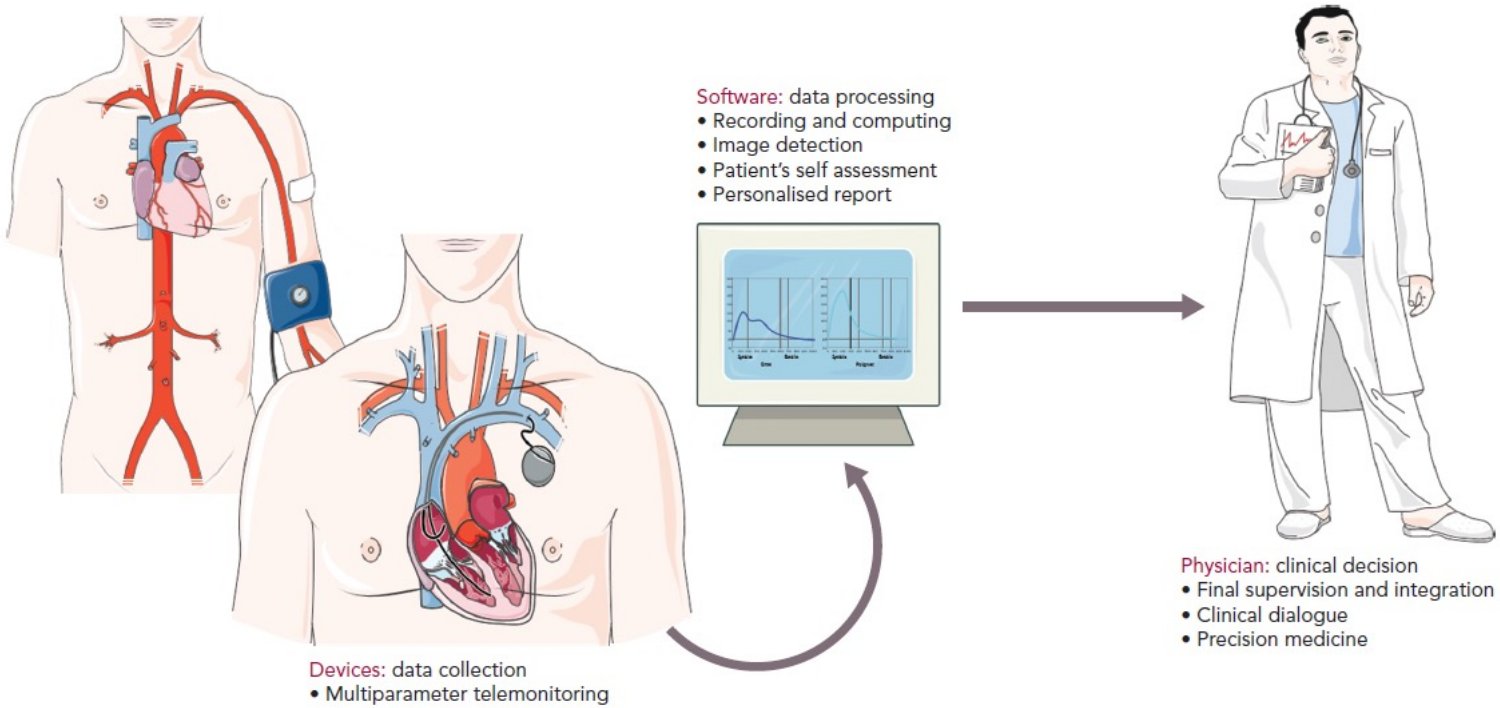


- AI for patient selection who require catheterization.
- Automated algorithms for edge detection and plaque recognition during cardiac catheterizations for deciding
  - bypass surgery,
  - maximal medical therapy
  - receiving a stent.



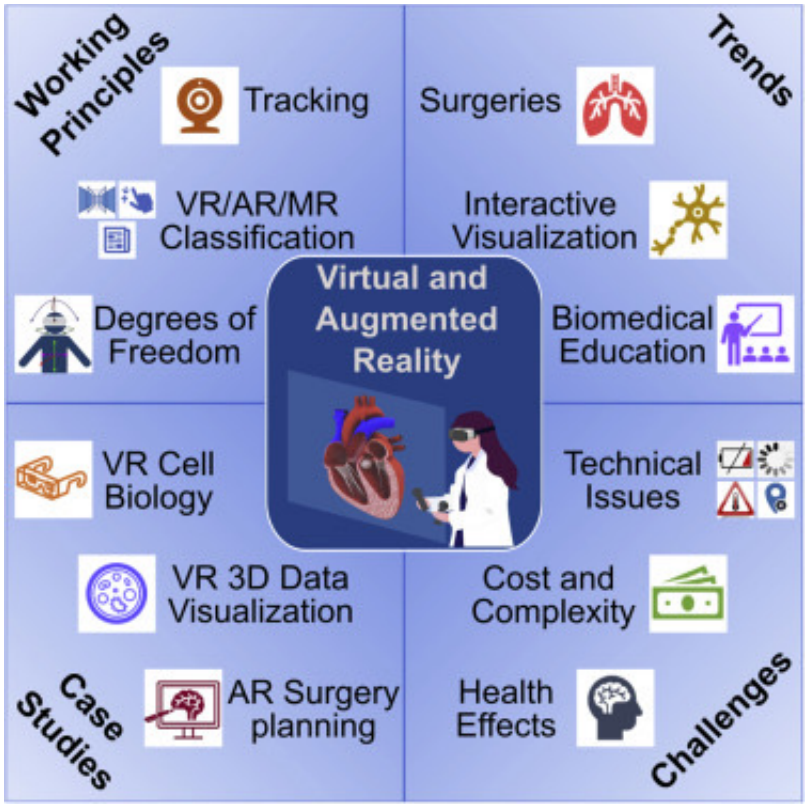
Implantable cardioverter defibrillator

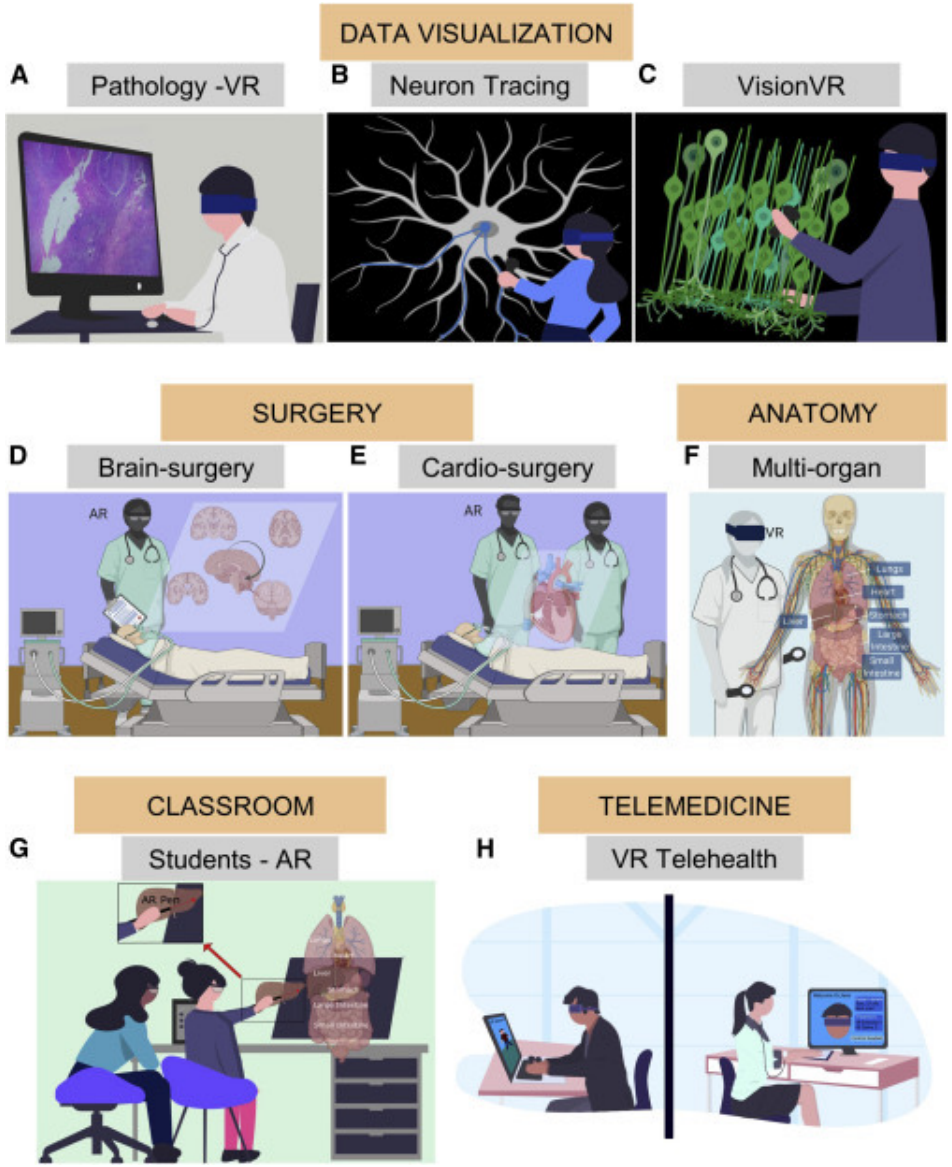
Analyze electronic health records and the anticoagulation status of patients with pacemakers for detecting abnormal heart rhythms and delivering a shock to treat the patient.



An ideal process is shown starting with the collection of data through wearable or implanted devices that allow telemonitoring of detailed cardiac and vascular function parameters. Data are recorded and computed by tools using sophisticated algorithms in order to provide the physician with personalised reports that further guide the final clinical decision. Source: Dilsizian and Siegel 2014.[11] Reproduced with permission from Servier Medical Art (https://smart.servier.com/).

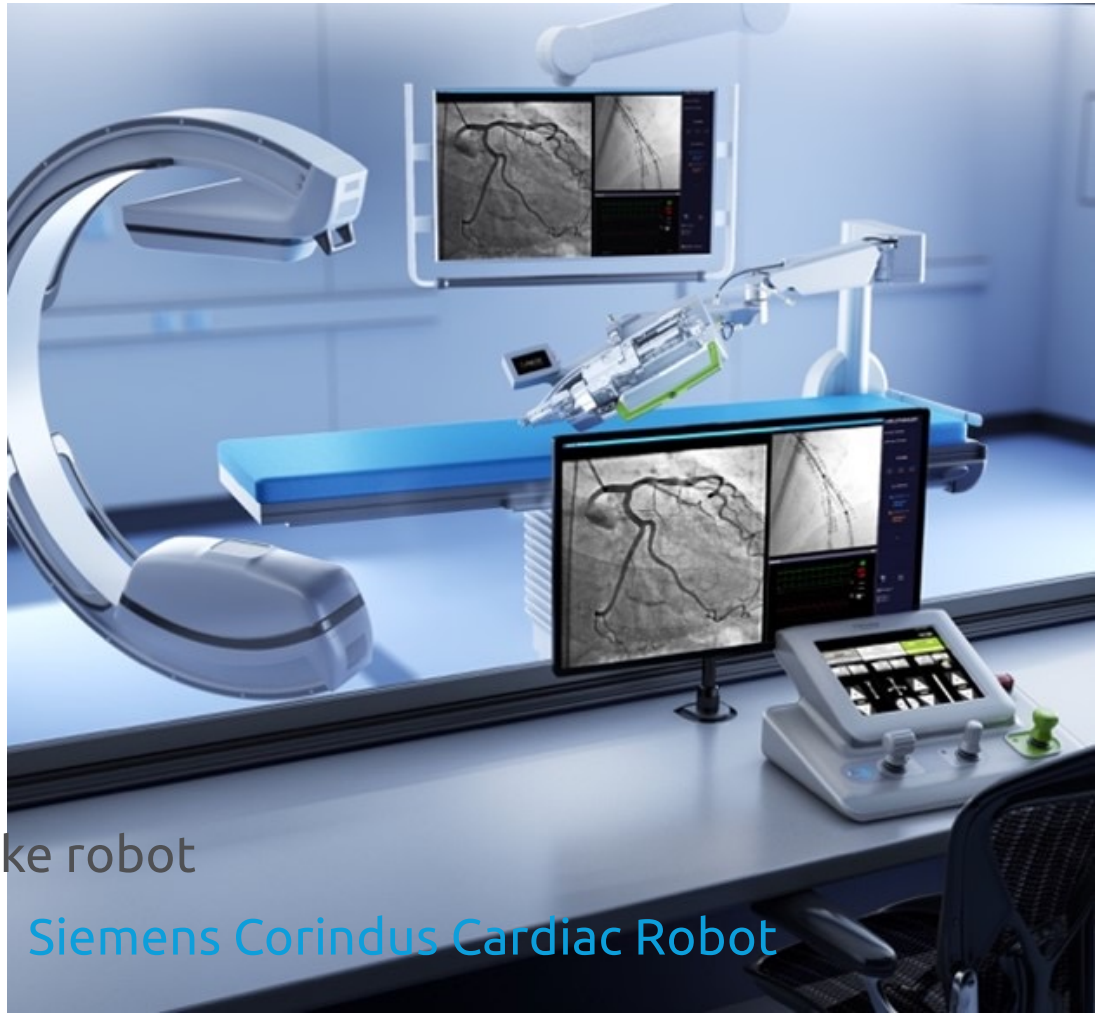
virtual reality





[1]Christian Jung et al, “Virtual and Augmented Reality in Cardiovascular Care: State-of-the-Art and Future Perspectives,” JACC: Cardiovascular Imaging, Volume 15, Issue 3, March 2022, Pages 519-532.
[2] My. Venkatesan, “Virtual and augmented reality for biomedical applications,” Cell Reports Medicine, Volume 2, Issue 7, 20 July 2021.

