دانشگاه علوم پزشکی و خدمات بهداشتی، درمانی ایران

Application of Artificial Intelligence in Surgery

دکتر نسیبه رادی راز

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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

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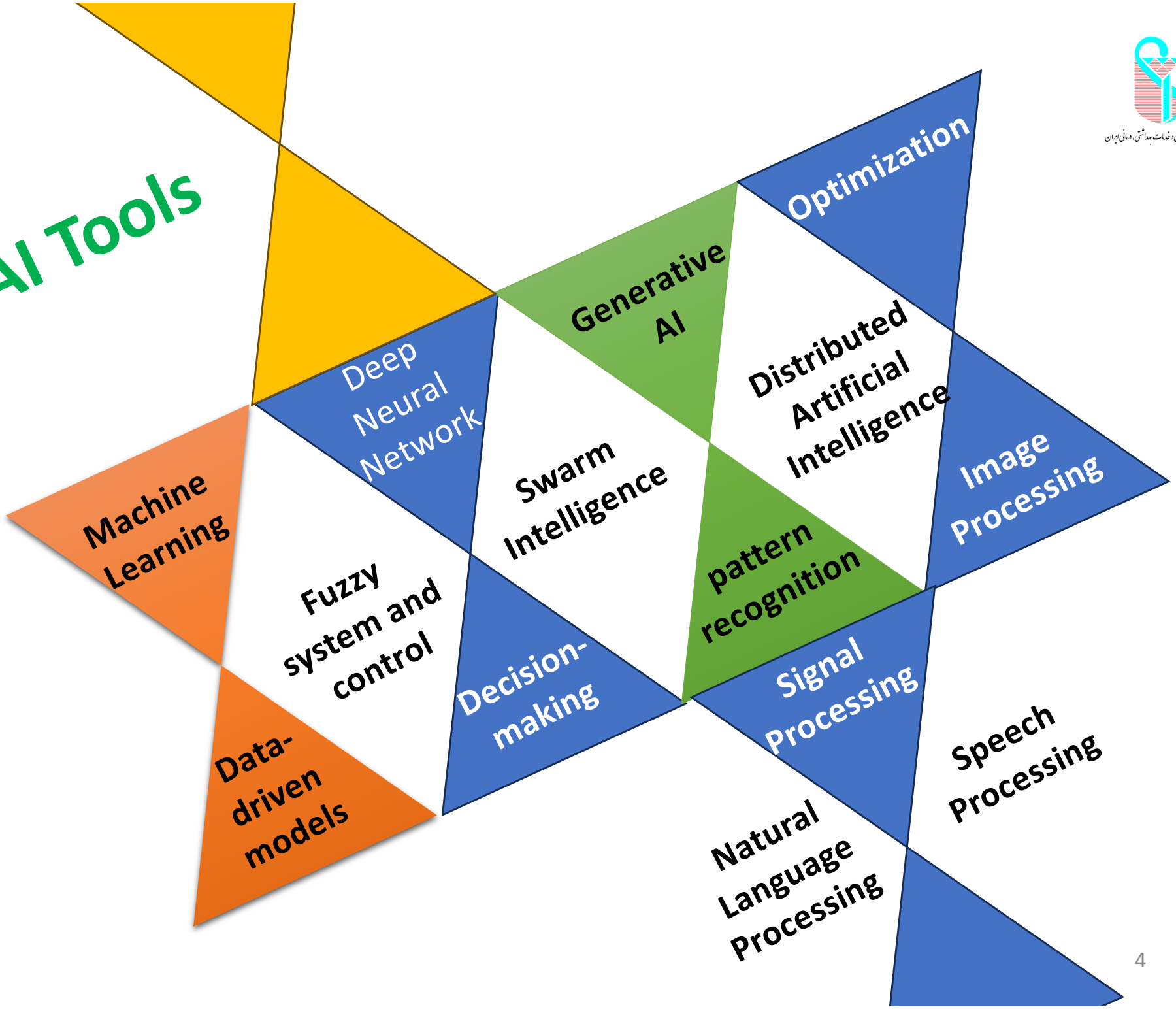
بسم الله الرحمن الرحیم

AI Tools

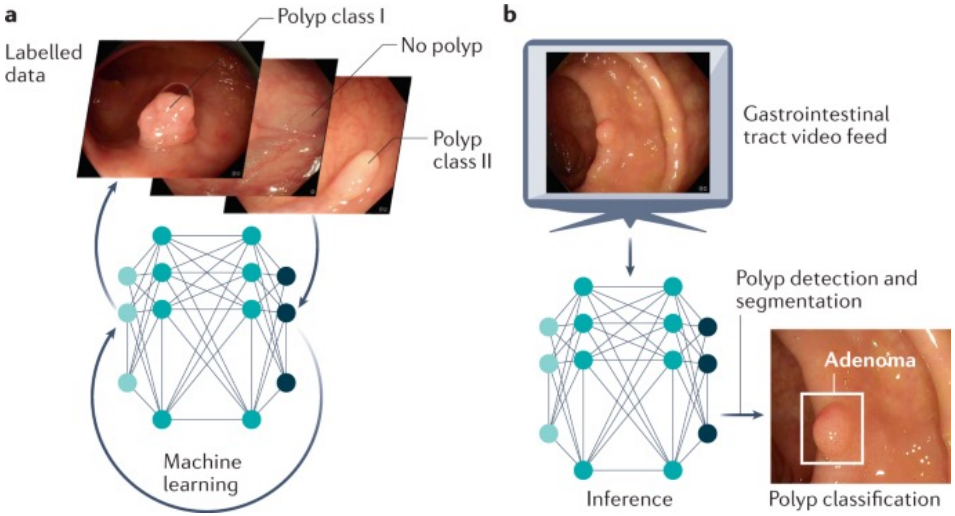

Machine Learning
Deep Neural Network
Generative AI
Optimization
Fuzzy system and control
Swarm Intelligence
Distributed Artificial Intelligence
Image Processing
Data-driven models
Decision-making
pattern recognition
Signal Processing
Speech Processing
Natural Language Processing

Improve patient outcomes

- Better access to surgery,
- Surgical education,
- Detection and management of postoperative complications,
- Optimization of surgical system efficiencies.

Minimally Invasive Surgery

- improvements in surgical outcomes,
- reducing postoperative infections, length of stay and postoperative pain
- Improving long-term recovery and wound healing.
- Enhanced recovery programs,
- Improved patient selection,
- broadening adjuvant approaches and organ-sparing treatments have also been important contributors.



AI in Surgery

Preoperative evaluation and risk-assessment

Intra-operative Phase

Post-operative Phase

AI in 3 Stages

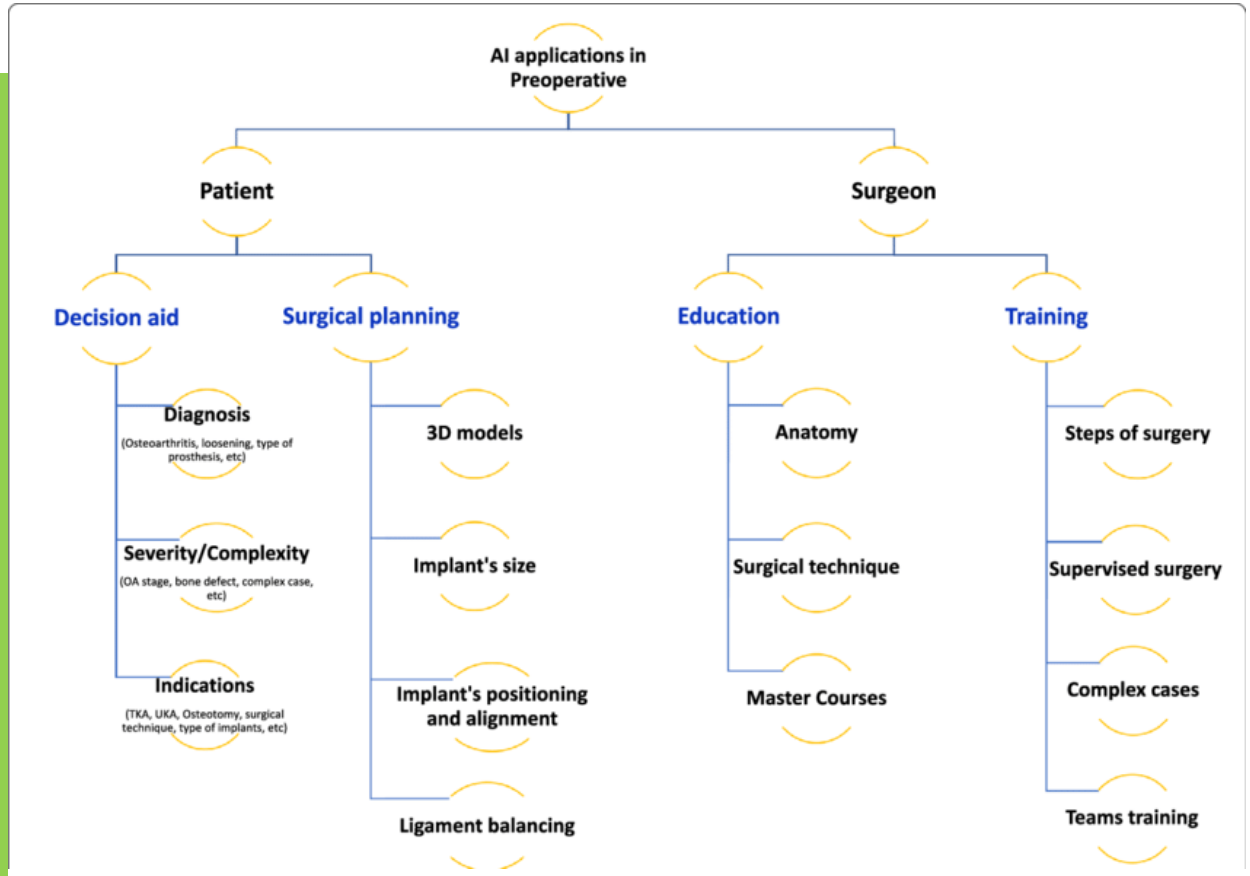
- Preoperatively, with regards to patient selection and preparation;
- Intraoperatively, for improving procedural performance, operating room workflows and surgical team functioning;
- Postoperatively, to reduce complications, reduce mortality from complications and improve follow-up.

Preoperative

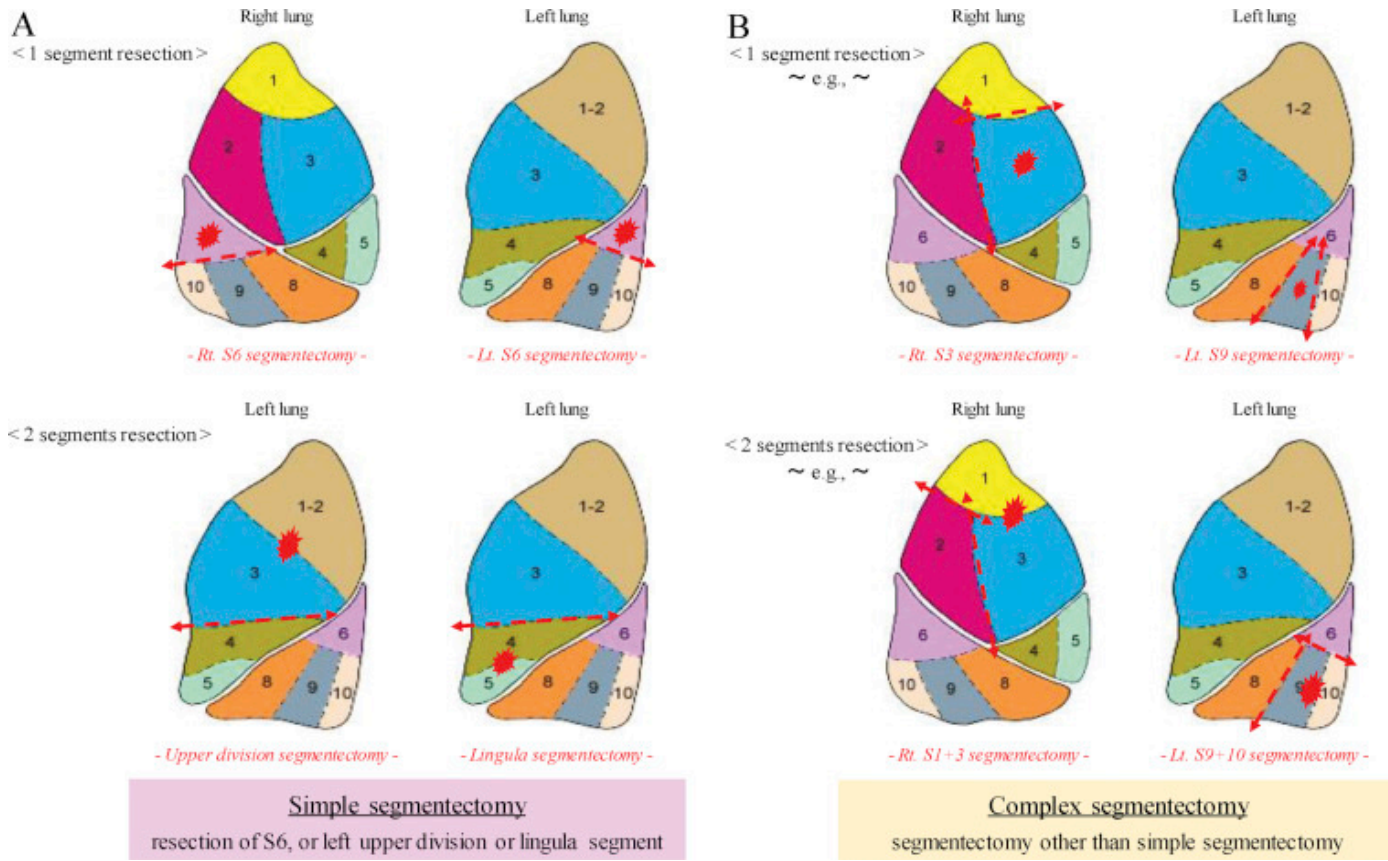
- Diagnostics,
- Risk prognostication,
- Patient selection,
- Operative optimization
- Patient counseling