Robotics using AI-driven algorithms

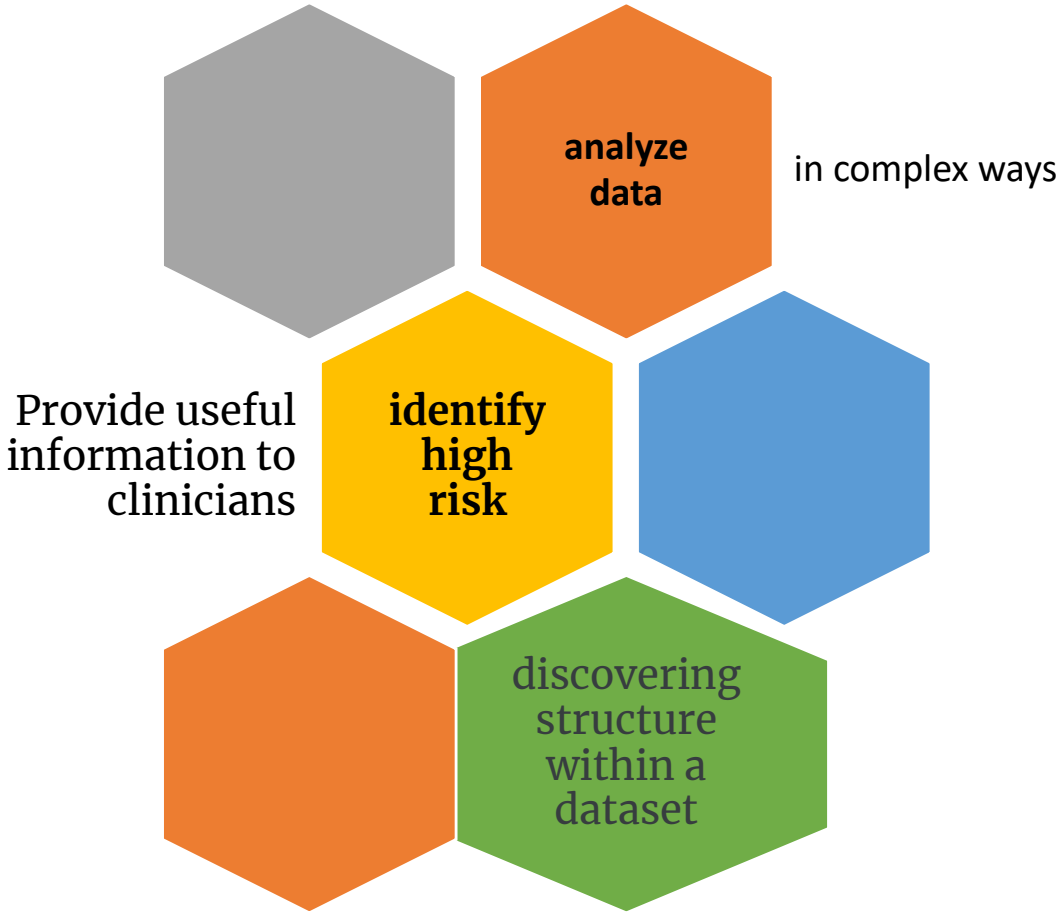


cardiac and stroke robot

Siemens Corindus Cardiac Robot

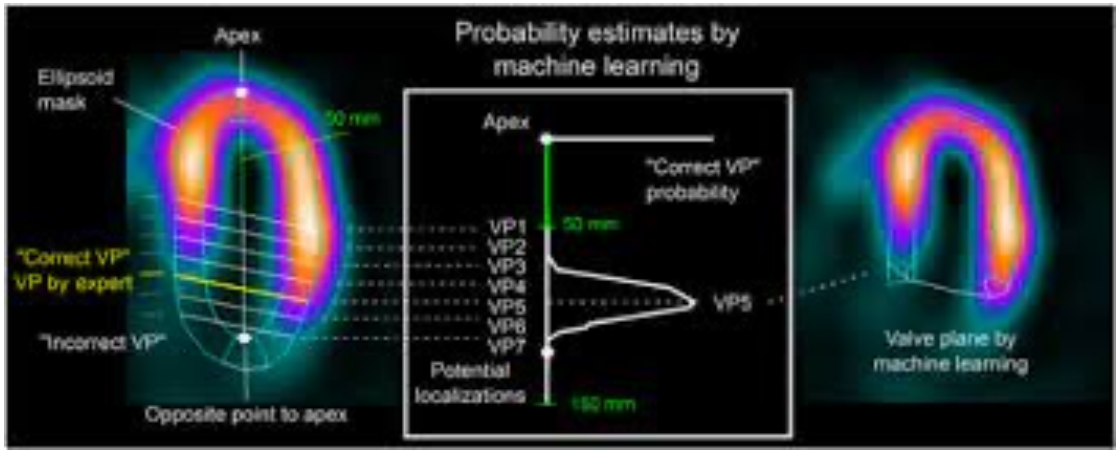
Alvin I. Chen et al, “Deep learning robotic guidance for autonomous vascular access,” Nature Machine Intelligence volume 2, pages104–115 (2020)

Analyze huge data



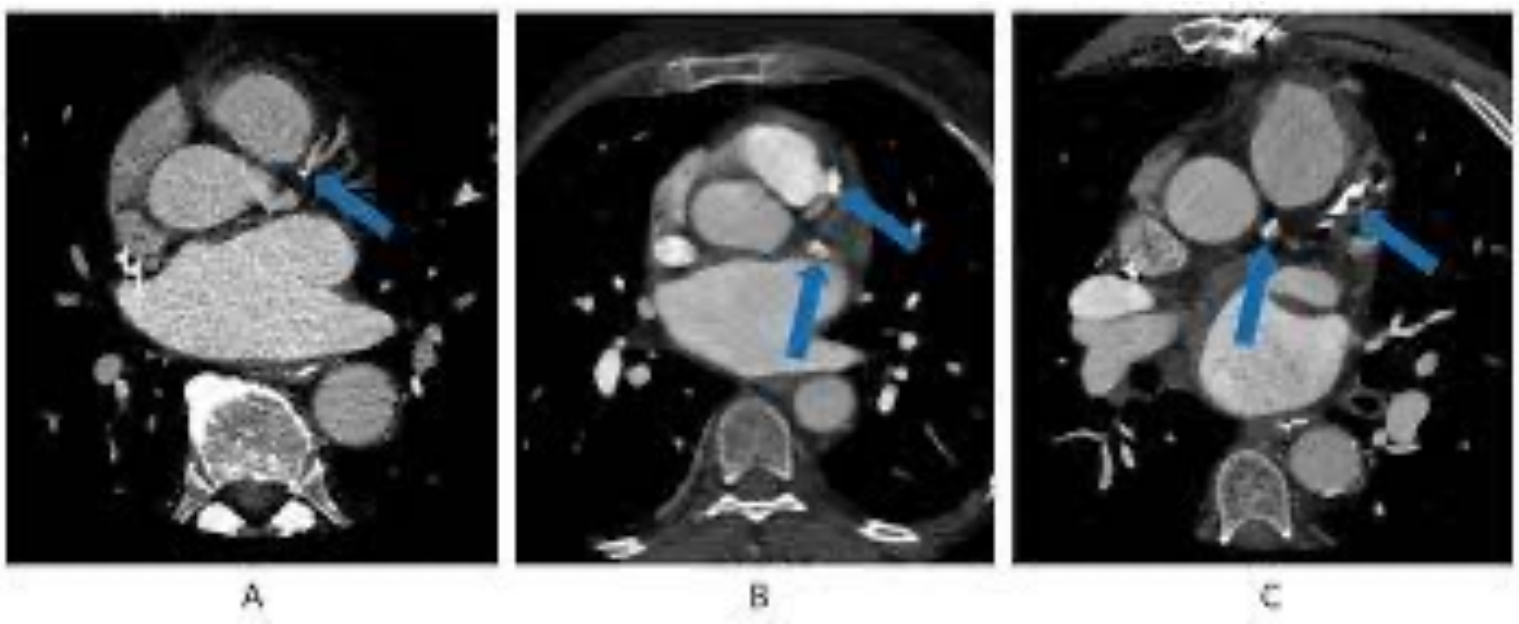
AI in nuclear cardiology

- AI has a potential to reduce cost, save time and improve image acquisition, interpretation, and decision-making



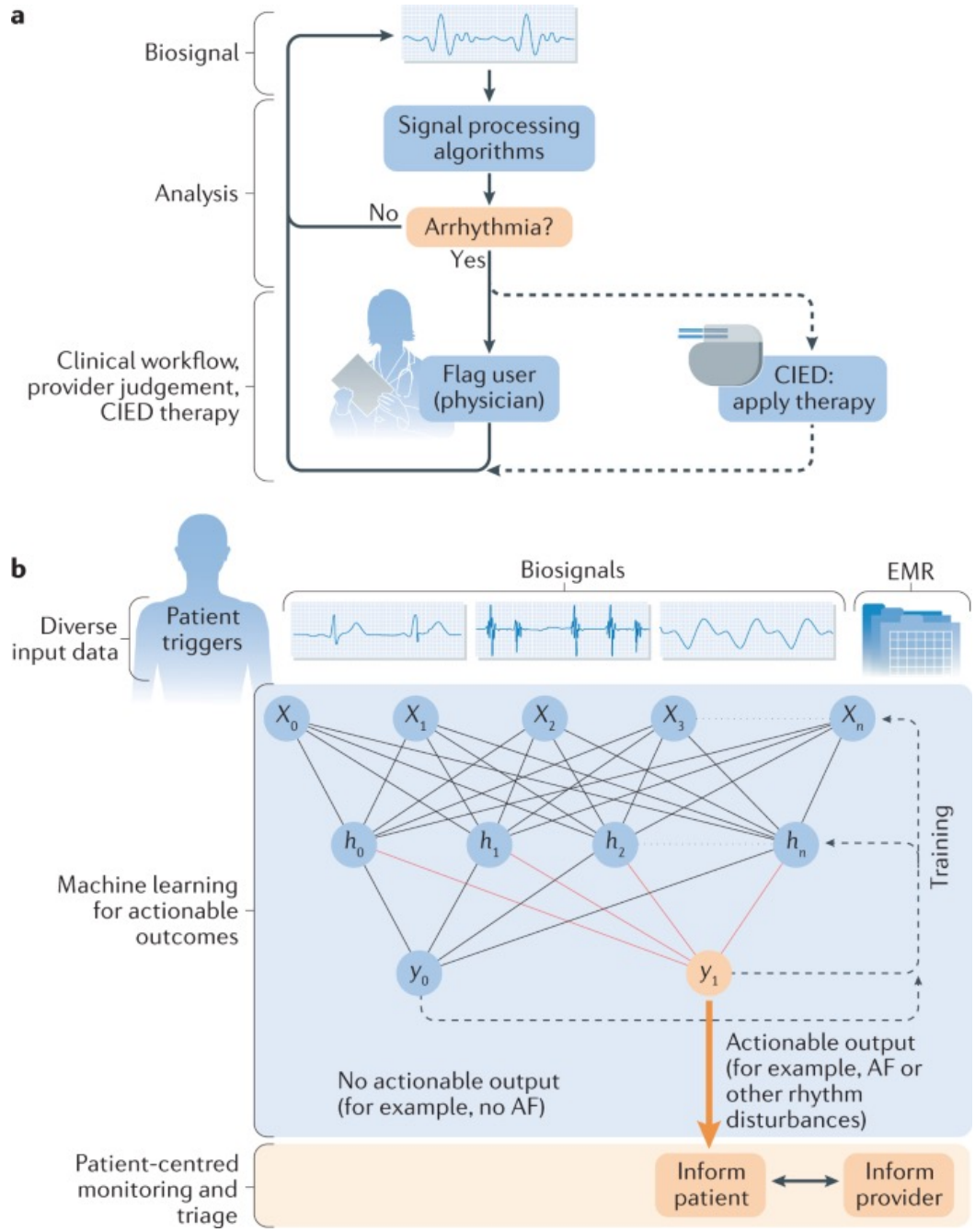
Yuka Otaki, Robert J. H. Miller & Piotr J. Slomka , The application of artificial intelligence in nuclear cardiology, Annals of Nuclear Medicine volume 36, pages111–122 (2022)