Preoperative diagnostics

- Patient selection and surgical planning
- Preoperative imaging for early diagnosis and surgical planning.
- a model-free reinforcement learning algorithm showed promise when applied to preoperative magnetic resonance images to identify and maximize tumor tissue removal while minimizing the impact on functional anatomical tissues during neurosurgery

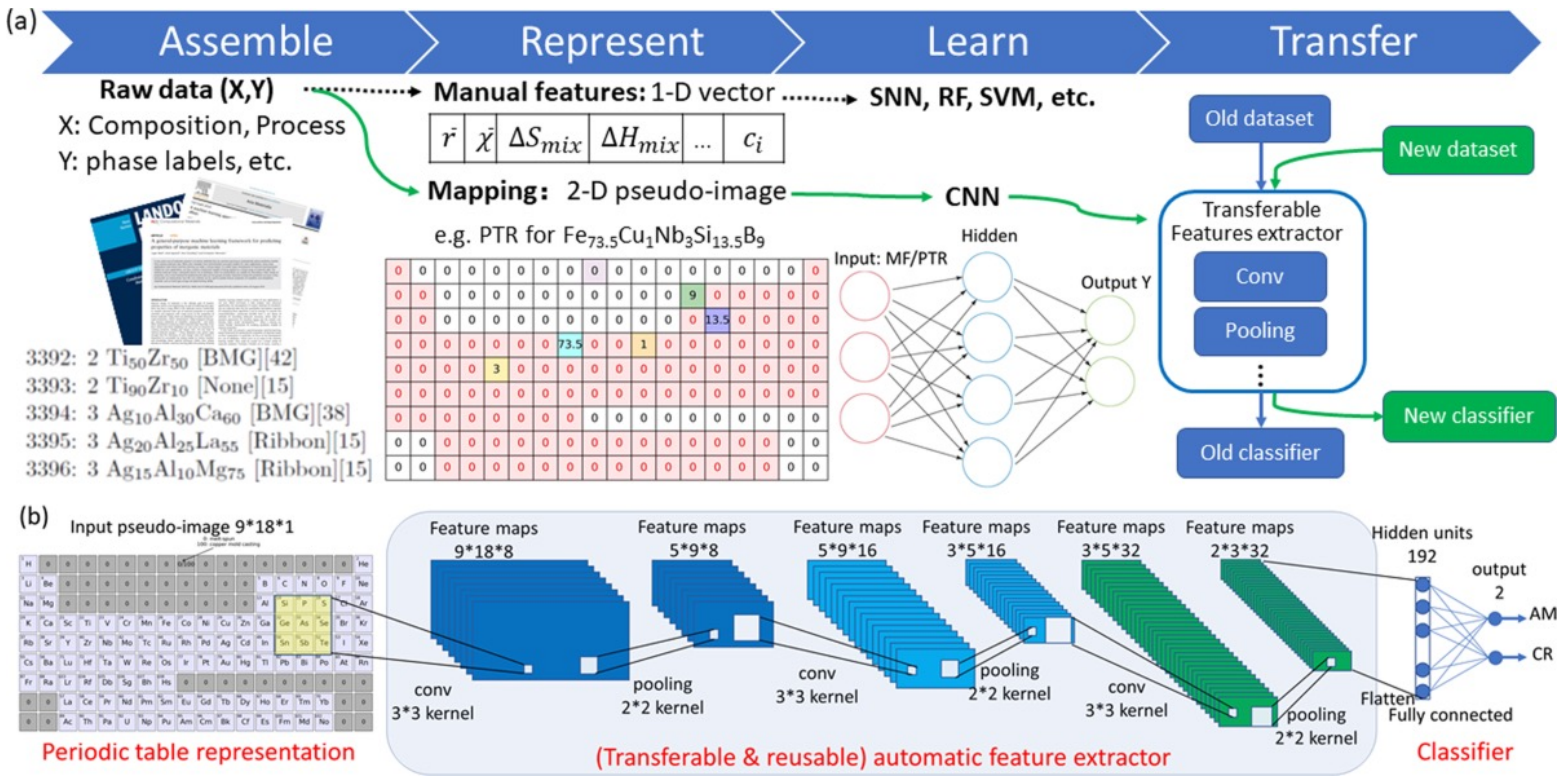


- challenging cases with high between-patient **anatomical variations**, such as in pulmonary segmentectomy, have been met with pioneering approaches to enhance preoperative planning with novel amalgamations of virtual reality and AI-based segmentation systems



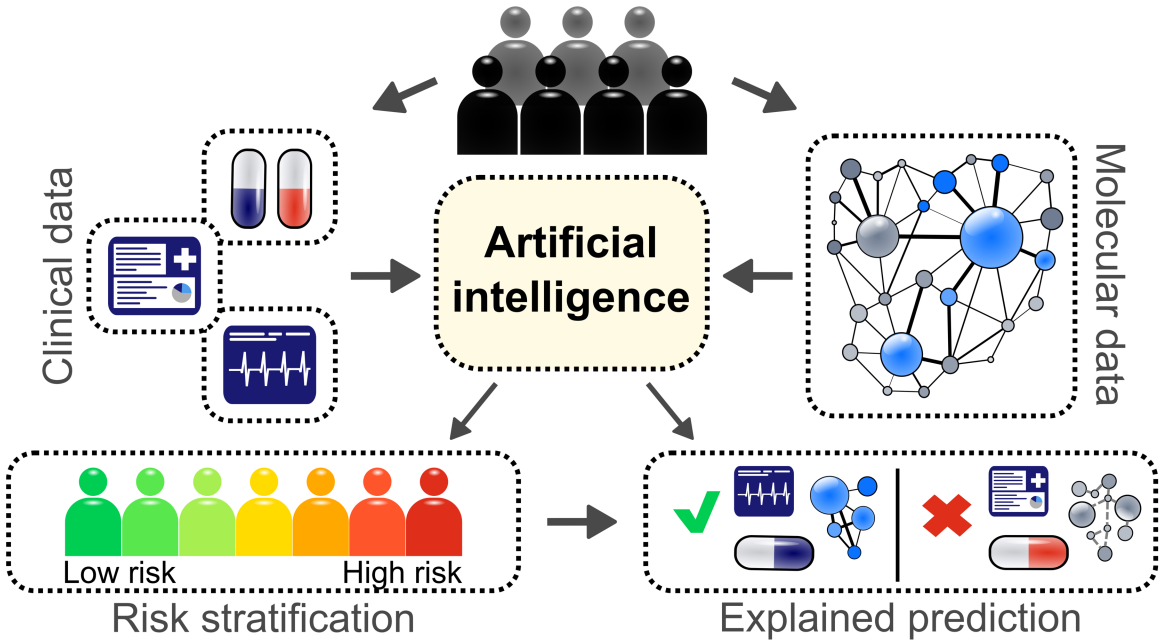
Multimodal Data

- Extraction of unstructured reports using transfer learning.

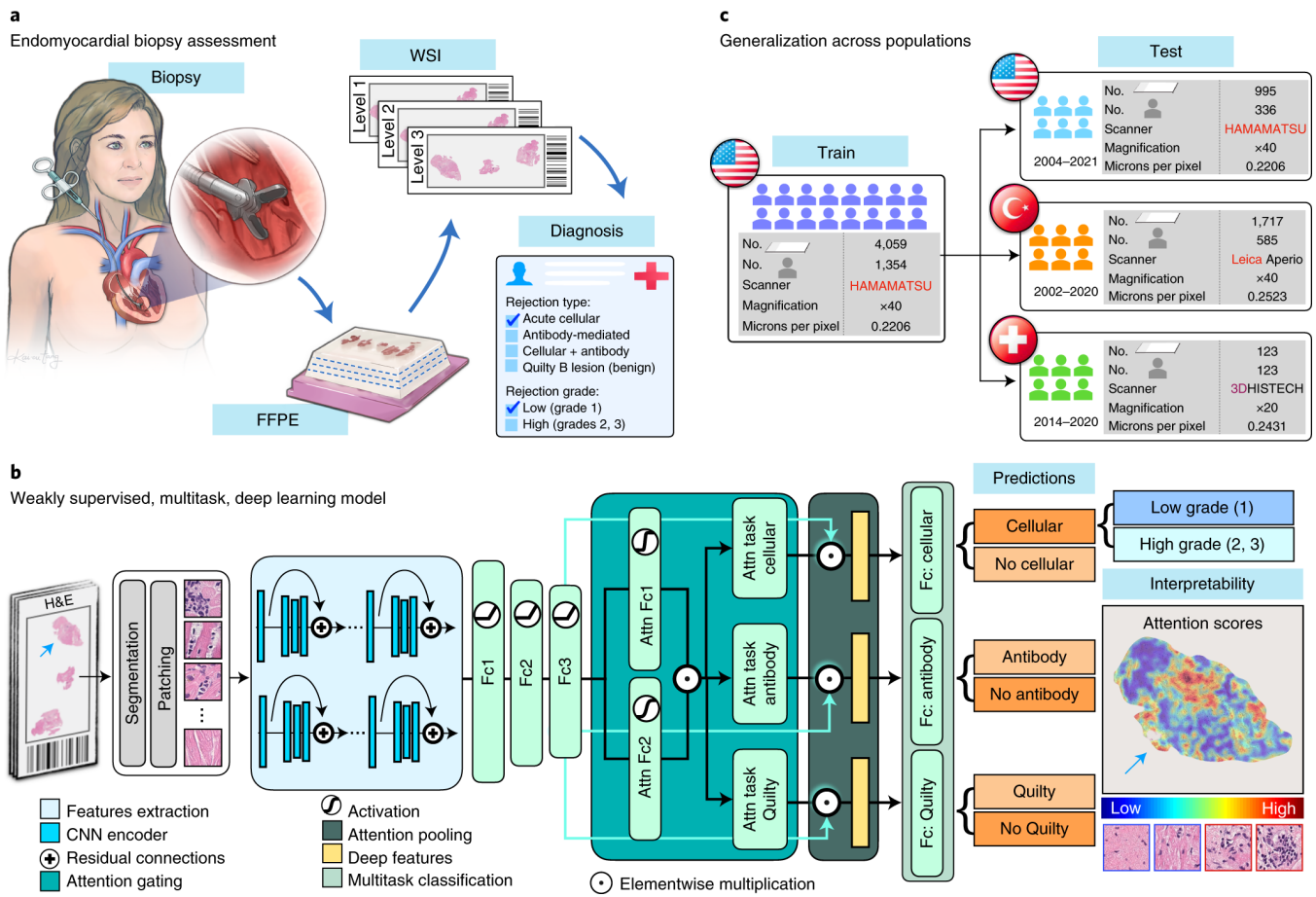


Clinical Risk Prediction and Patient Selection

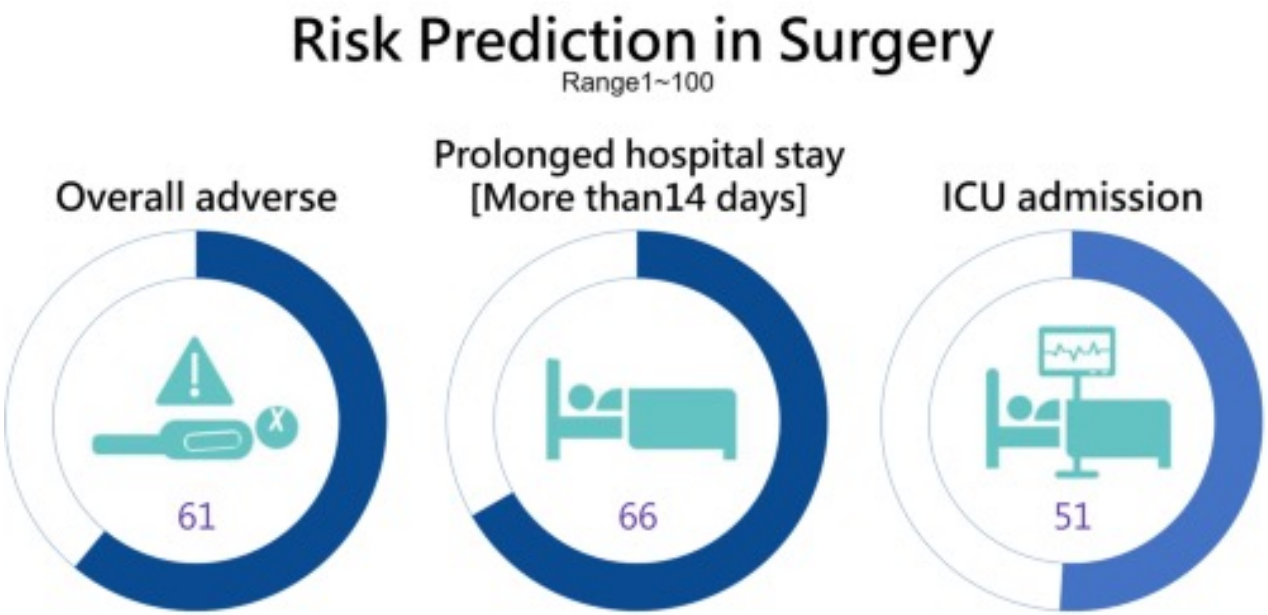
- High-accuracy risk prediction seeks to enable enhanced patient selection for operative management to improve outcomes,
- reduce futility,
- better inform patient consent and shared decision-making,
- triage resource allocation
- enable pre-emptive intervention.



Cardiac transplantation outcomes



Surgical Risk Prediction



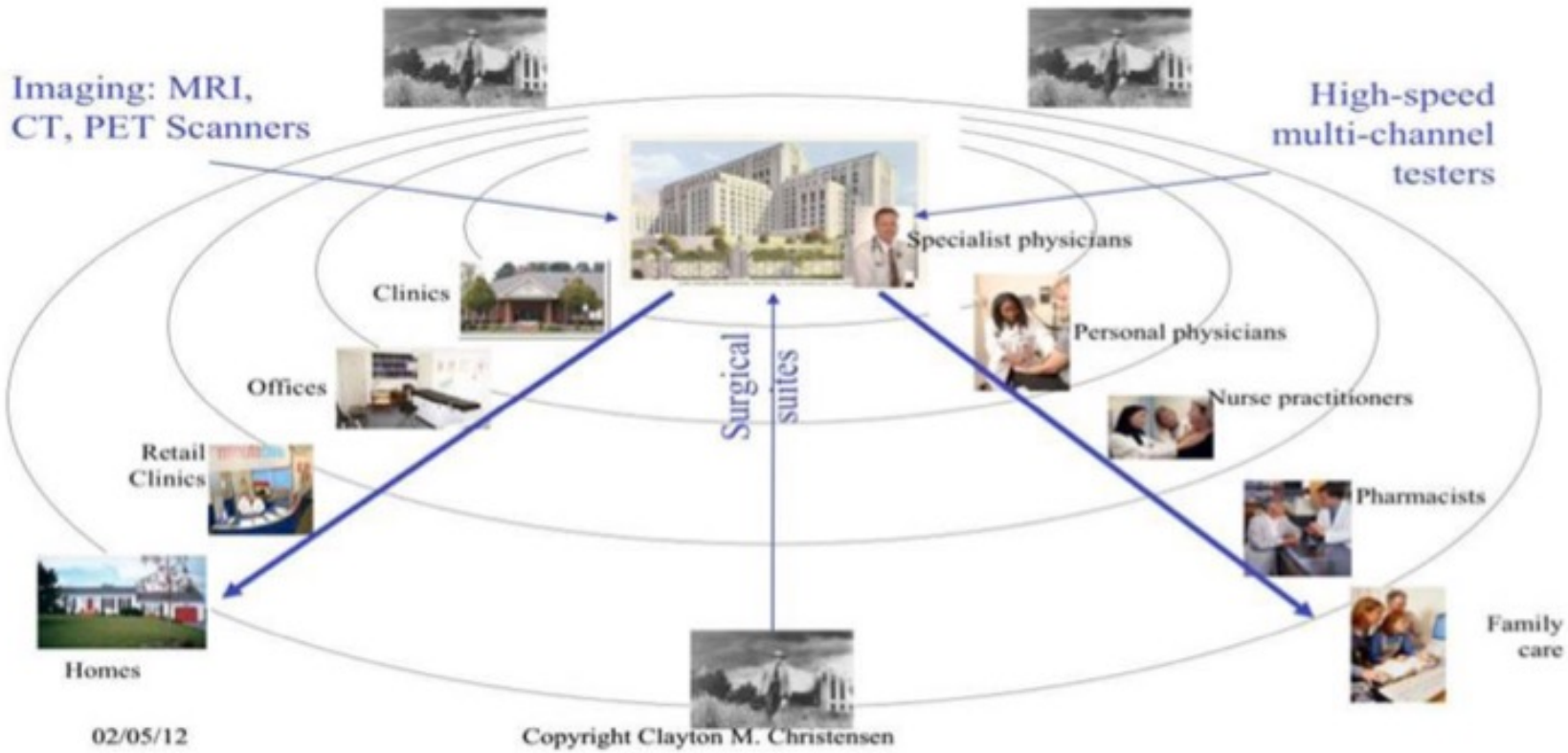
Feature	
Age	88
Sex	Female
BMI	25.78
Smoking	0
Emergency	0
ASA classification	3
CVC	0
Arterial line	0
ALT	19
eGFR	2
Hb	7.7
aPTT	37.6
Platelet	111
Pro.T	13.7
Dementia	0
Hypertension	1
Liver disease	0
CKD-stage	1
Malignancy	0
Heart disease	0
Stroke	1
Respiratory	0

Preoperative optimization

A multifaceted appreciation of patients' cardiovascular fitness, frailty, muscle function and optimizable biopsychosocial factors could be accurately characterized through multimodal AI approaches leveraging the full gamut of -omics data

Decentralized Digital Health

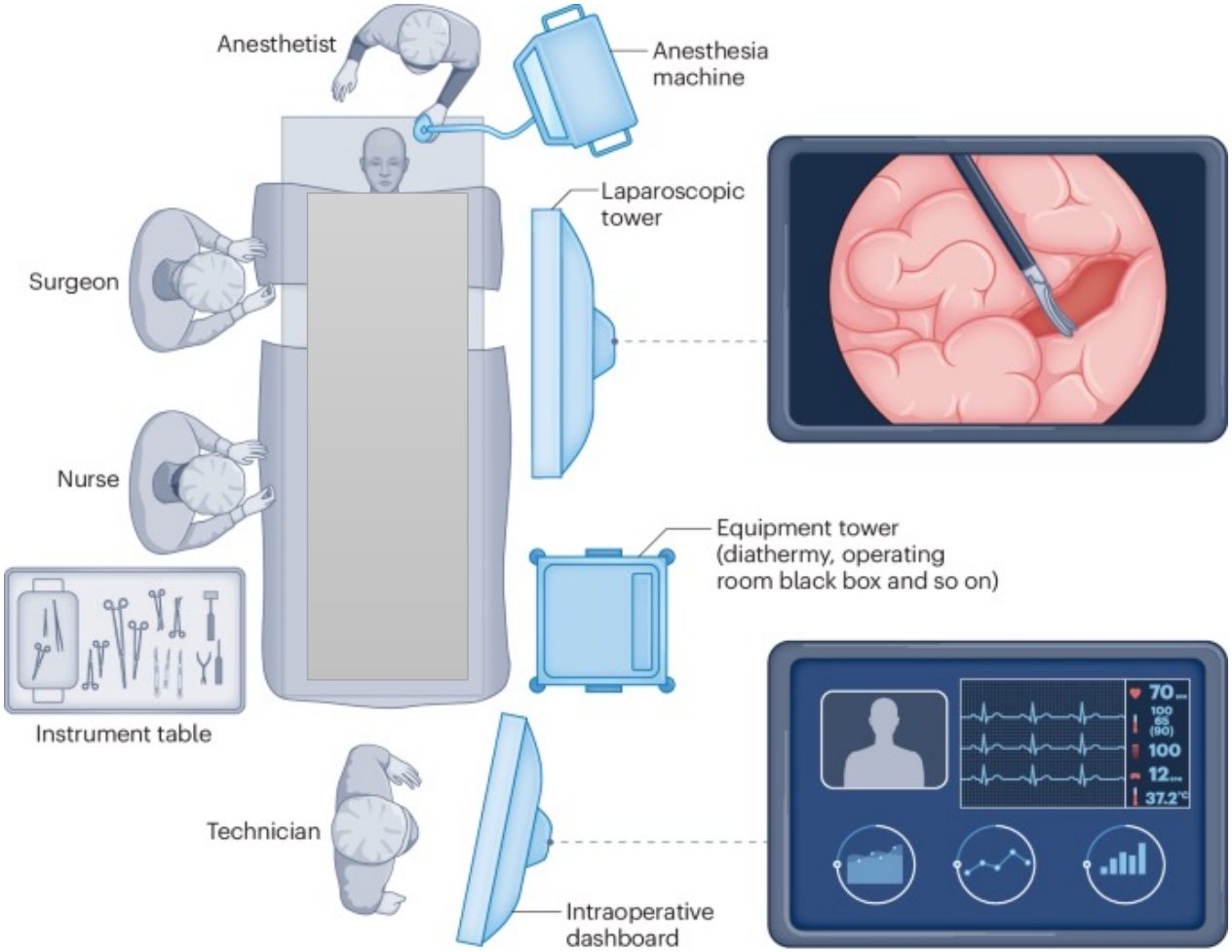
enable wider access to healthcare,
hospital-at-home :
preoperative counseling, surgical consent and postoperative recovery and follow-up could all be augmented by patient-facing AI models



Intraoperative

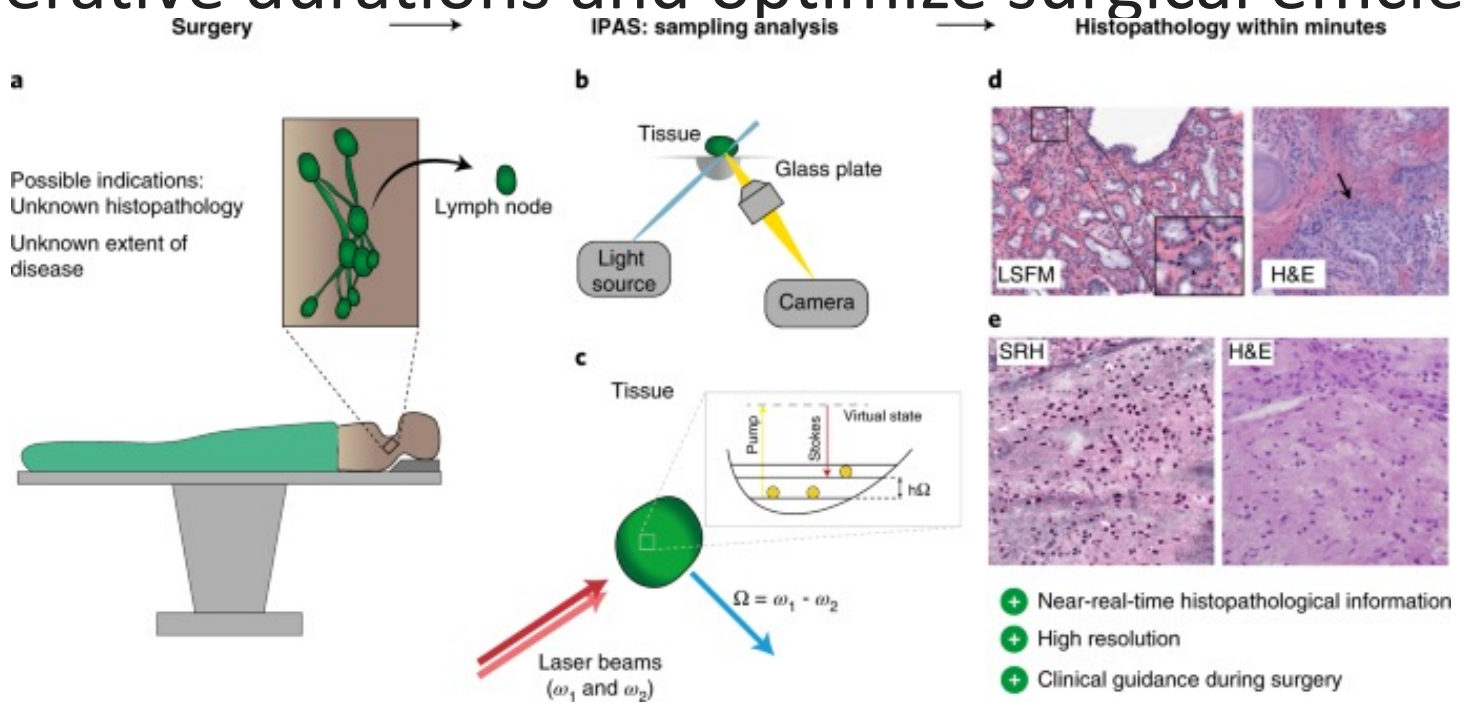
- Advances in intraoperative AI based have enabled preliminary progress in :
- analysis of anatomy, including assessment of tissue characteristics and dissection planes,
- pathology identification.
- stage of operation and the prediction of procedural next steps

Operating room components with the potential for AI integration



Intraoperative decision-making

- Enhanced pathological diagnostics from tissue specimens
- could optimize surgical resection margins, reduce operative durations and optimize surgical efficiency.

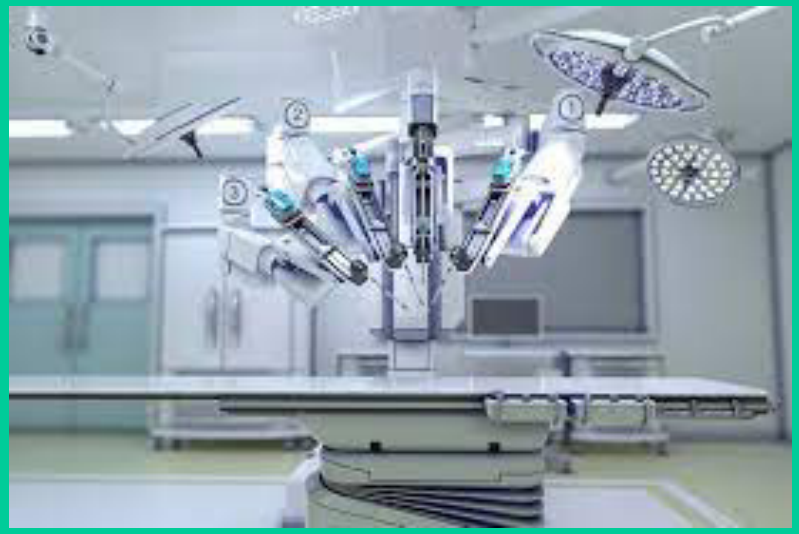


The operative team

- A particularly novel advance toward optimizing surgical teamwork comes from preliminary work toward an AI coach to infer the alignment of mental models within a surgical team.
- Shared mental models, whereby teams have a collective understanding of tasks and goals, have been identified as a critical component to decreasing errors and harm in safety-critical fields such as aviation and healthcare.
- Such approaches require further interrogation within a real-world operating room context, but highlight the breadth of opportunities for digital innovation in surgery.

Surgical robotics and automation

- Unimodal video data to identify surgical activity, gestures, surgeon skill and instrument actions.



Operative education

- Objective metrics and useful mechanisms for feedback to trainee operators.

Helping in Medical Decision Making

Inside the operation room, precision, timely assistance, and the surgeon's expertise are the key to success.