AI and Cardiovascular calcification



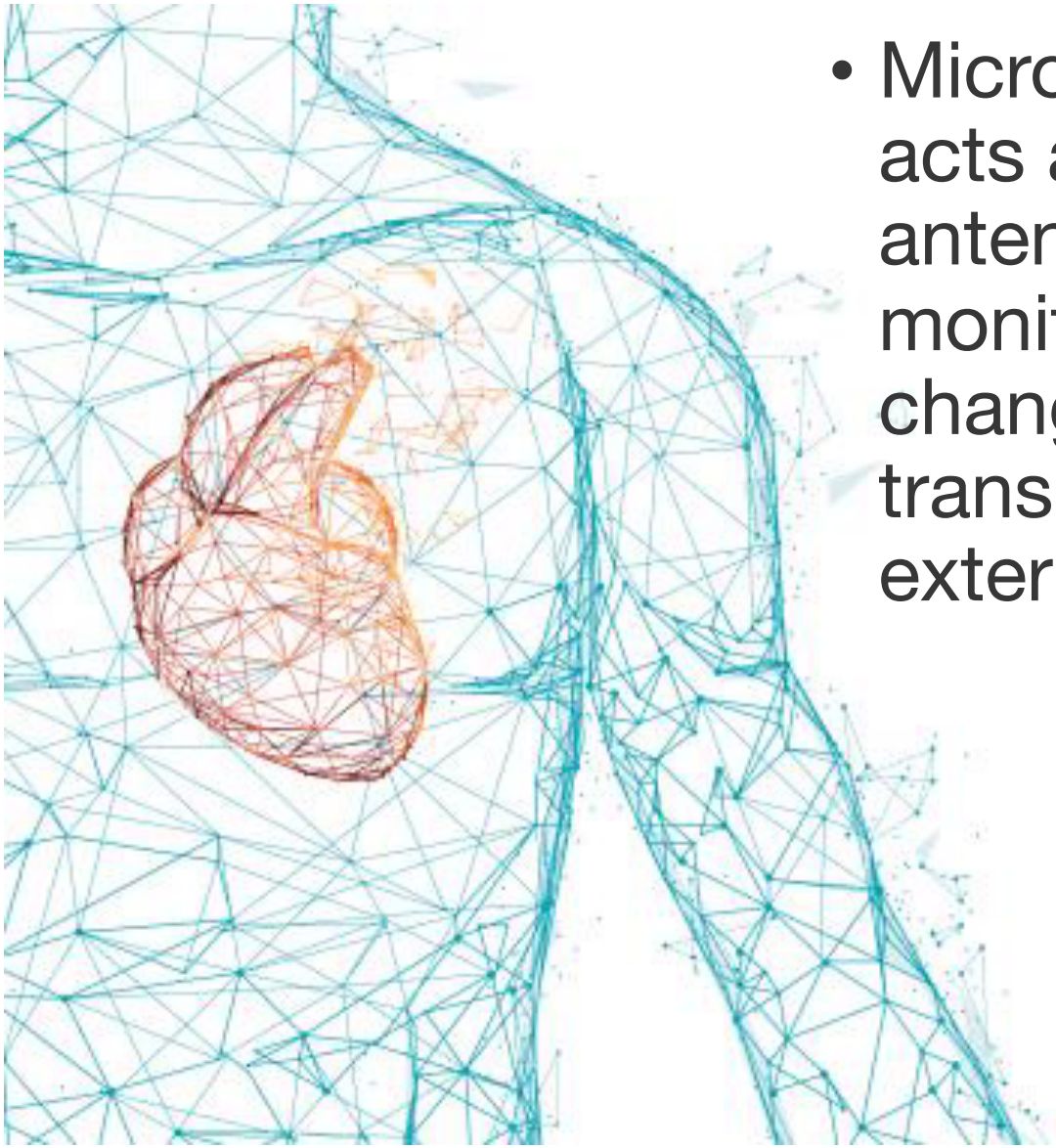
Maximillian A. Rogers & Elena Aikawa," Cardiovascular calcification: artificial intelligence and big data accelerate mechanistic discovery," Nature Reviews Cardiology volume 16, pages261–274 (2019)

Traditional analytical monitoring models V.S. AI-based models



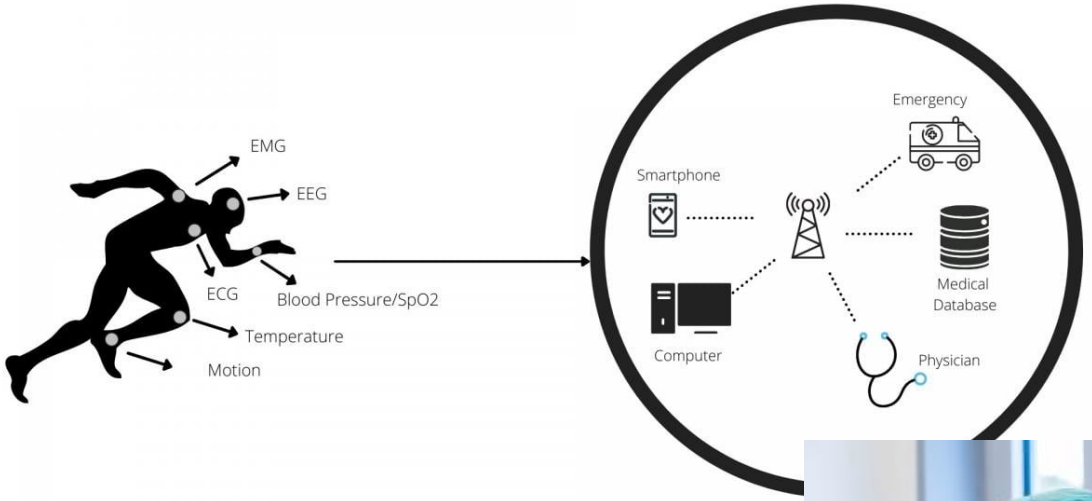
Chayakrit Krittanawong et. Al, “Integration of novel monitoring devices with machine learning technology for scalable cardiovascular management, “Nature Reviews Cardiology volume 18, pages75–91 (2021)

AI in smart stent



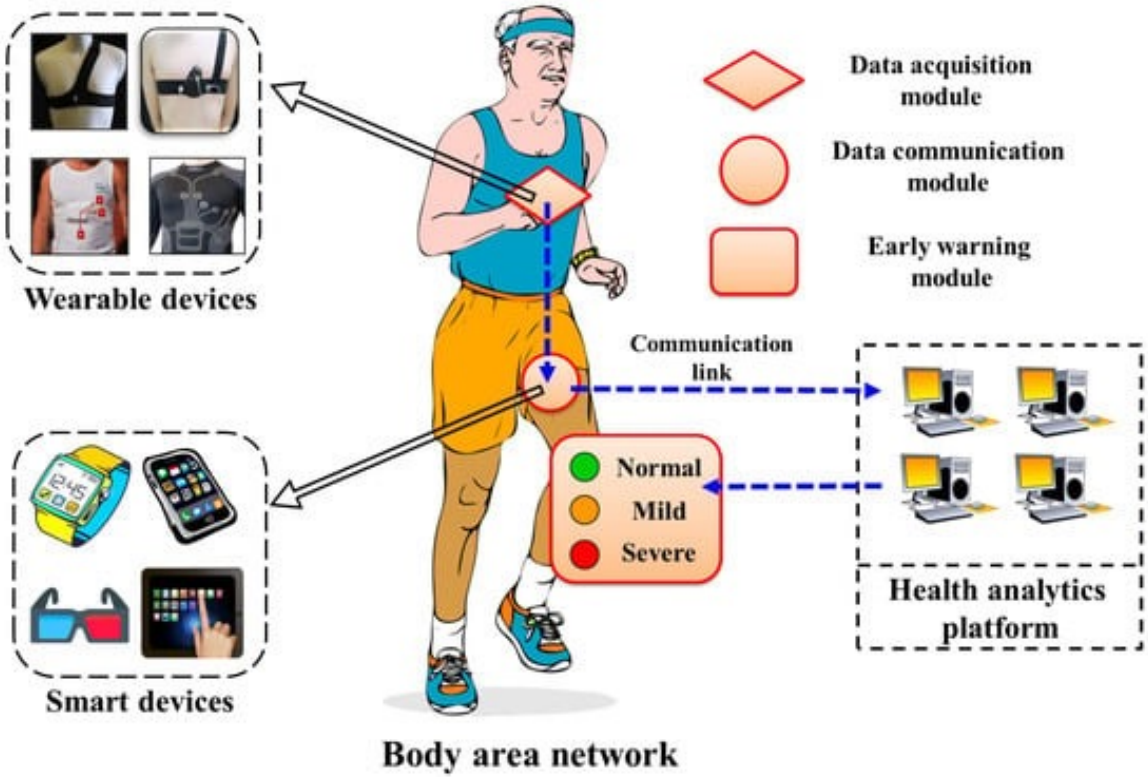
- Micro/nano-sensor that acts as a miniature antenna to continuously monitor hemodynamic changes in the artery and transmit those data to an external reader

AI and in-hospital monitoring



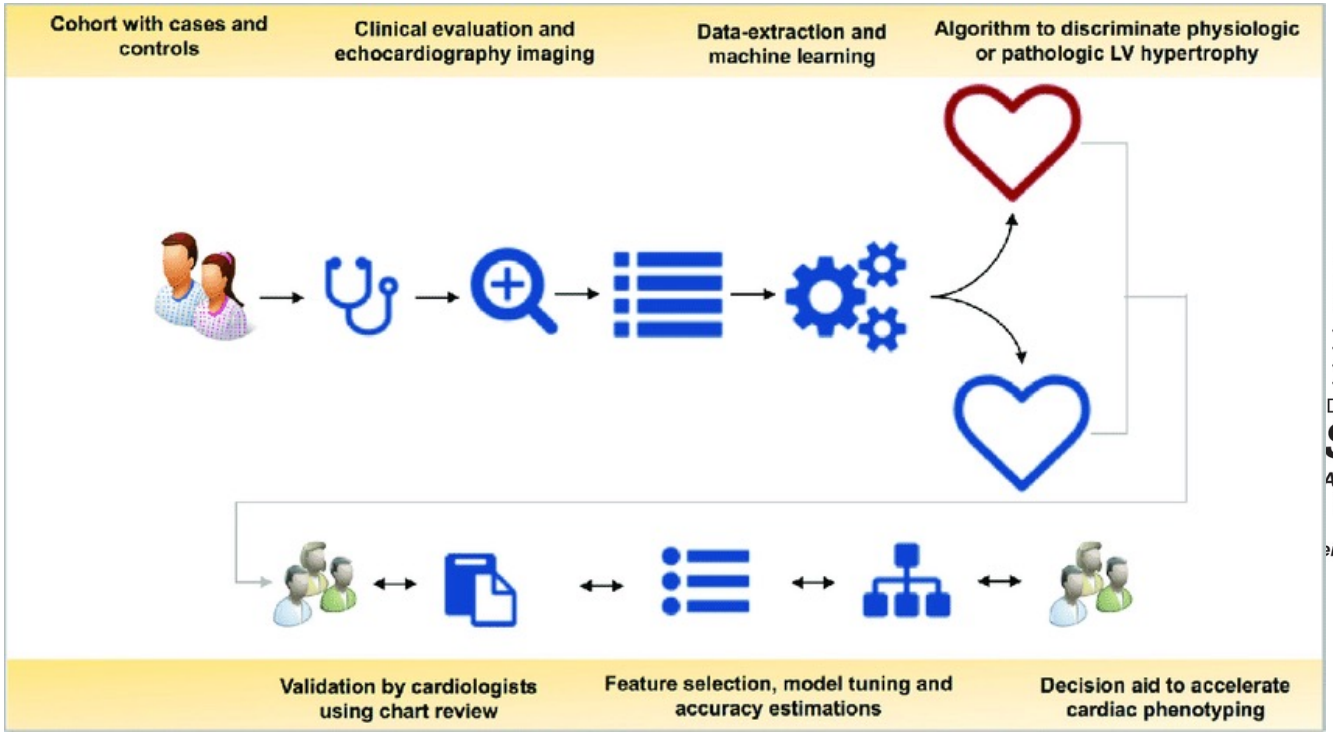
Monitoring to detect signs of severe heart failure or cardiac arrest