- Uncertainty in Decision Making
- Cooperative Decision Making
- High Complexity
- interrelationships
- Time Constraint
- Reliable and effective

Predict the risk of major complications after surgery

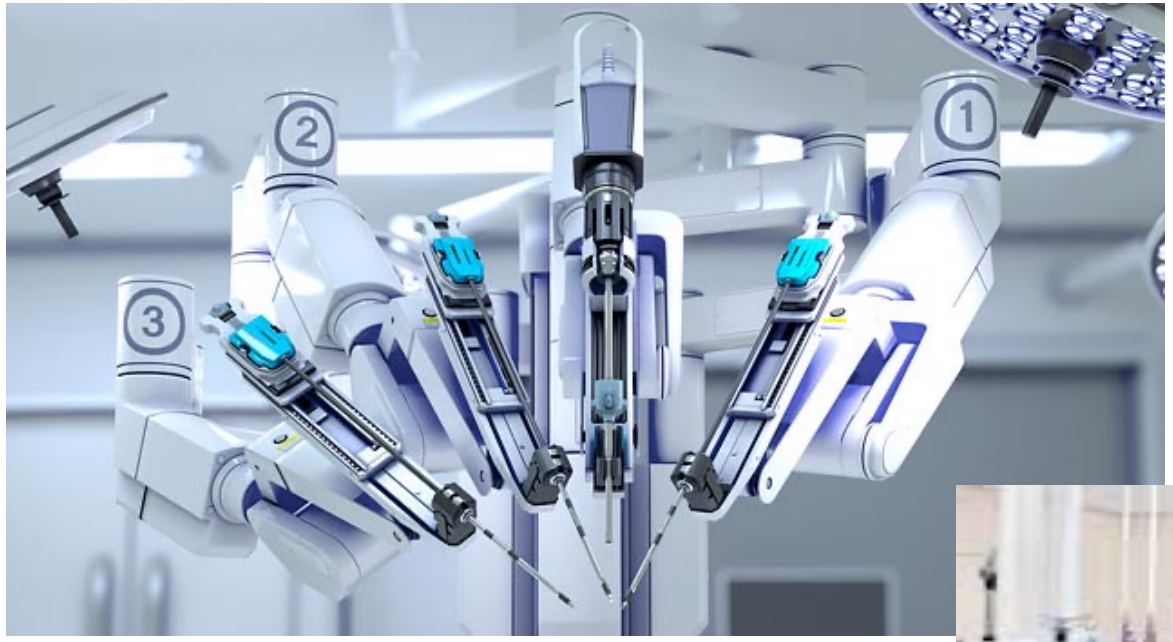
- flap failure
- surgical site infection
- wound dehiscence
- deep vein thrombosis,
- reintubation

Benjamin Shickel Et al., “Dynamic predictions of postoperative complications from explainable, uncertainty-aware, and multi-task deep neural networks,” Scientific Reports volume 13, Article number: 1224 (2023)

Predict the risk of mortality after surgery

Seung Wook Lee Et al., “Multi-center validation of machine learning model for preoperative prediction of postoperative mortality,” npj Digital Medicine volume 5, Article number: 91 (2022)

Medical Robotics



Post-operative Phase

- Surgical room organization
- Estimating remaining surgical time
- Estimating patient’s recovery time
- Estimating blood loss
- Patient Monitoring
- Remote Patient Monitoring
- Modification of medical treatment

Pranav Rajpurkar Et al, “AI in health and medicine,” Nature Medicine volume 28, pages31–38 (2022).
Julián N. Acosta Et al., “Multimodal biomedical AI,” Nature Medicine volume 28, pages1773–1784 (2022)

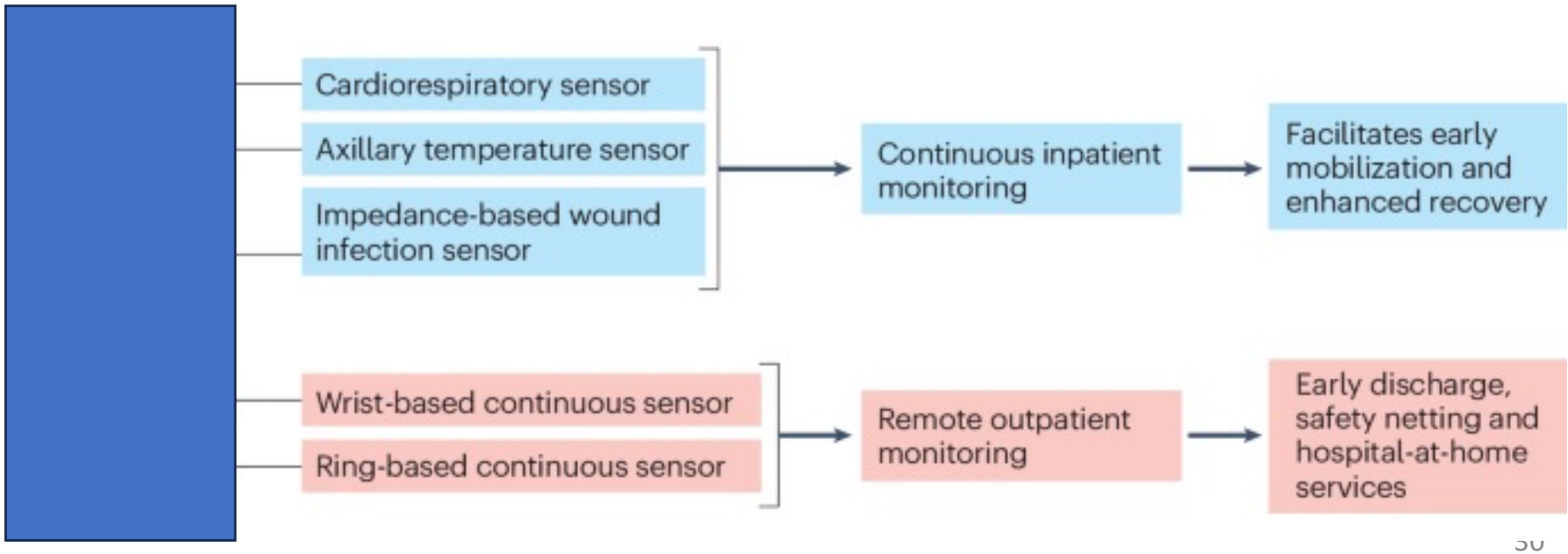
Postoperative monitoring

- enhanced postoperative monitoring,
- early warning systems
- better appreciation of important contributors to recovery.
- The implementation of enhanced recovery after surgery programs has been pivotal toward this goal.

Real-time physiological sensing of wound healing

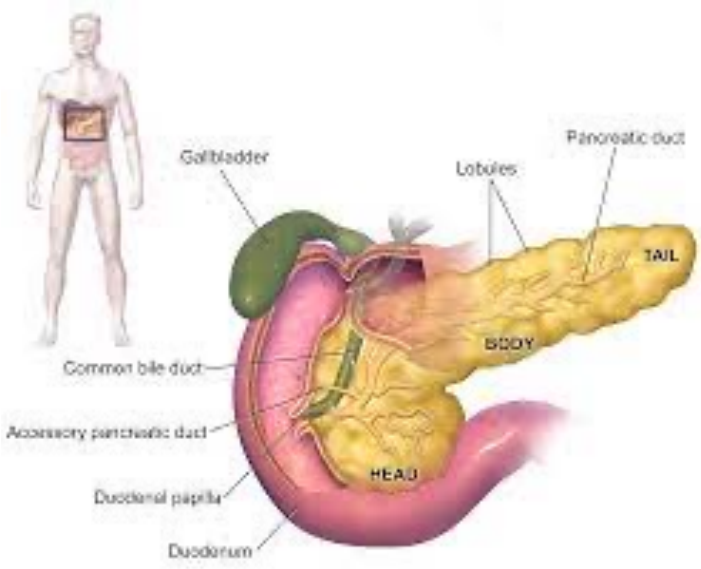
Remote identification of superficial skin infections

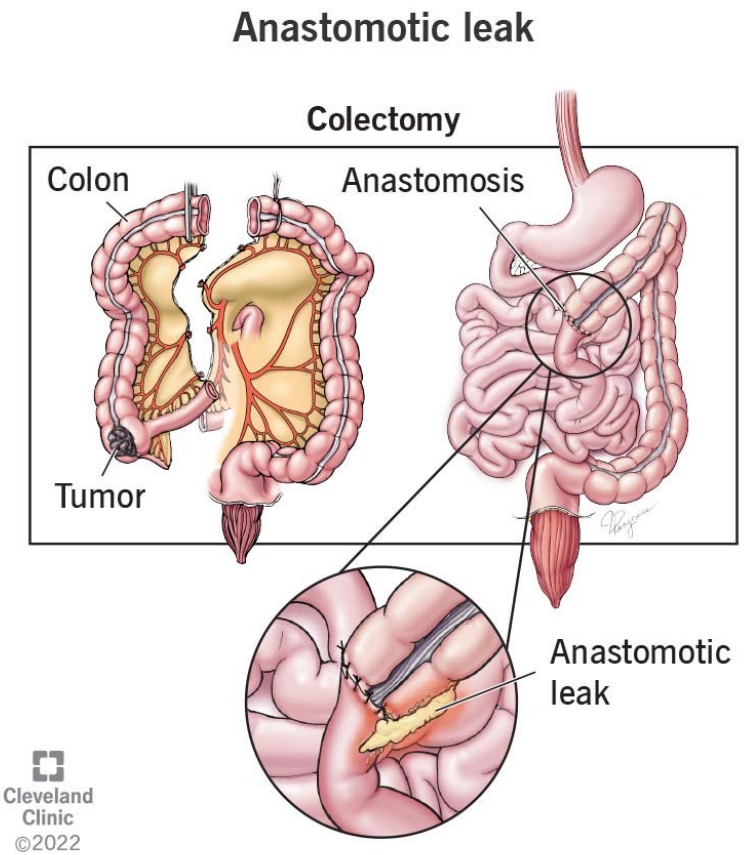
Cardiorespiratory sensors are all putative technologies to enhance postoperative monitoring



Complication prediction

- Anastomotic leaks after rectal cancer surgery
- and postoperative pancreatic fistulas after pancreatic surgery





Cleveland Clinic
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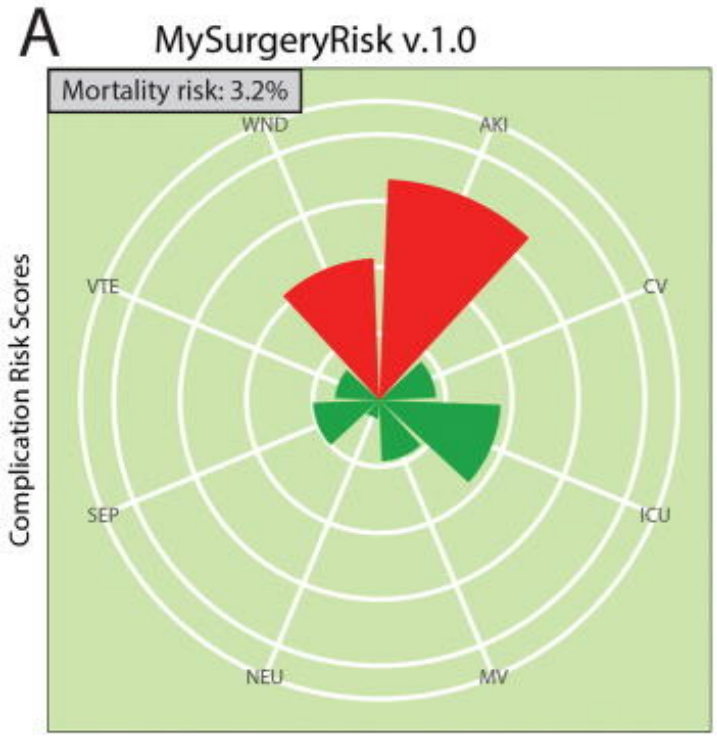
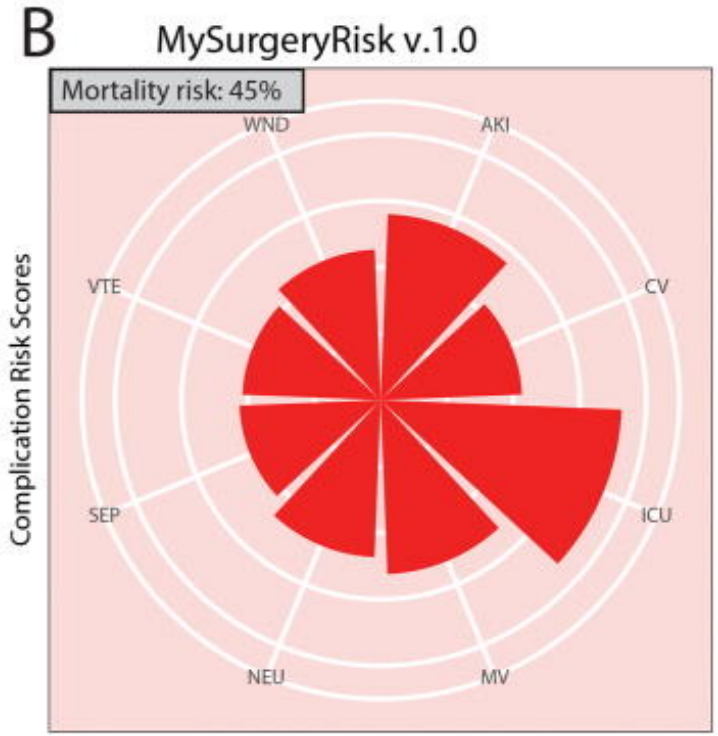
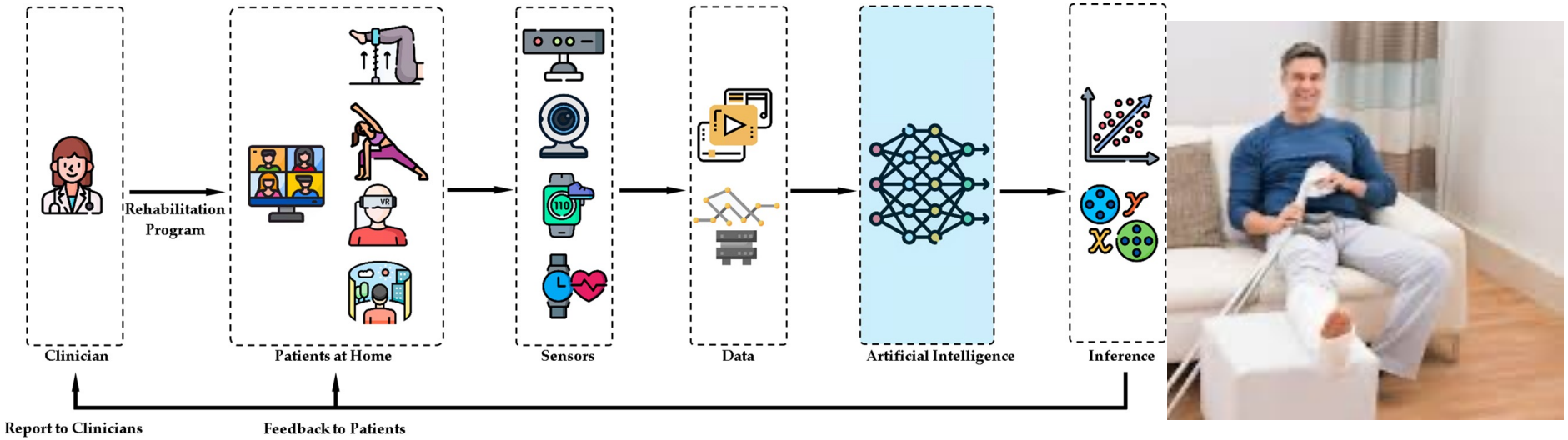
- MySurgeryRisk represents one of the few advances in complication prediction, using a machine learning algorithm.
- 