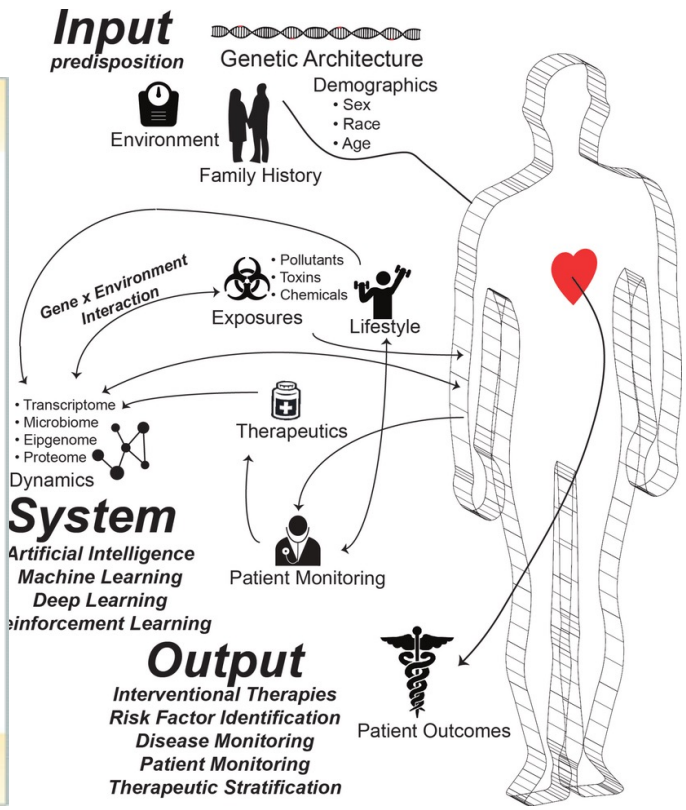
pulse,
cardiac output,
blood pressure levels,
heart rhythm,
respiratory rate,
electrolyte levels,
sympathetic nerve activity, galvanic skin resistance,
thoracic and lower-extremity oedema



Nature Reviews Cardiology **volume 18**, pages75–91 (2021)

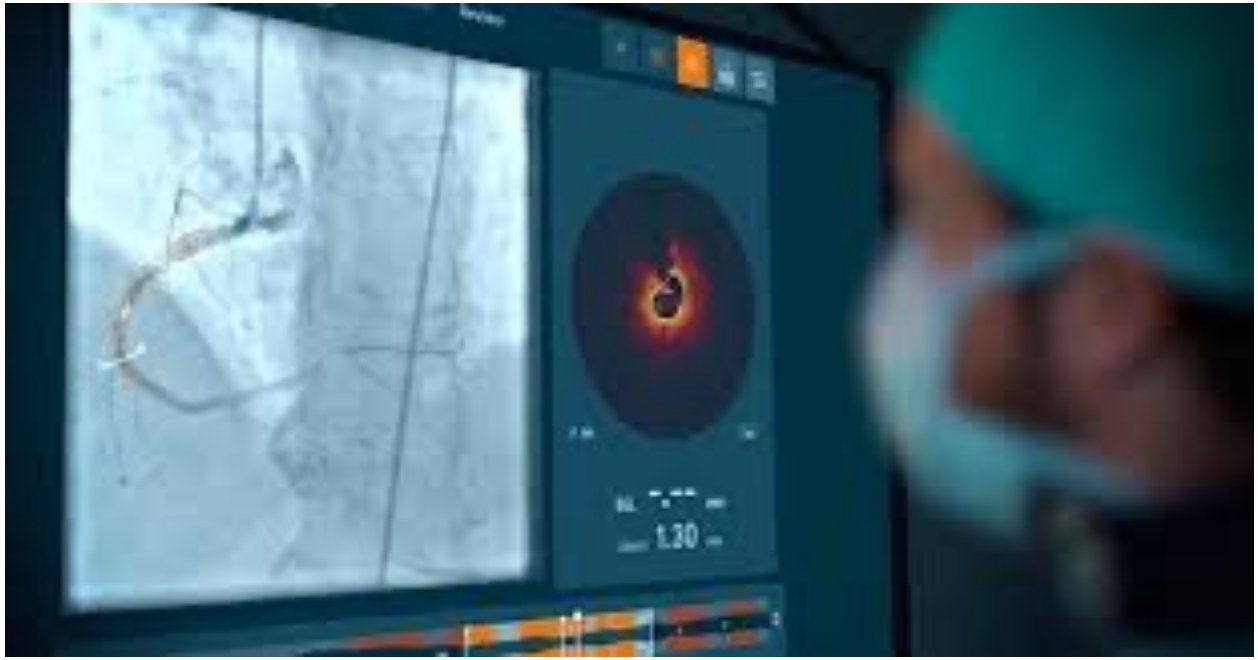
AI and Cardiovascular Genetics

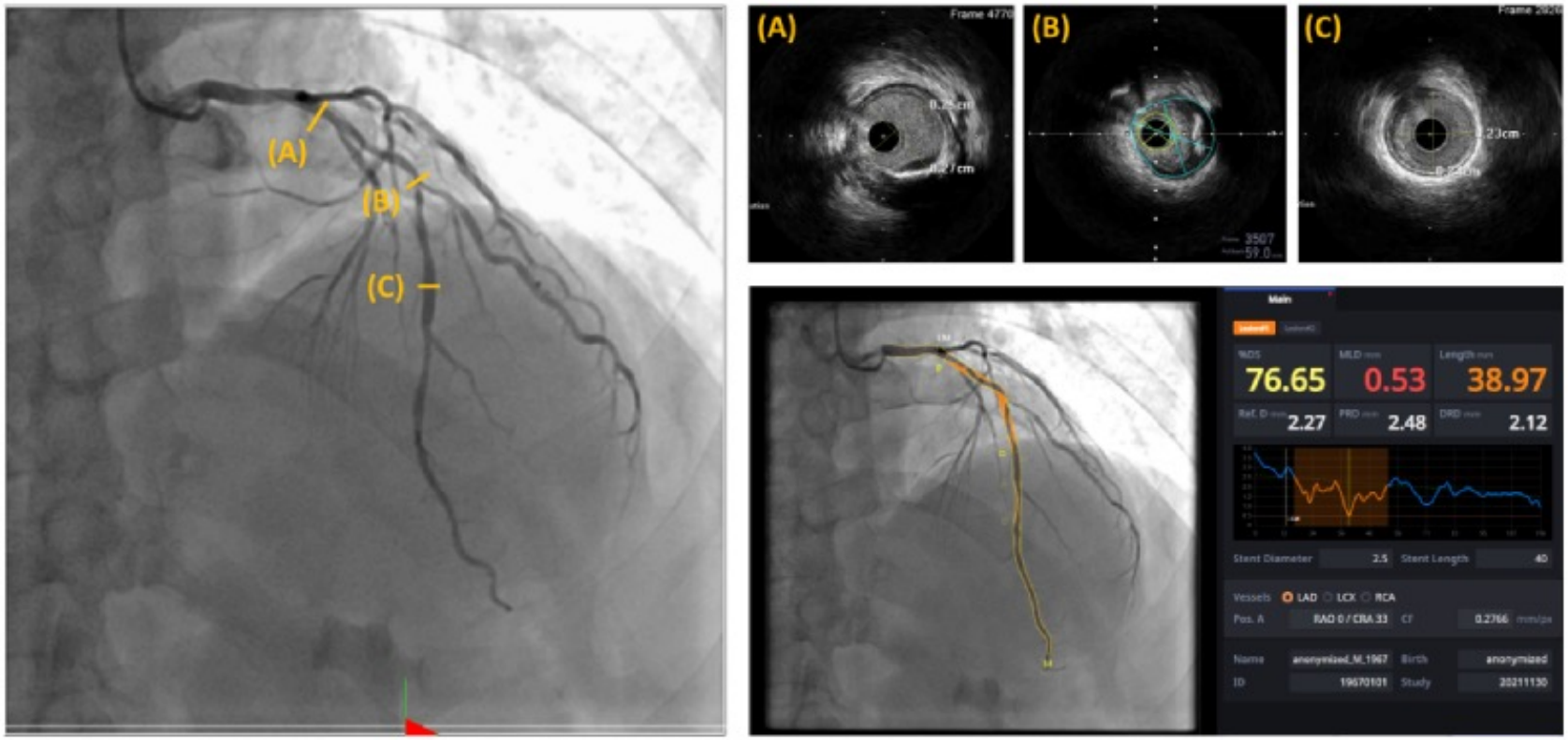




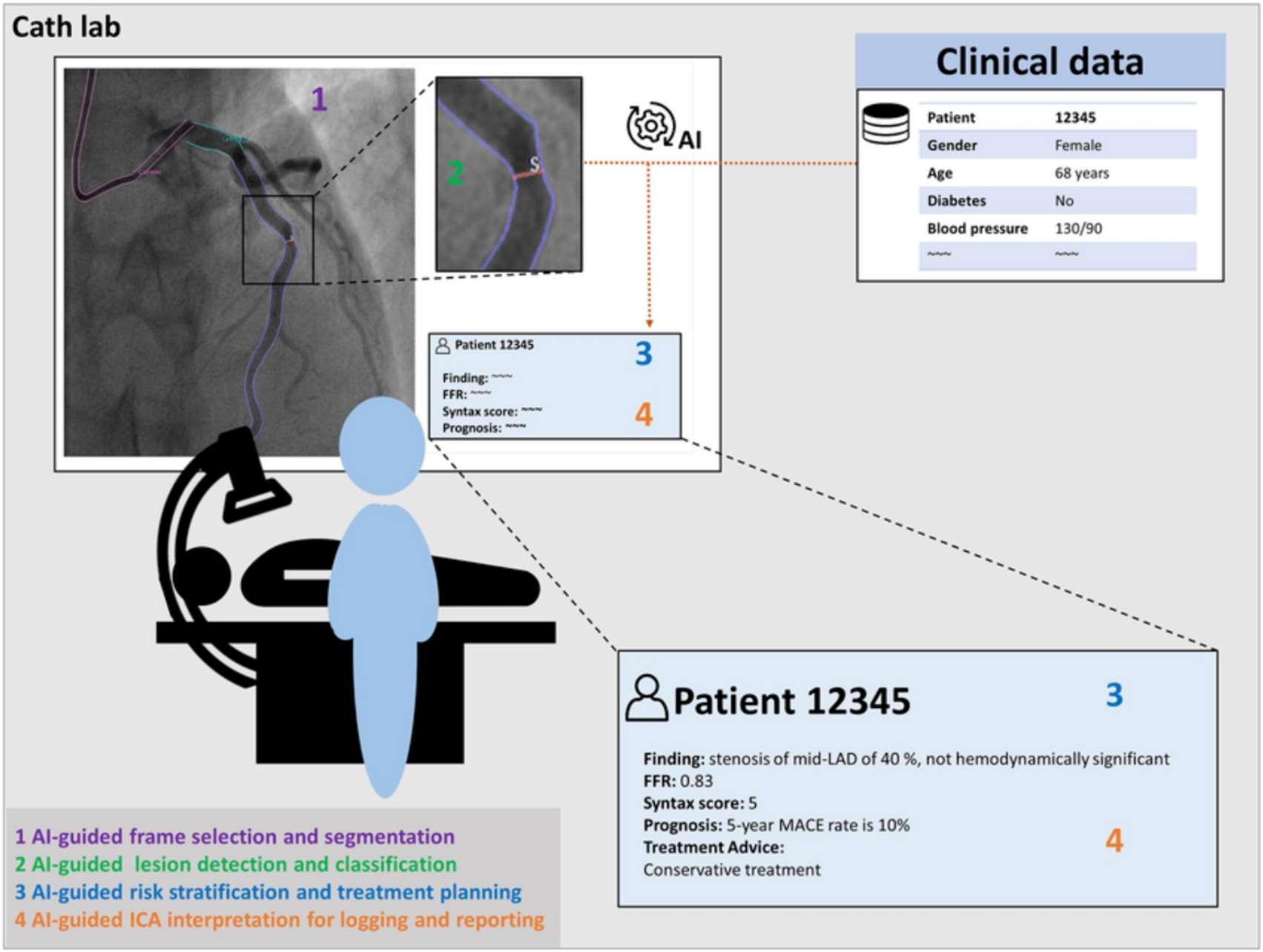
AI and interventional cardiology

- Assisting intraprocedural guidance,
- Intravascular imaging
- Providing additional information for you

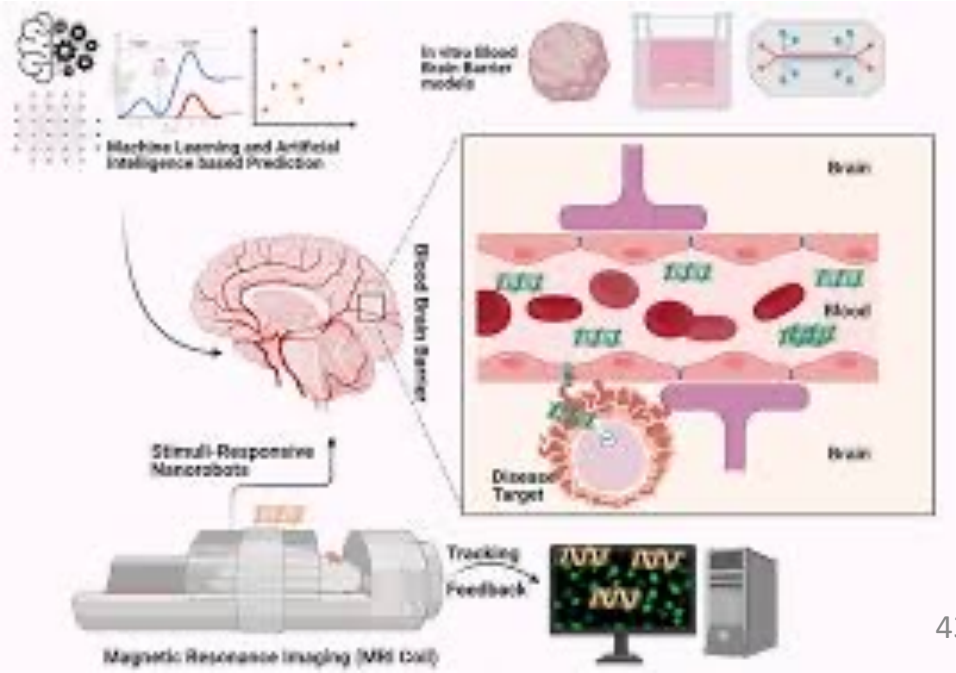



(A)
(B)
(C)
(A)
(B)
(C)
76.65
0.53
38.97
2.27
2.48
2.12

Cath lab of the future

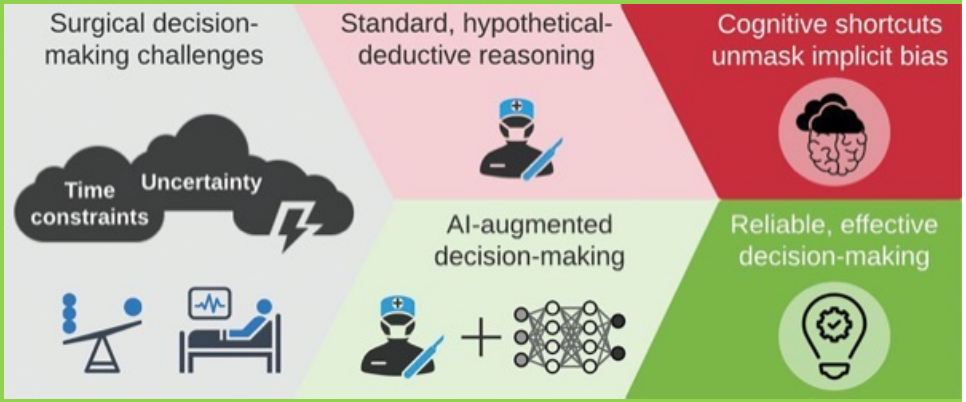


Early Detection of Disease



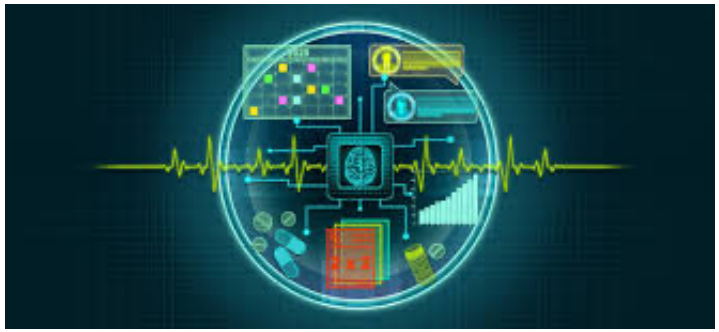
Surgery

- Improve patient care
- Extract features and predict the likelihood of malignancies
- Estimating remaining surgical time, patient's particular condition, and recovery
- Performing robotic surgery
- Anticipating complications e.g flap failure, surgical site infection, wound dehiscence and infection, deep vein thrombosis, and reintubation
- Decreasing blood loss
- Training
- Diagnosing
- Cooperative Data Analyzing
- Optimizing supply and instrument use
- Staffing
- Electronic health records (EHR) improvement, coding, and billing

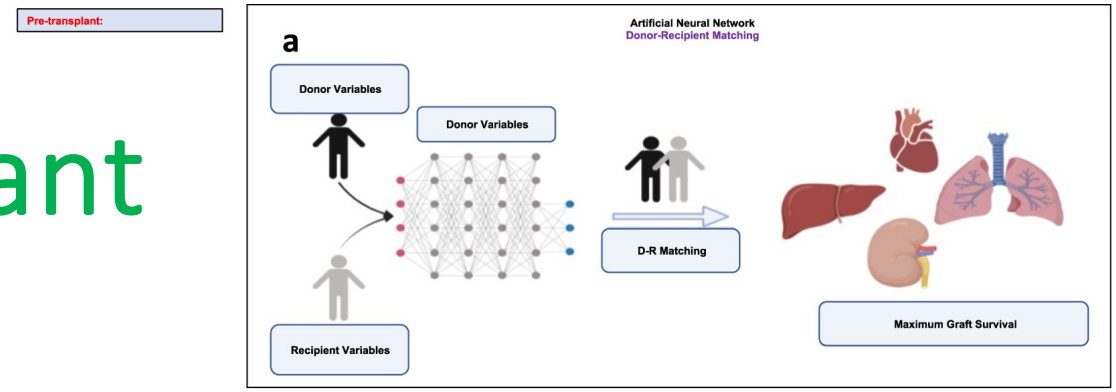


AI and Urgency detection

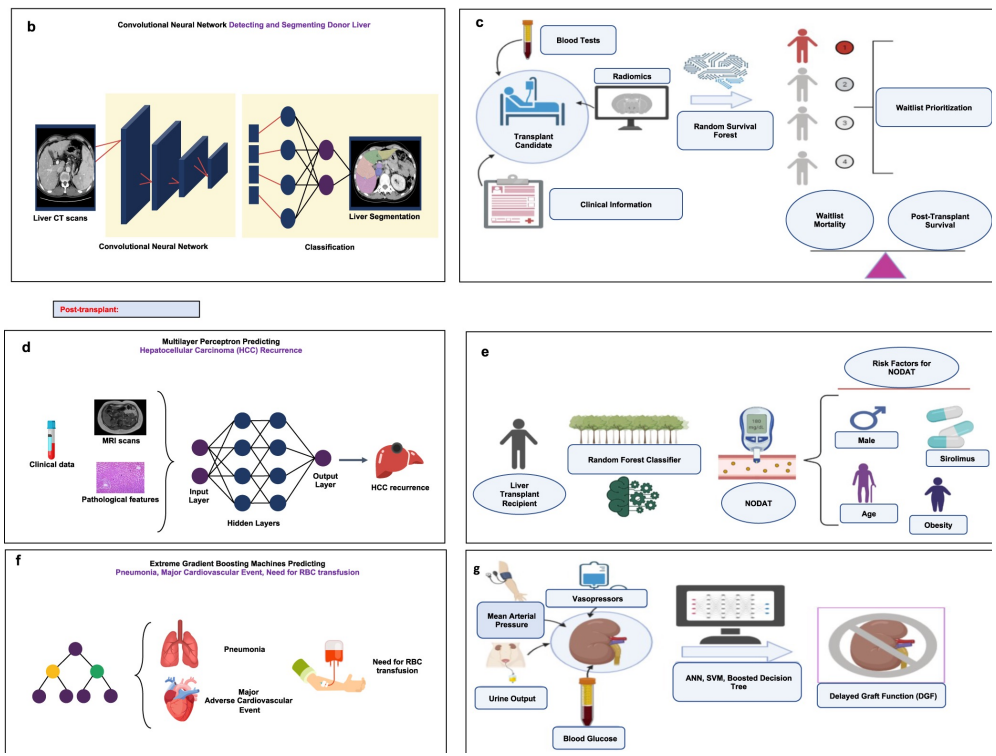
- Which patient is more urgent for doctor to see?



Organ Transplant



- Optimal transplant donor organ
- organ-allocation



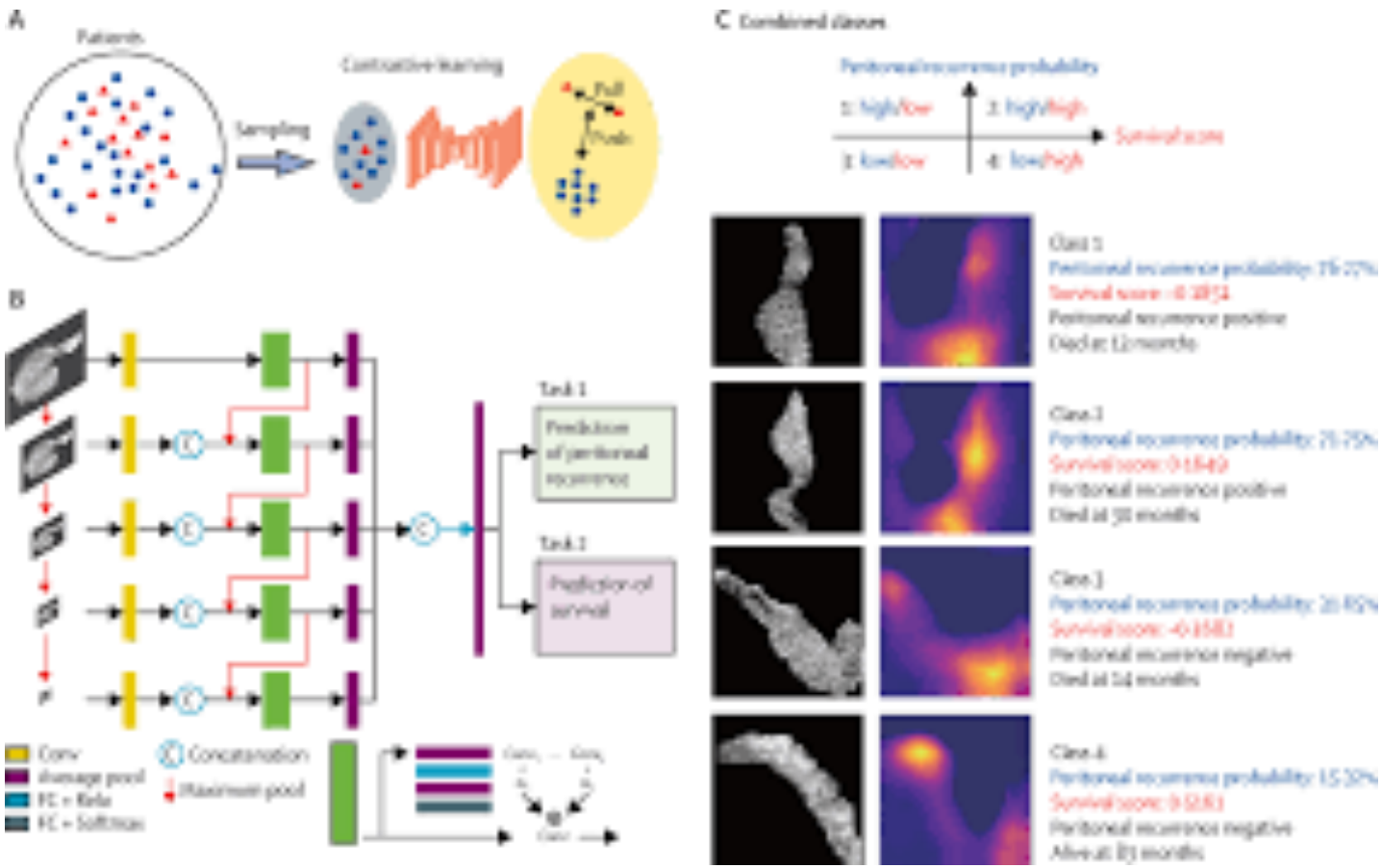
[1] N. Gotlieb Et al., “The promise of machine learning applications in solid organ transplantation,” *npj Digital Medicine,* vol. 5, No. 89, 2022.

Hospitalization, Triage tools, Operating Room

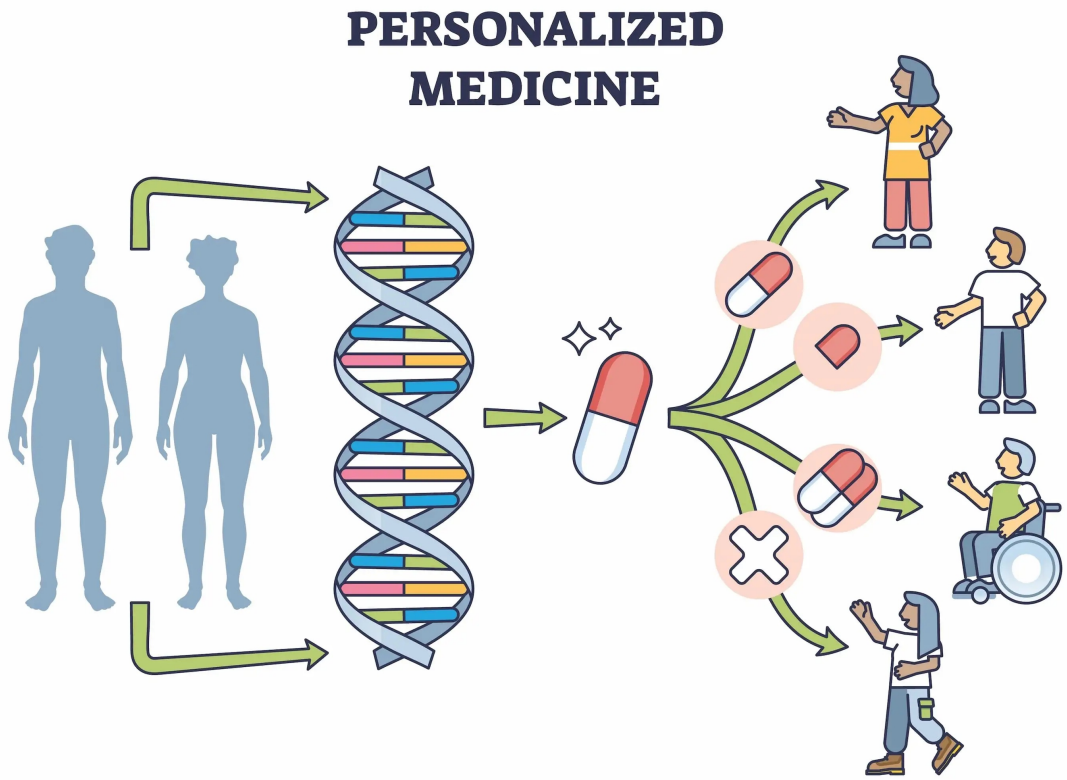
- Predictions of the surgical case duration
- Precise scheduling, limiting waste of resources
- Identifying surgeries with high risks of cancellation

[1] J.-Ting Lee, “Prediction of hospitalization using artificial intelligence for urgent patients in the emergency department,” *Scientific Reports,* vol. 11, No. 19472, 2021.