Home-based recovery

- With advancing age, recovery can be prolonged and periods of return to baseline activities of daily living (ADLs) can extend beyond several months.
- AI-driven, home-based recovery model enabled by frequent, noninvasive assessments of ADLs.



Multimodal AI in Surgery

- Current AI applications in surgery have been mostly limited to unimodal deep learning.
- Transformers are a particular recent breakthrough in neural network architectures.

clinical risk prediction

automation and computer vision in robotic surgery

intraoperative diagnostics

enhanced surgical training

postoperative monitoring through advanced sensors

resource management

discharge planning

AI Models

Unimodal AI: models that operate and process data of a singular format, such as images, text or audio alone.

Multimodal AI: models that simultaneously integrate diverse data formats provided as training and prompt inputs, including images, text, biosignals, -omics data and more.

Generative AI: AI systems that can generate new content, such as texts, images and other data formats. LLMs are an example of generative AI. These are trained on a vast corpus of language-based parameters.

Transformer models: a type of model that uses self-attention rather than recurrence and convolutions in making predictions that offer advantages in understanding long-range dependencies in input parameters, scalability and improved performance.

Foundation models: large pretrained models that serve a variety of purposes. These models are trained on diverse data sources and can be fine-tuned for specific tasks.

AI Models

Supervised learning: models trained on labeled datasets (the majority of applications to date).

Self-supervised learning: models that attempt to create their own data labels on unlabeled input data.

Unsupervised learning: models that evaluate unlabeled input data for inherent structures and relationships using clustering and dimensionality reduction methods.

Patient-facing AI for consent and patient education

- Large language models (LLMs):

Medical entrance exams and surgery student evaluation,

Patients interaction with surgeon as an initial clinical contact point.

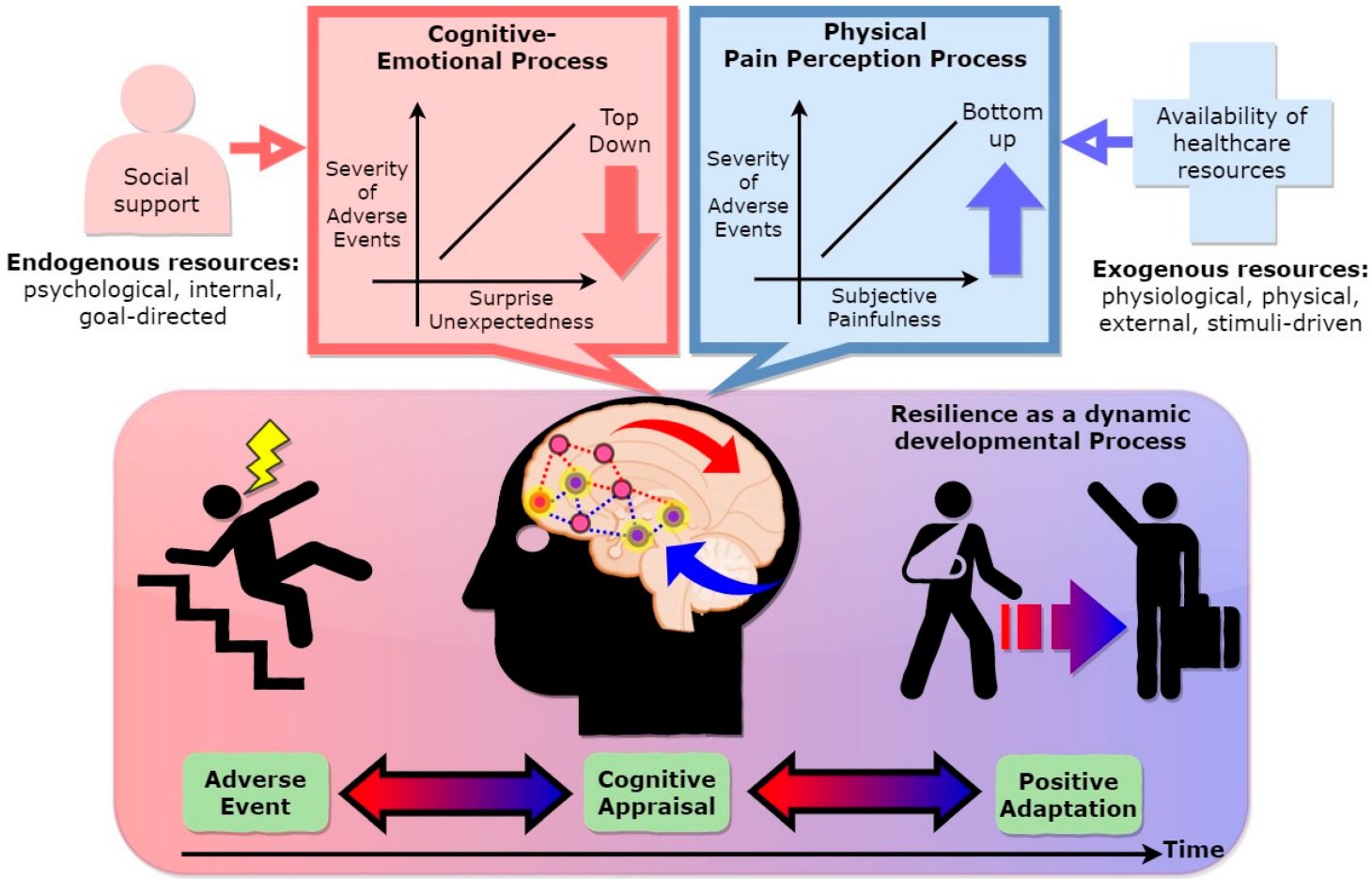
AI for clinician empathy, contribute to reliable informed consent and reduce documentation burdens.

Chatbot-derived material for informed consent compared with surgeons. These advances offer a unique opportunity for tailored patient-facing interventions.

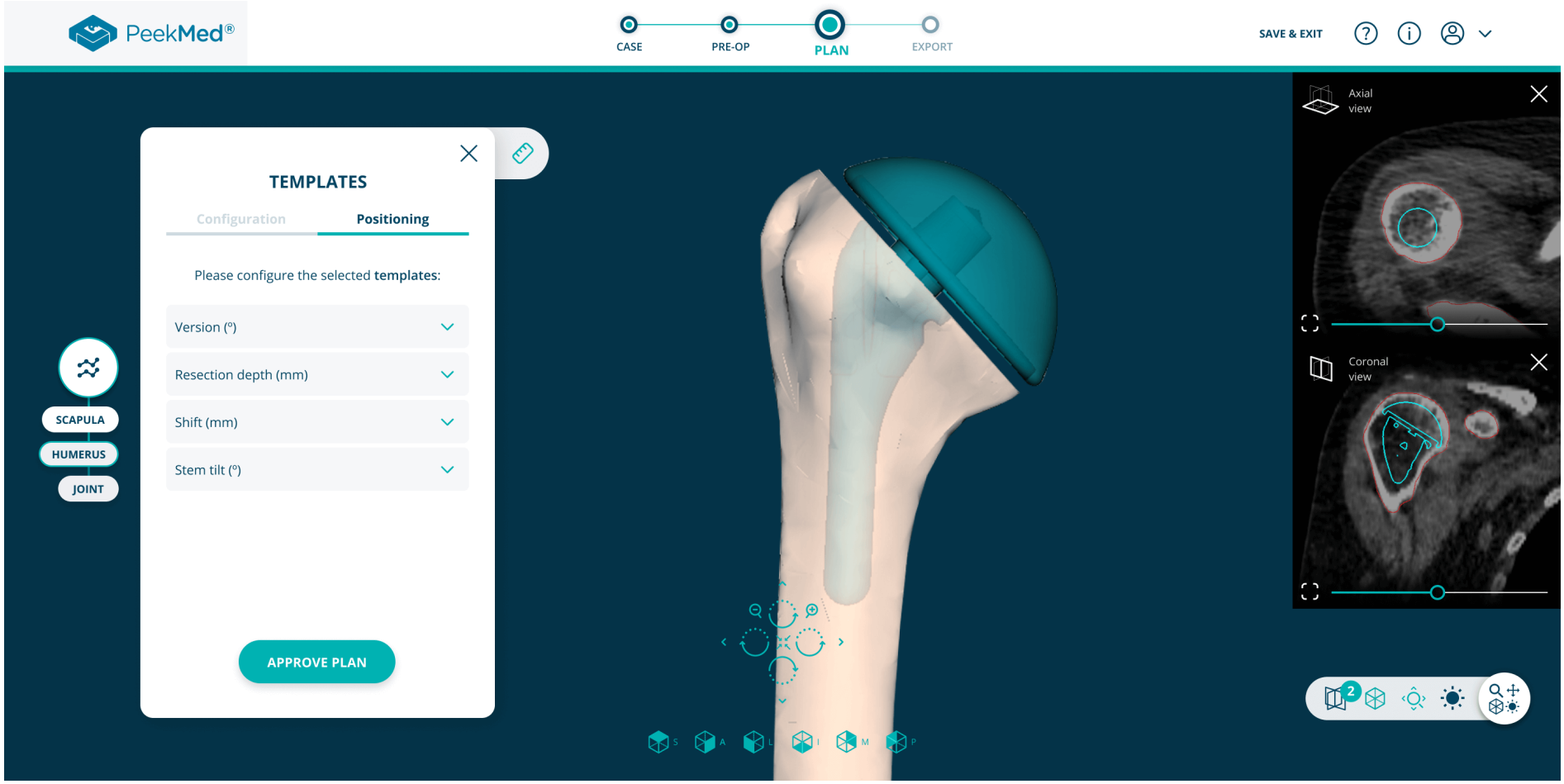
Application	Countries	Centre(s)	Sample size	Speciailty	Domain	End points	Comparison	Results	Modality	AI Type
App-based, knowledge AI-driven tailored self-management strategies for patients	Denmark and Norway	Multiple	461	Orthopedic	Lower back pain management	Questionnaire scores	AI versus routine care	Significant improvement: adjusted mean difference in Roland–Morris Disability Questionnaire = 0.79 (95% CI = 0.06–1.51)	Structured	Case Based Reasoning
Machine learning prediction of surgical resource utilization	United States	Single	683	Colorectal and gynecology	Surgery length prediction	Mean absolute error time	AI versus routine care	Significant improvement in the prediction of case duration plus decreased wait time by 33.1 min per patient	Structured	Unspecified
AI-based intraoperative planning based on image segmentation	France	Single	20	Orthopedic	Percutaneous vertebroplasty	Technical feasibility	Assisted versus unassisted	Significant improvement: decreased time to trocar deployment (642 ± 210 versus 336 ± 60 s; P = 0.001)	Video	CNN

Machine learning predictor of intraoperative hypotension	Greece	Single	99	Noncardiac	Hypotension management	Time-weighted hypotension	Assisted versus unassisted	Significant improvement: decreased time-weighted average mean arterial pressure intraoperatively (mean difference = −0.28; 95% CI = −0.48–0.09 mmHg; P = 0.0003)	Waveform	Unspecified
Machine learning predictor of intraoperative hypotension	Germany	Single	49	Orthopedic	Hypotension management	Time-weighted hypotension	Assisted versus unassisted	Significant improvement: decreased frequency of intraoperative hypotension ((n)/h) (48 versus 80%; P < 0.001)	Waveform	Unspecified
Machine learning predictor of intraoperative hypotension	The Netherlands	Single	60	Noncardiac	Hypotension management	Time-weighted hypotension	Assisted versus unassisted	Significant improvement: median difference of 16.7 min of intraoperative hypotension per patient (95% CI = 7.7–31.0; P < 0.001)	Waveform	Unspecified

Relieve cognitive and physical stress



PeekMed® | AI-Based Preoperative Planning System



PeekMed® | AI-Based Preoperative Planning System

PeekMed

AI Plastic Surgery Simulator

peripheral nerve and hand surgery, AI can predict the success rate of engineered nerve grafts.