Disease Recurrence Prediction



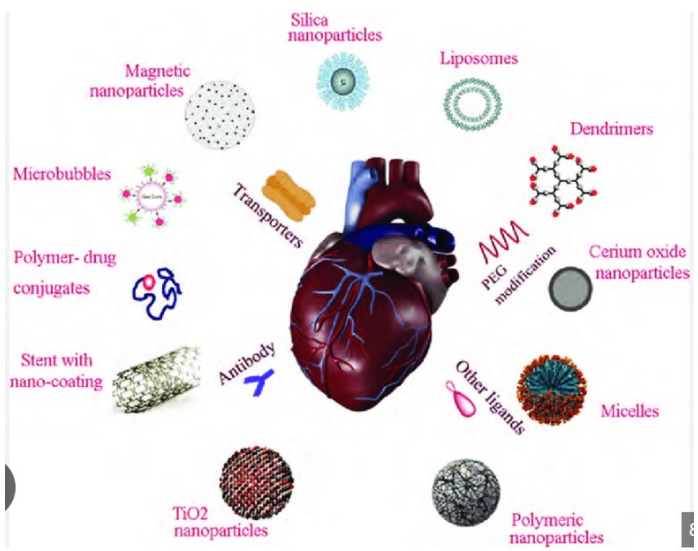
Personalized Medicine

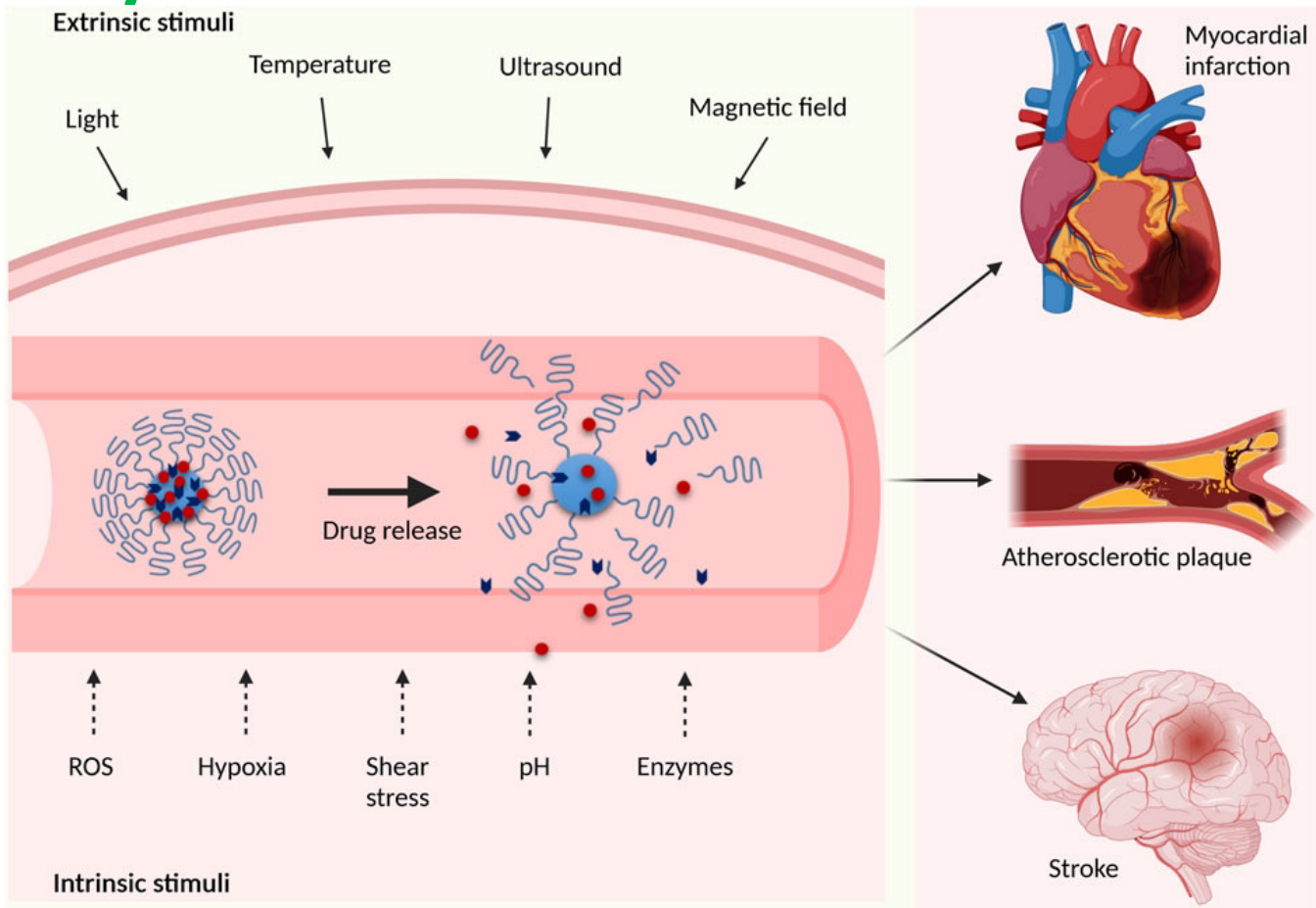


Drug Discovery and Targeted Drug Delivery

Properties

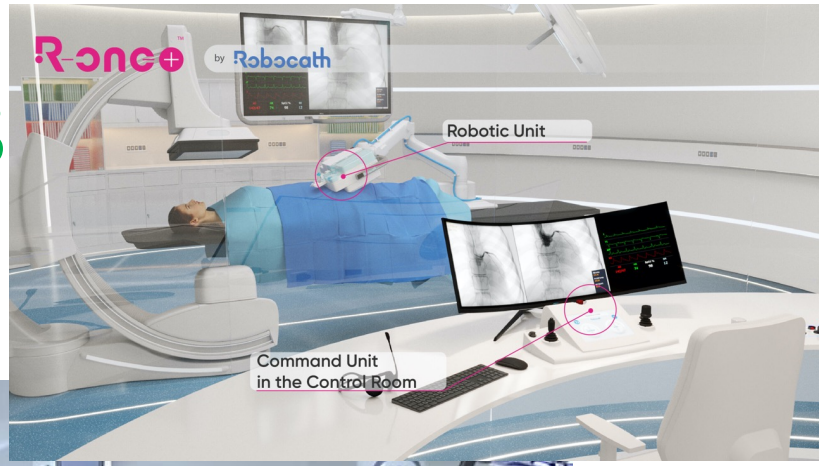
- **Sustained release behavior**
- **Targeting properties**
- **Biocompatibility**
- **Biodegradability**
- **Biodistribution**
- **Low toxicity**