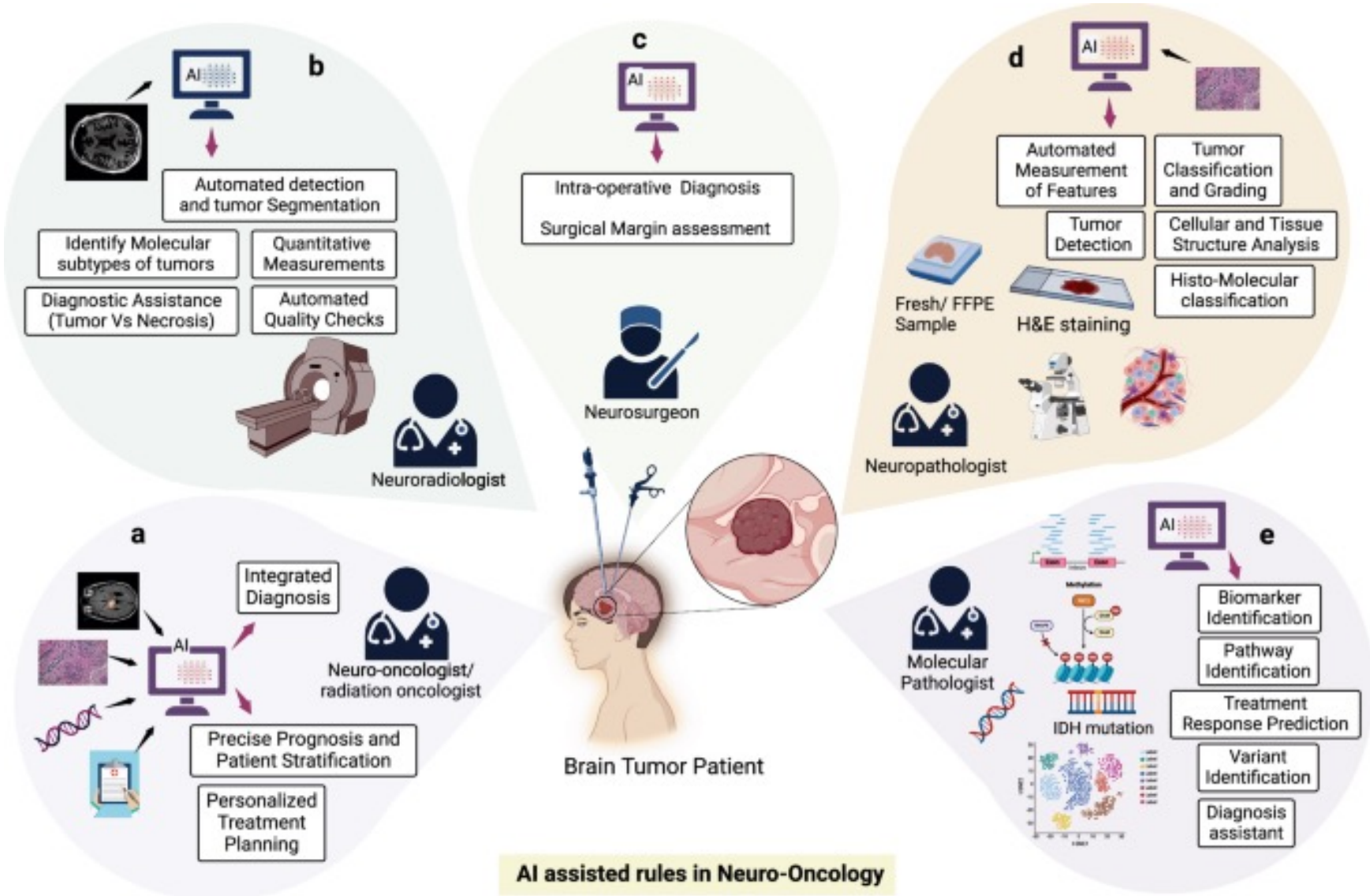
AI is already in existence to predict healing possibilities of burn victims and assessing the depth of burns.

aesthetic surgery, AI can create real-time stimulations to predict the outcomes of reconstructive breast surgery or facial surgeries

Artificial Intelligence Cataract Surgery

- **Increased Accuracy**
- **Minimized Human Error**
- **Tailored Procedures**
- **Enhanced Safety**
- **Better Outcomes**

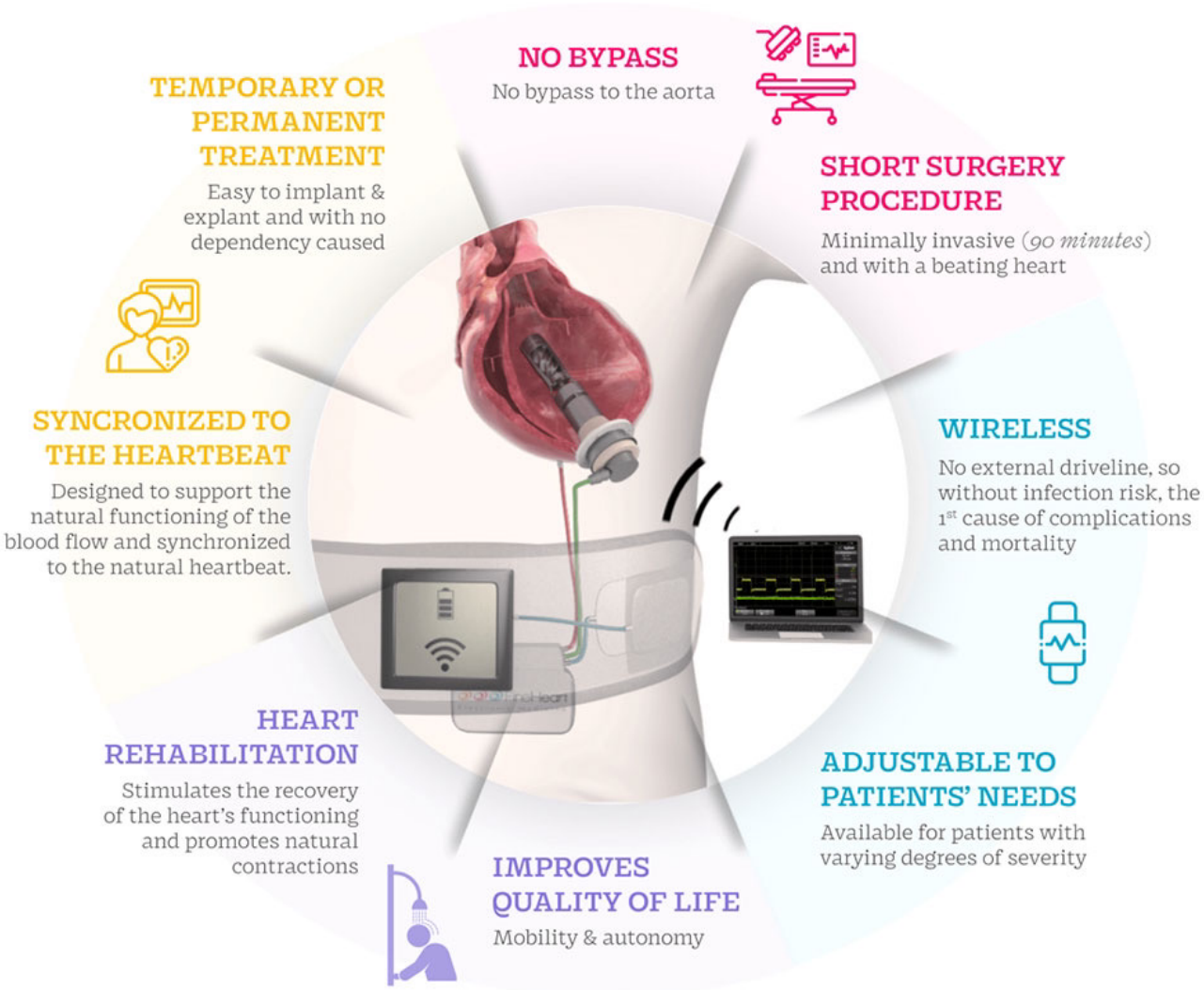
neuro-oncology Surgery



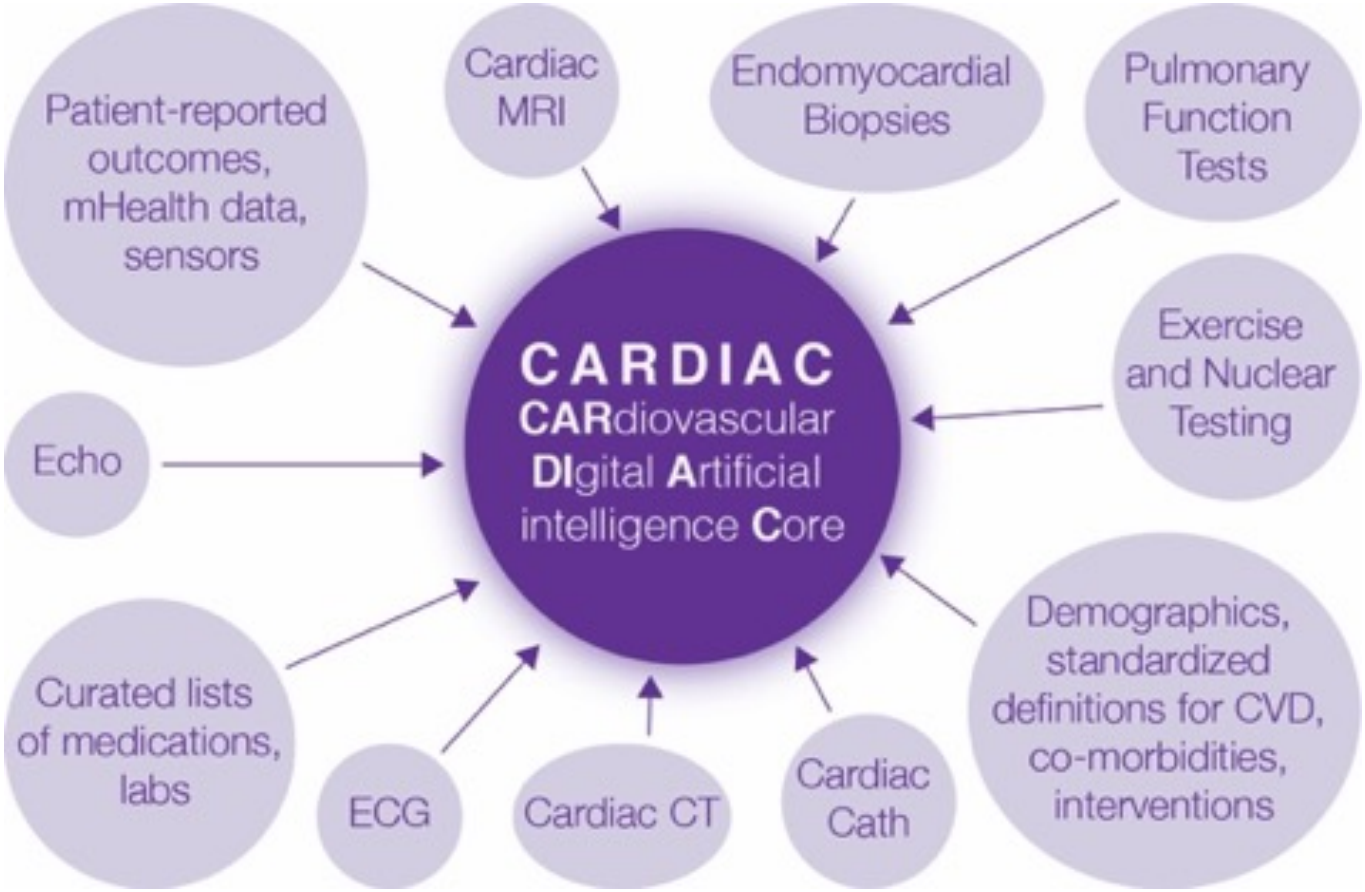
AI algorithms enhance its digital capabilities within post-operative analysis.

AI for **brain aneurysms**

AI and Cardiovascular Surgery



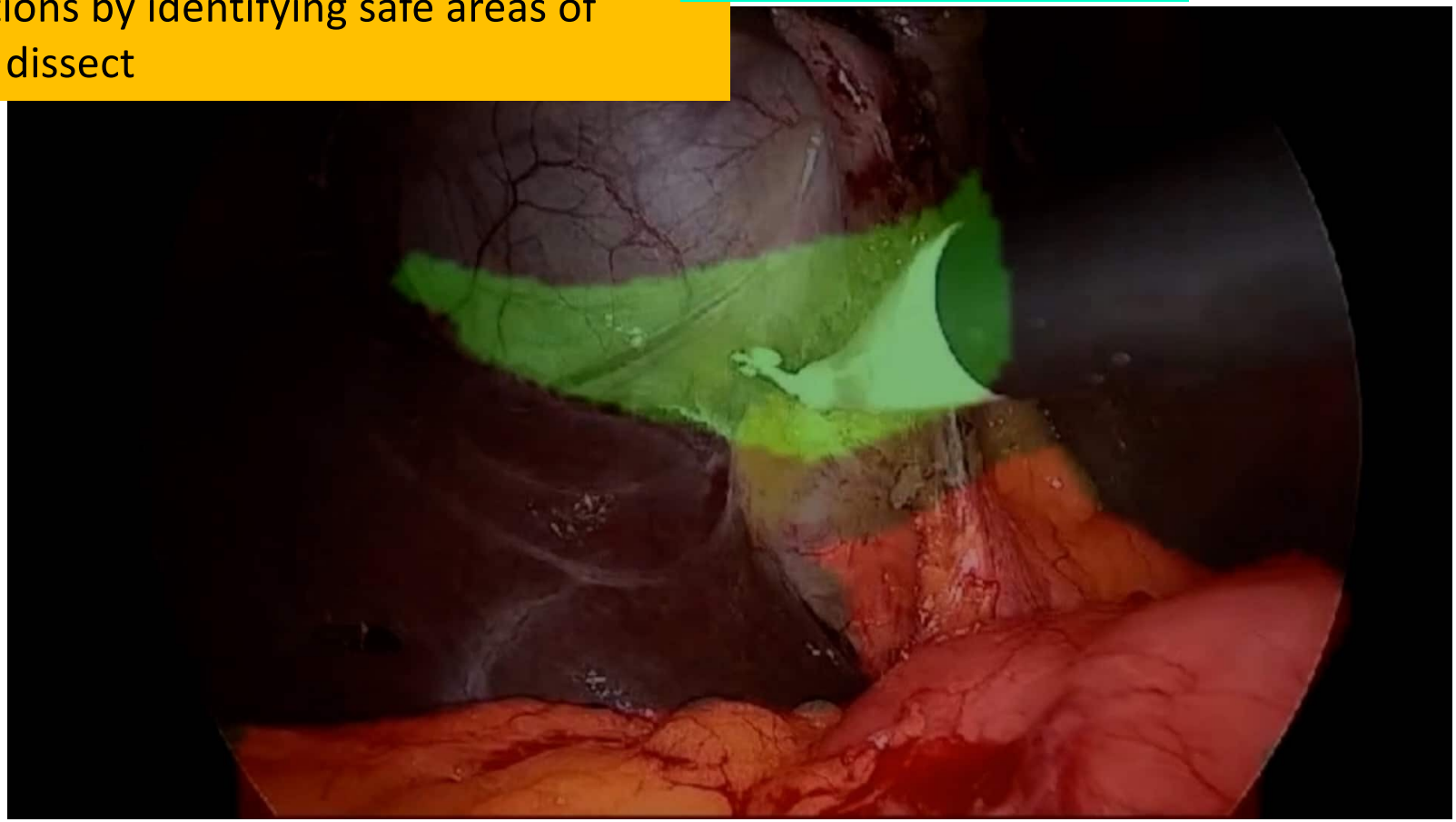
Data


Patient-reported outcomes, mHealth data, sensors
Cardiac MRI
Endomyocardial Biopsies
Pulmonary Function Tests
Exercise and Nuclear Testing
Echo
CARDIAC
CARdiovascular
DIgital Artificial
intelligence Core
Curated lists of medications, labs
ECG
Cardiac CT
Cardiac Cath
Demographics, standardized definitions for CVD, co-morbidities, interventions

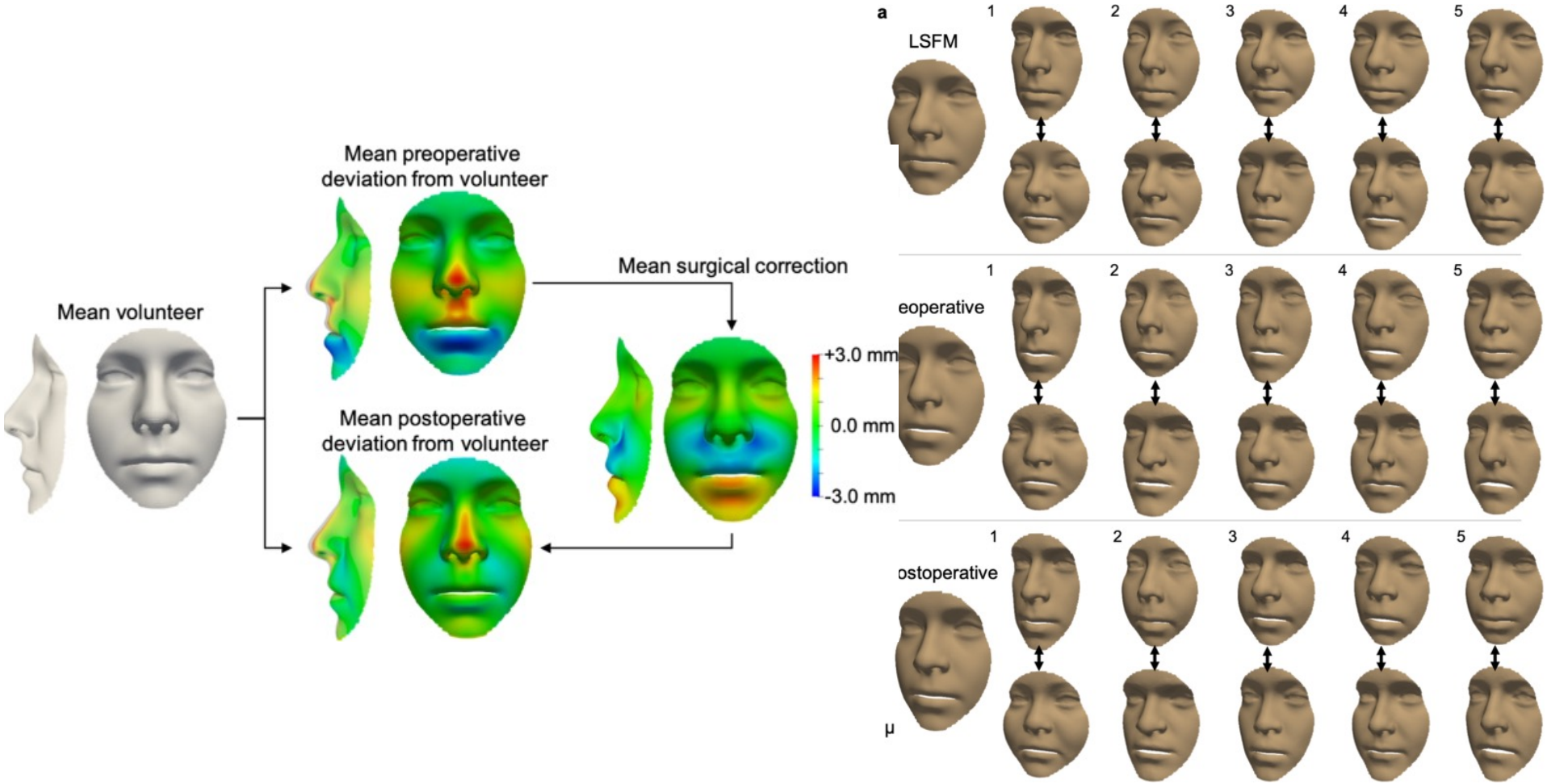
AI prototype to help reduce surgical complications

Software meant to reduce harmful complications by identifying safe areas of organs to dissect

gallbladder surgery



AI in **plastic and reconstructive surgery**

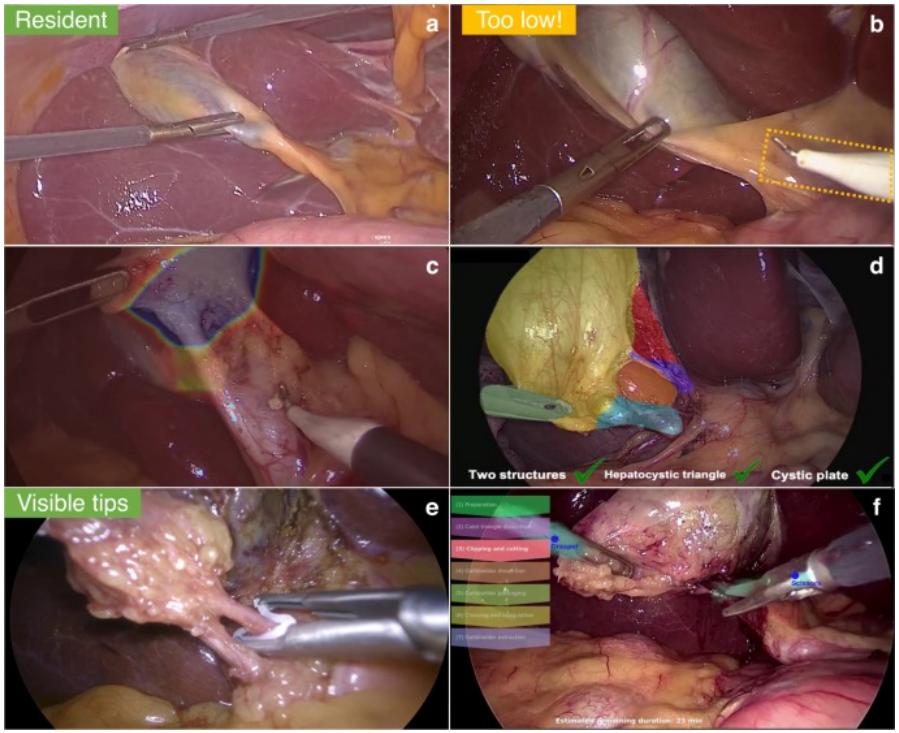


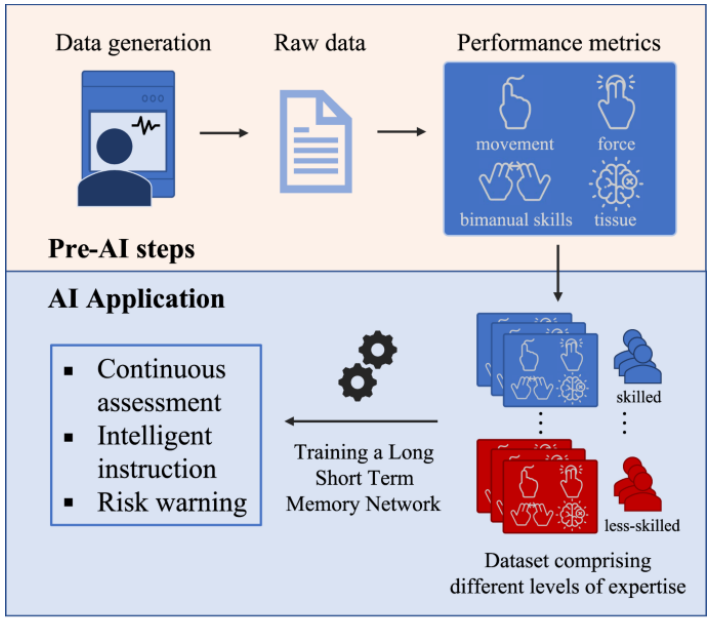
Scientific Reports **volume 9**, Article number: 13597 (2019)

Before
After

Enhance surgical training

- Training
- Scoring the performance of surgical trainees.





AI: artificial intelligence

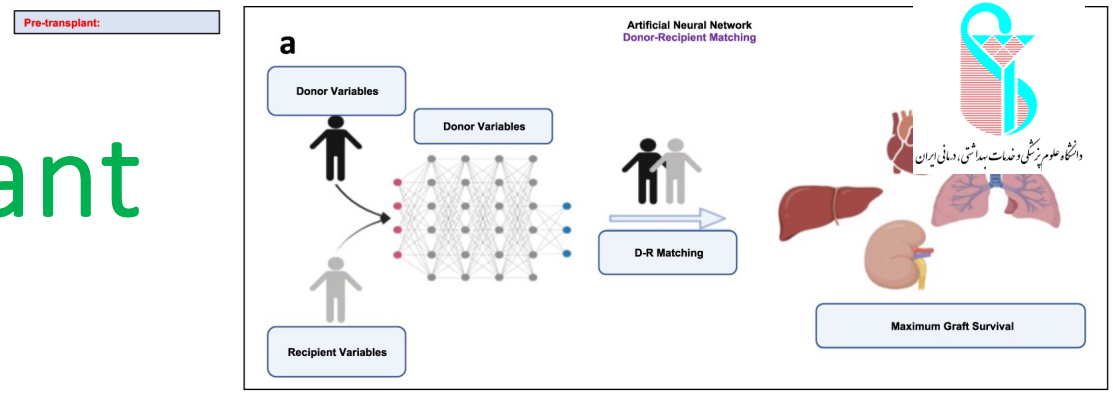
Omri Bar Et al., “Impact of data on generalization of AI for surgical intelligence applications,” Scientific Reports volume 10, Article number: 22208 (2020)
Recai Yilmaz Et al., “Continuous monitoring of surgical bimanual expertise using deep neural networks in virtual reality simulation,” npj Digital Medicine volume 5, Article number: 54 (2022).
Pietro Mascagni Et al., “Computer vision in surgery: from potential to clinical value,” npj Digital Medicine volume 5, Article number: 163 (2022) .