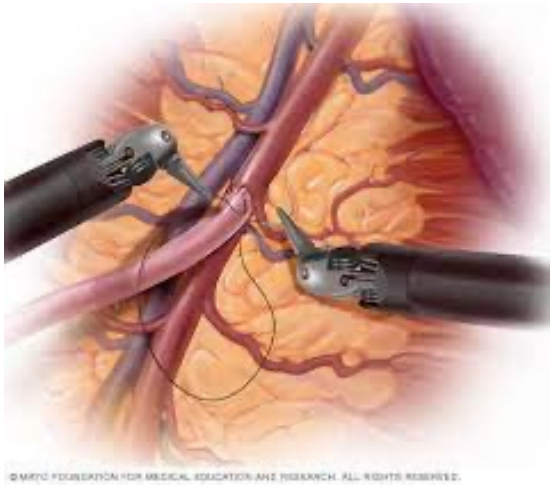


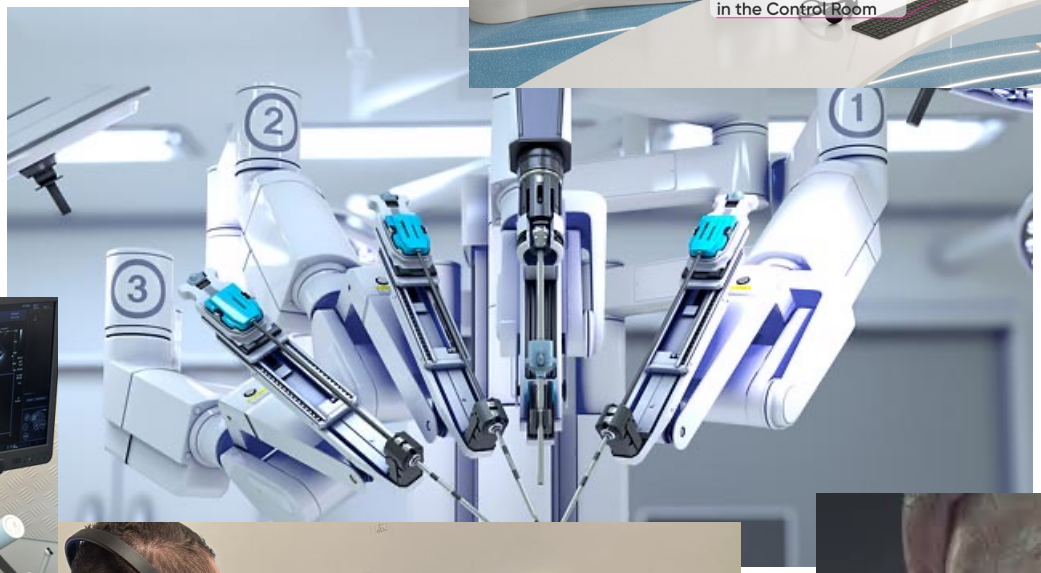


Medical Robotics

coronary angioplasties

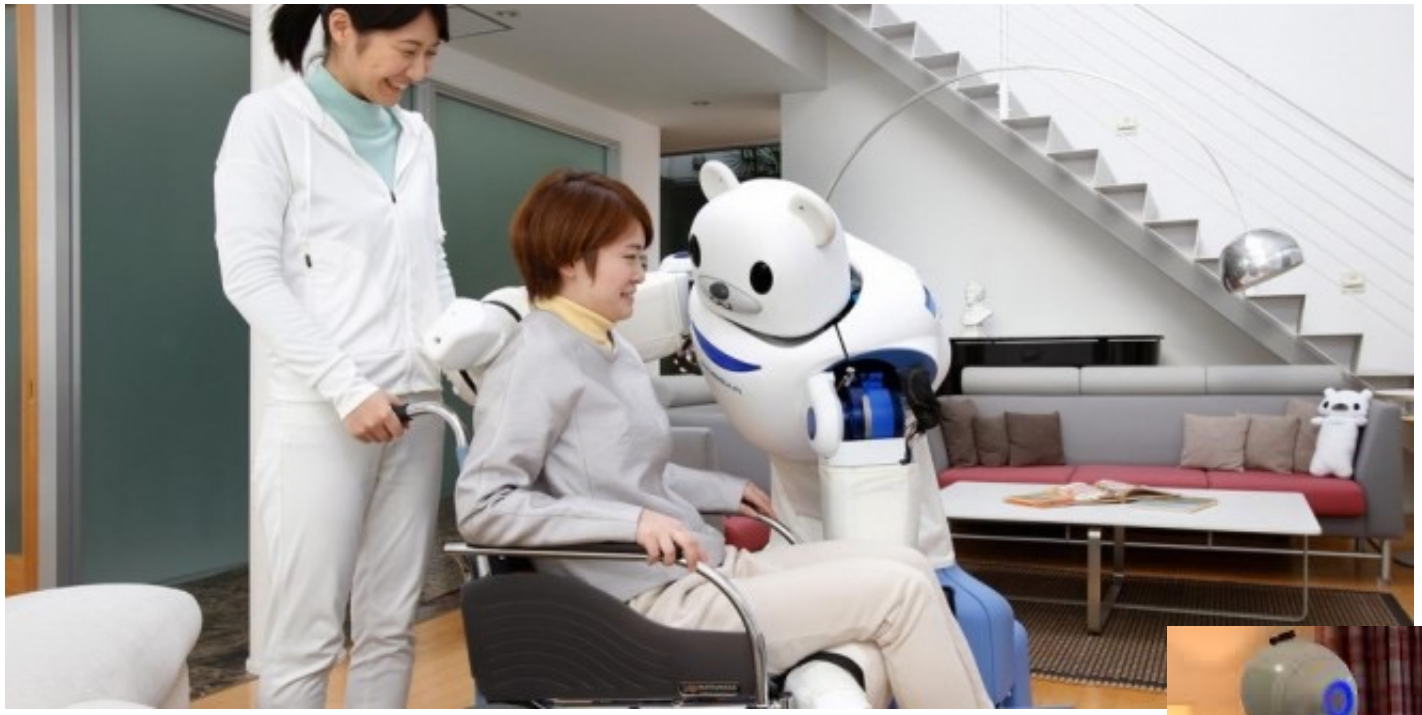






world-first cardiac robotic ultrasound

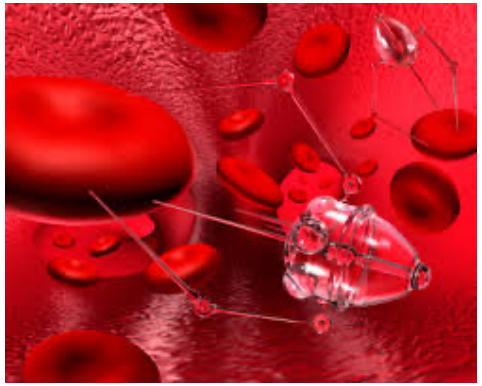
Nursing Robotics

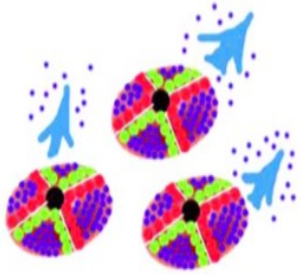


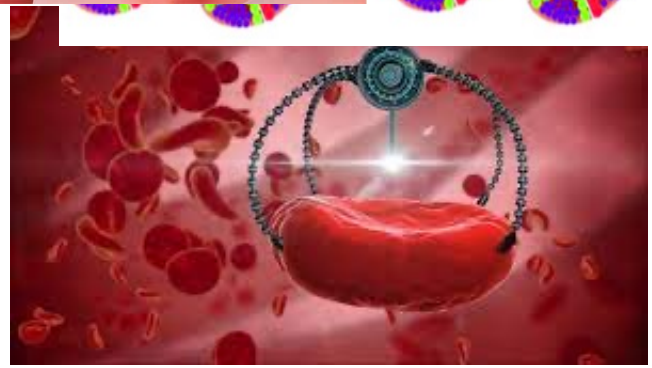
Tele Pharmacy

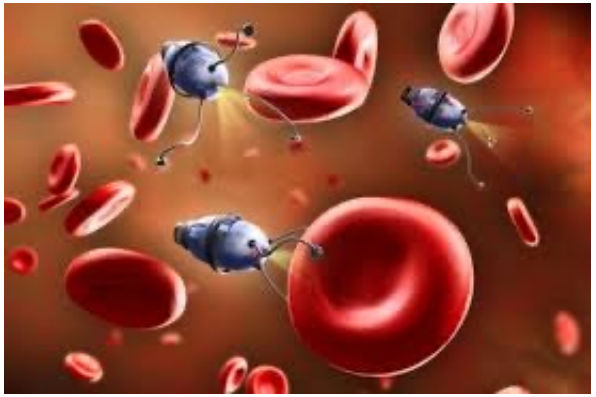
Telemedicine

Nanomedicine







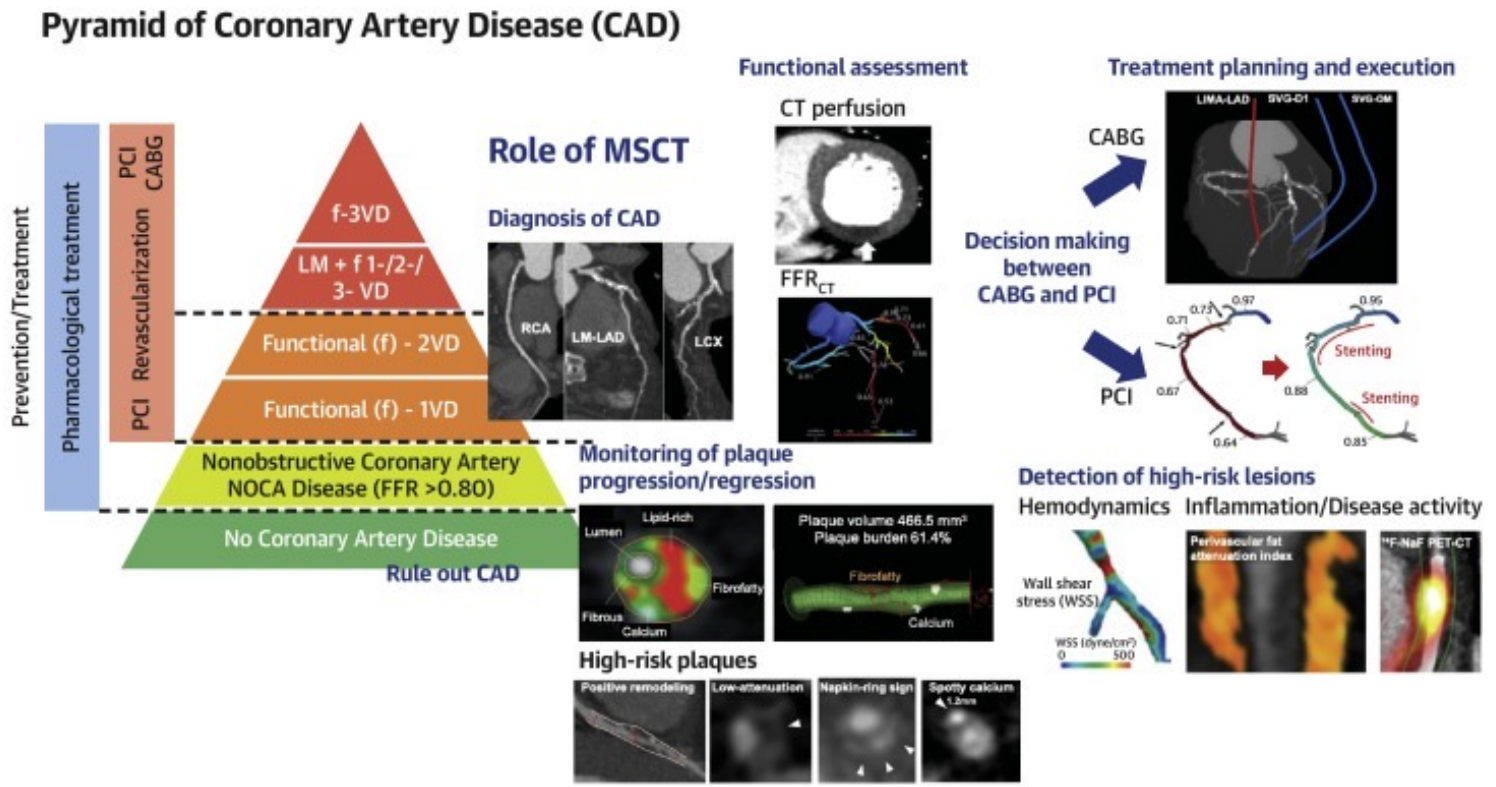


[1] N. Rady Raz, M. R. Akbarzadeh T., "Target Convergence Analysis of Cancer Inspired Swarms for Early Disease Diagnosis and Targeted Collective Therapy,"*IEEE Transactions on Neural Networks and Learning Systems*, 2022.

[2] N. Rady Raz, M. R. Akbarzadeh T., "Swarm-Fuzzy Rule-Based Targeted Nano Delivery Using Bioinspired Nanomachines,"*IEEE Transactions on NanoBioscience*,Vol.18, No.3, pp. 404 - 414, July 2019.

[3] N. Rady Raz, M. R. Akbarzadeh T., M. Tafaghodi, "Bio-Inspired Nanonetworks for Targeted Cancer Drug Delivery,"*IEEE Transactions on NanoBioscience*,Vol.14, No.8, pp. 894-906, Dec. 2015.

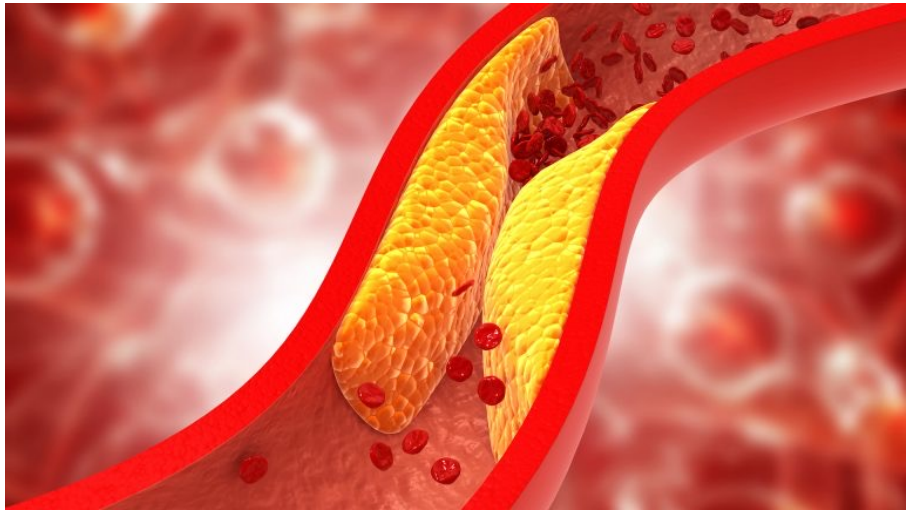
CENTRAL ILLUSTRATION: The Pyramid of Coronary Artery Disease and the Diagnostic Role of Multislice Computed Tomography

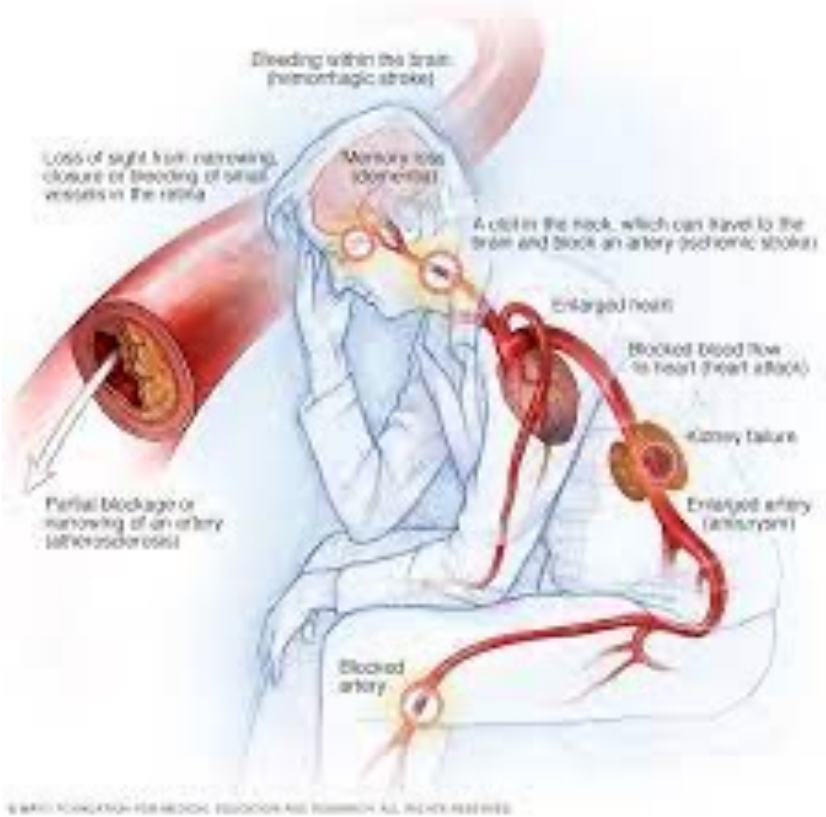


Serruys, P.W. et al. J Am Coll Cardiol. 2021;78(7):713–736.

High cholesterol

npj Digital Medicine **volume 3**, Article number: 142 (2020)





High blood pressure

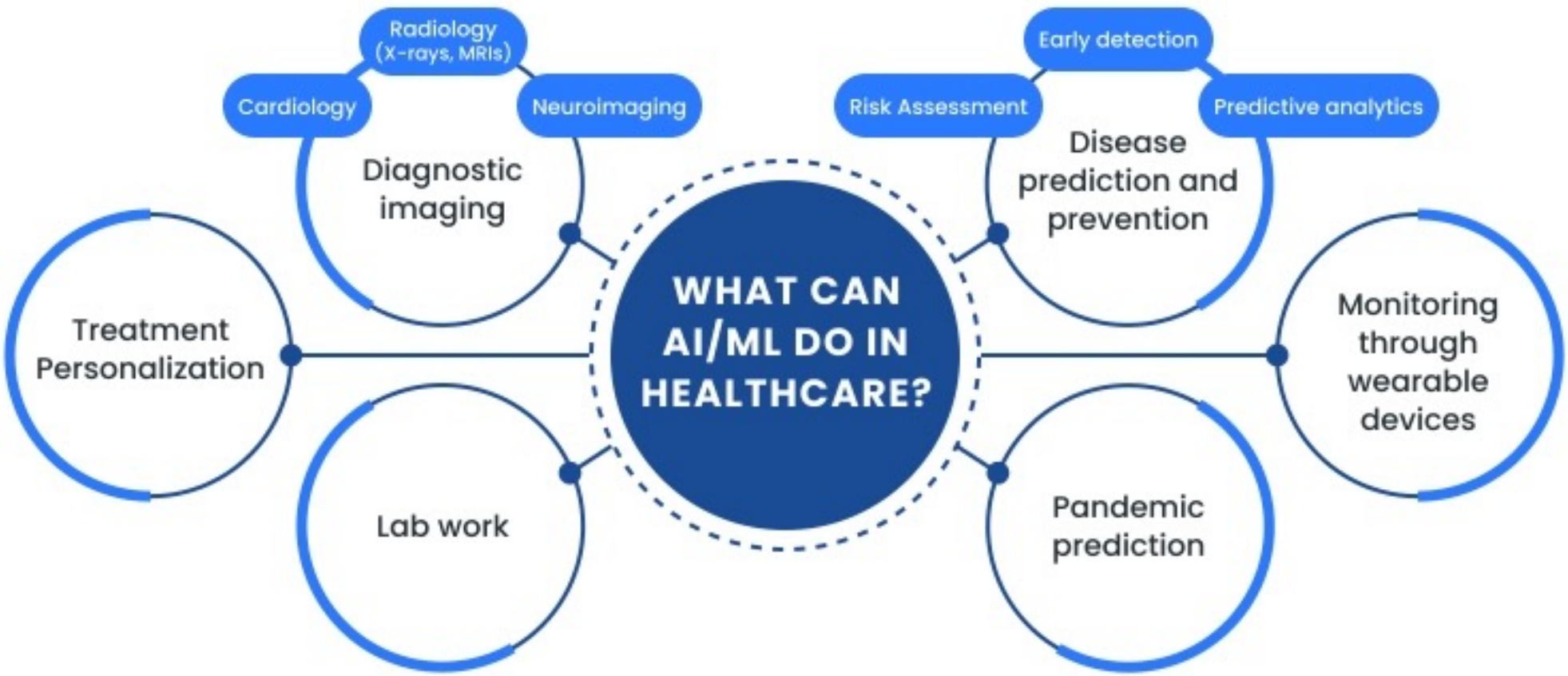
Future possibilities for artificial intelligence in the practical management of hypertension
Hypertension Research **volume 43**, pages1327–1337 (2020)

Challenges and Ethical Considerations

data privacy,

potential biases in datasets

interpretability of algorithms,

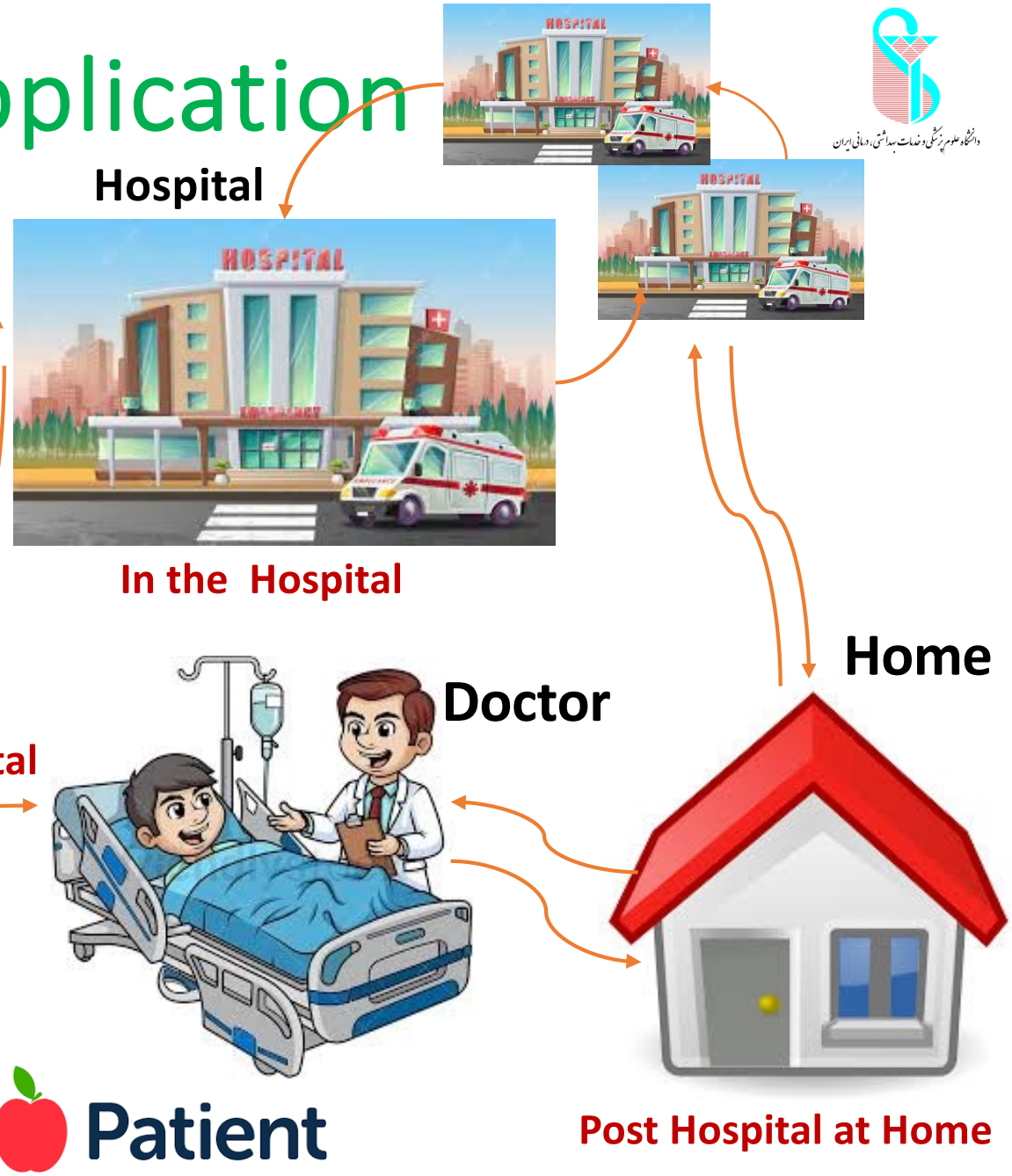


Note that!!

- AI may not replace human doctors.
- Since doctors are trained to not only diagnose and treat diseases but also to provide emotional support to patients.
- AI cannot replace the empathy and compassion that doctors bring to their work.

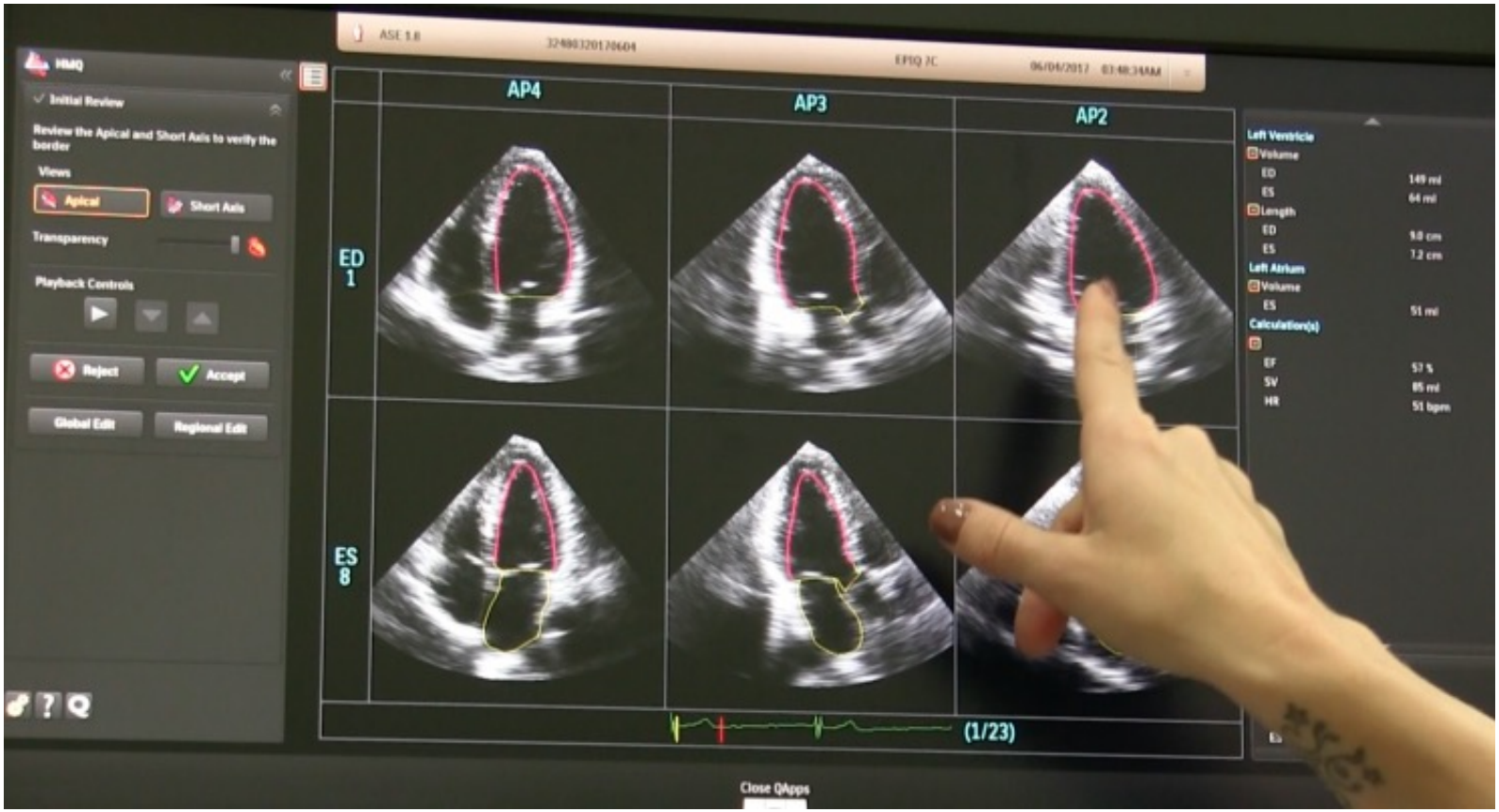
8-AI Medical Application

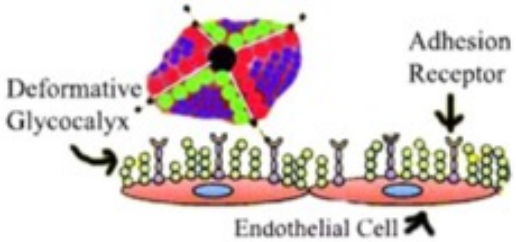
Prevention	Screening
Early Detection	Diagnosis
Recurrence Prediction	Critical Decision Making
Treatment Selection and Analysis	Mortality and Morbidity Prediction
Triage	…

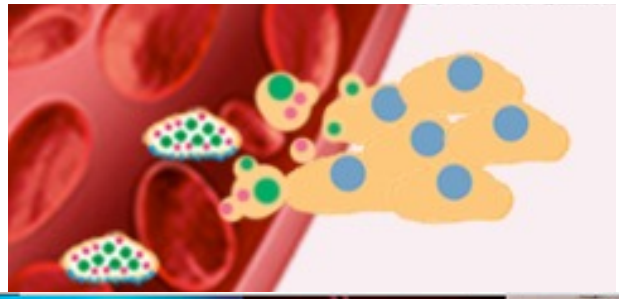


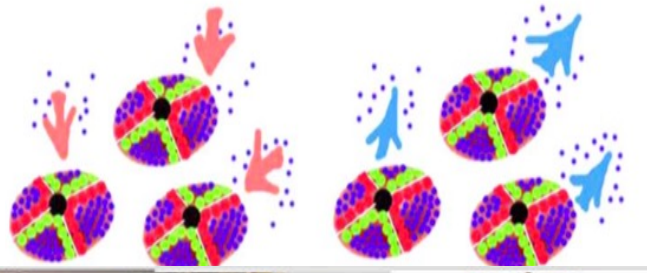
Standard view location

- Computer-aided detection of standard views constantly supports clinicians.









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Research Interest:

Artificial Intelligence, Artificial Intelligence in Medicine, Complex Systems, Biomimicry, Cognitive Science, Swarm Intelligence, Nanomedicine, Targeted Drug Delivery, Early Detection of Disease, Swarm Nano Robotics, Cancer Research, Fuzzy Logic and Control, Soft Computing, Neural Networks, Machine Learning, Multi-agent Systems, Distributed Decision Making, Biomarkers, Biophysics, Nature Inspired Algorithms, Computational Cellular/Molecular Biology, Protein Folding

Artificial Intelligence for Good (AI for Good)