Hospitalization, Triage tools, Operating Room

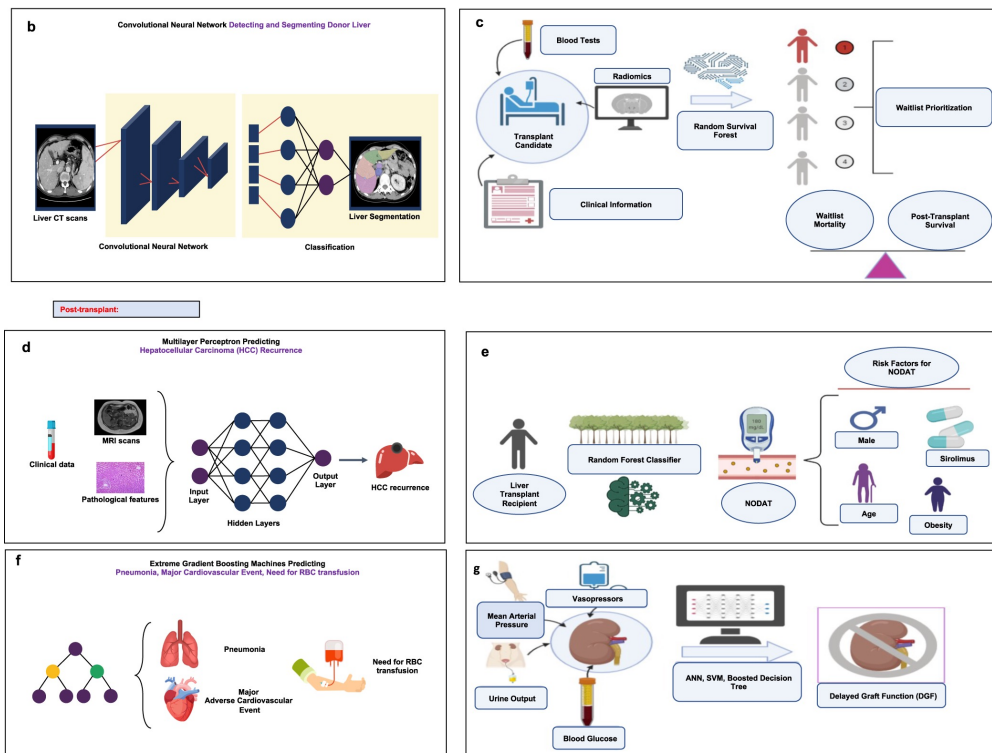
- Predictions of the surgical case duration
- Precise scheduling, limiting waste of resources
- Identifying surgeries with high risks of cancellation

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

Organ Transplant

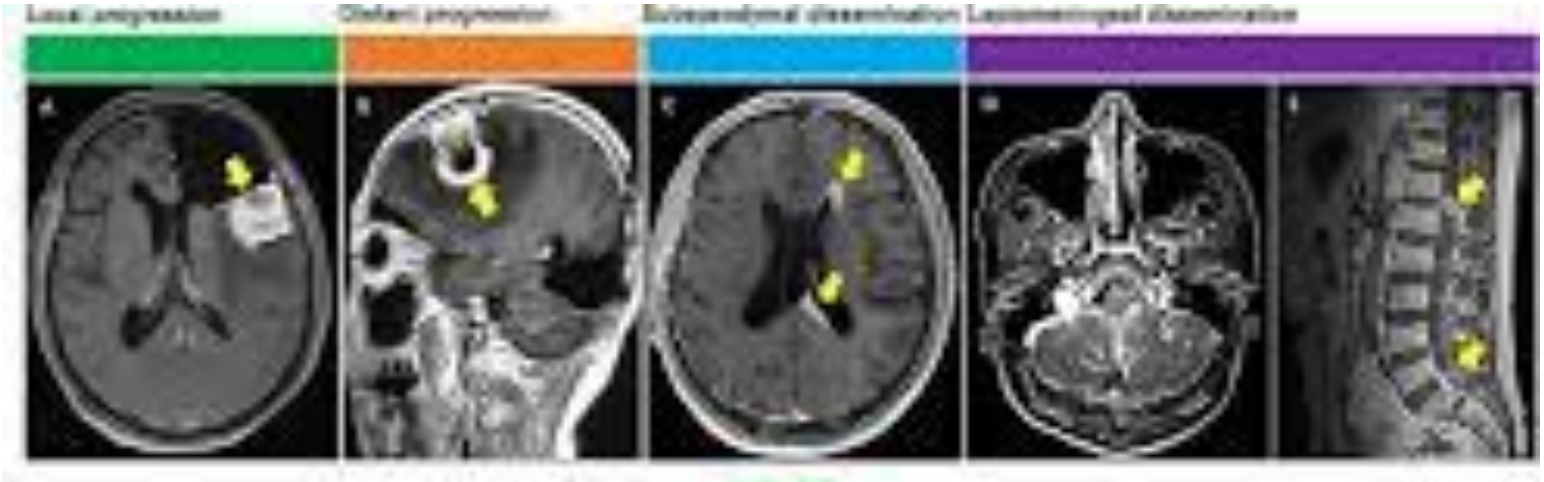


- Optimal transplant donor organ
- organ-allocation

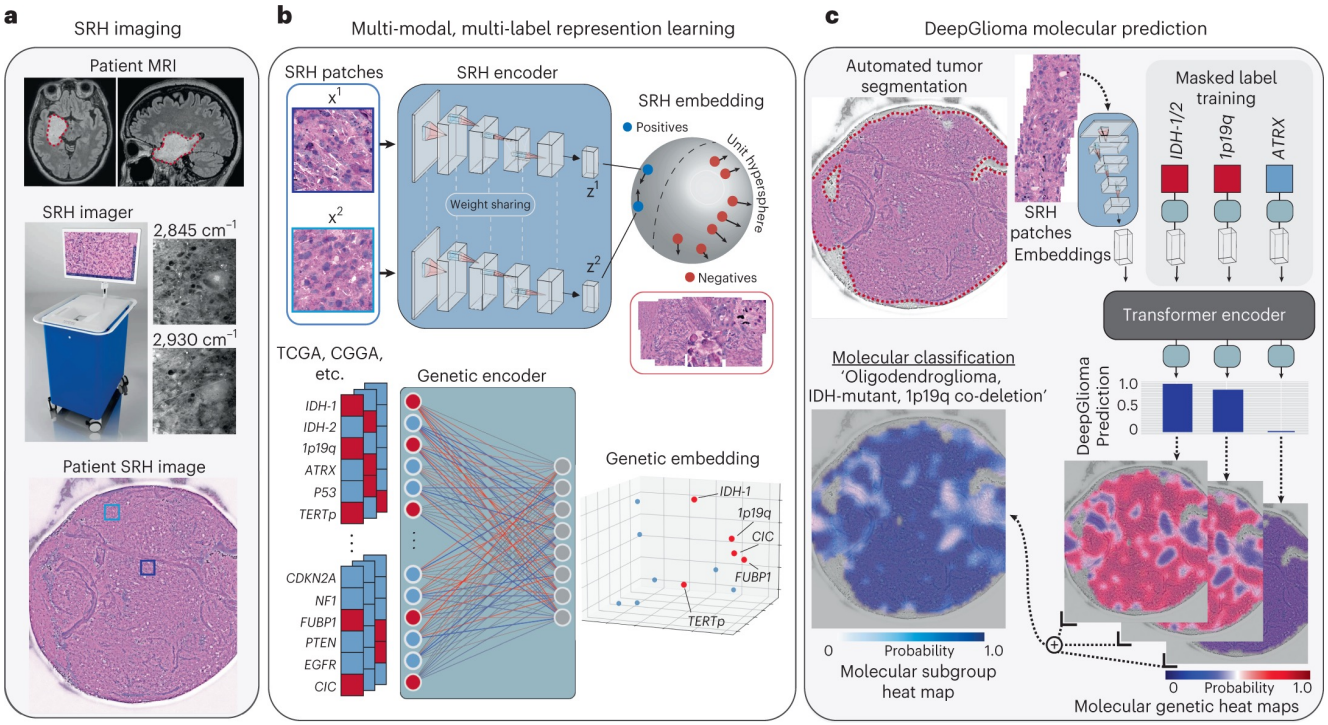


[1] N. Gotlieb Et al., “The promise of machine learning applications in solid organ transplantation,” *npj Digital Medicine,* vol. 5, No. 89, 2022.

AI can predict the progression of a disease



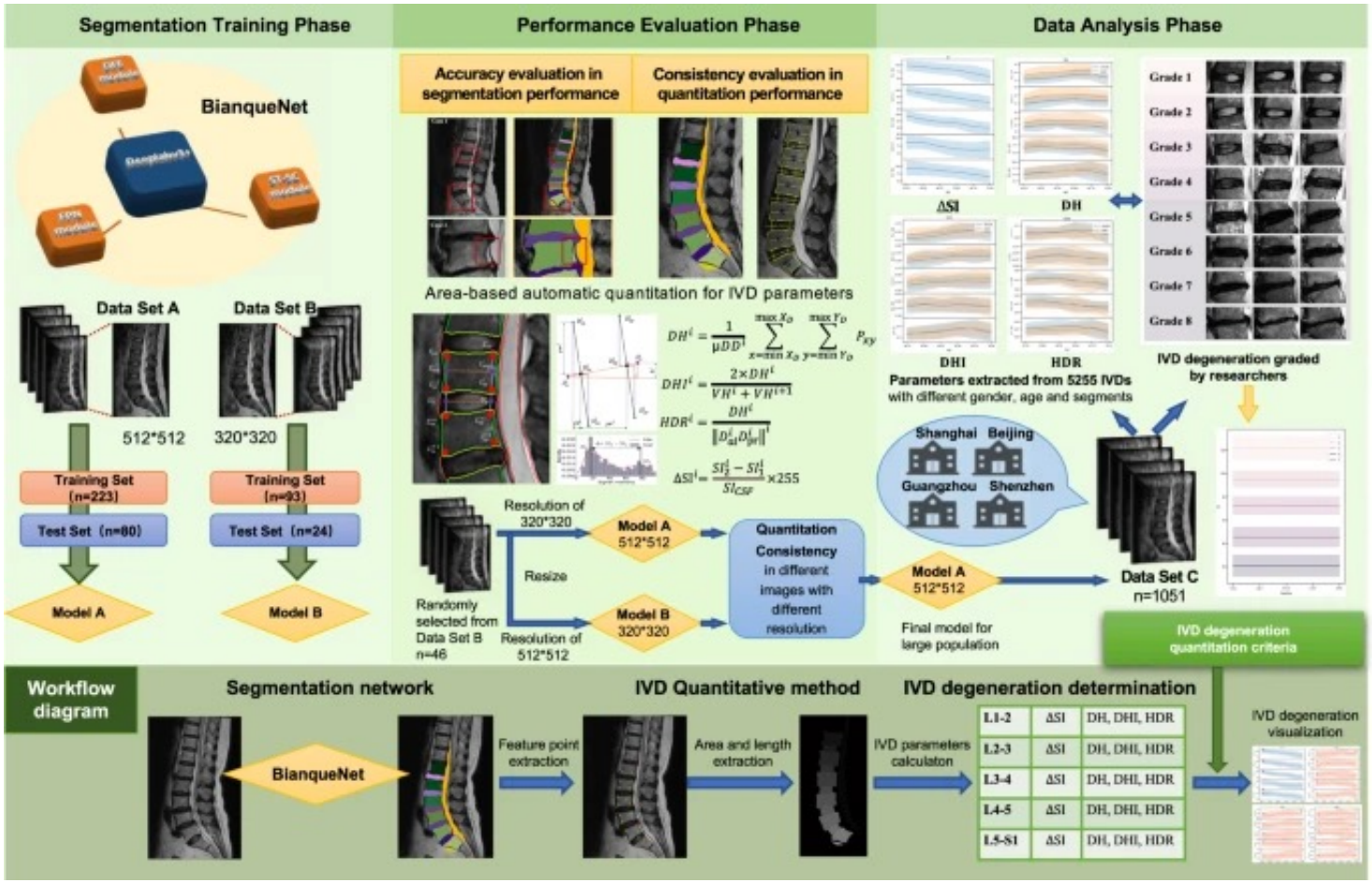
Brain Cancer (AI and optical histology (SRH))



- Molecular classification has transformed the management of brain tumors by enabling more accurate prognostication and personalized treatment.

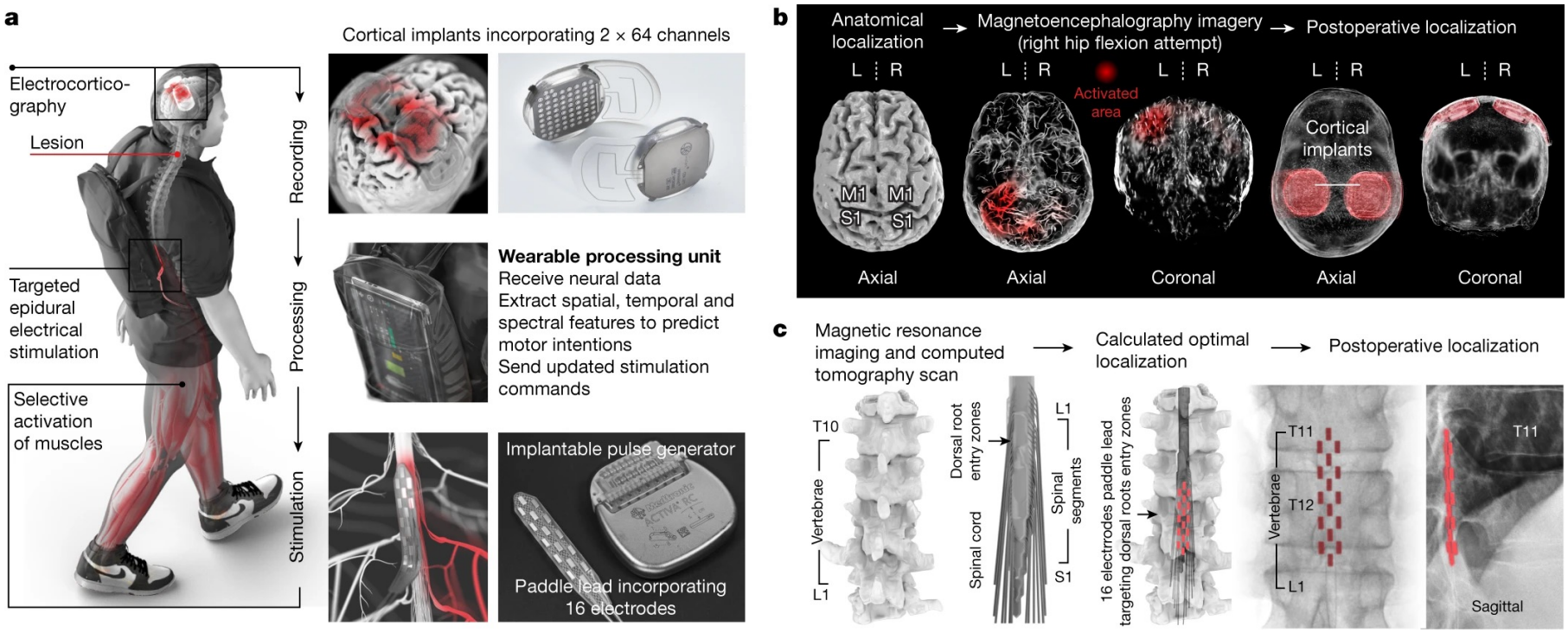
Artificial-intelligence-based molecular classification of diffuse gliomas using rapid, label-free optical imaging, Nature Medicine volume 29, pages828–832 (2023)

Disc degeneration from MRI



Deep learning-based high-accuracy quantitation for lumbar intervertebral disc degeneration from MRI, Nature Communications volume 13, Article number: 841 (2022)

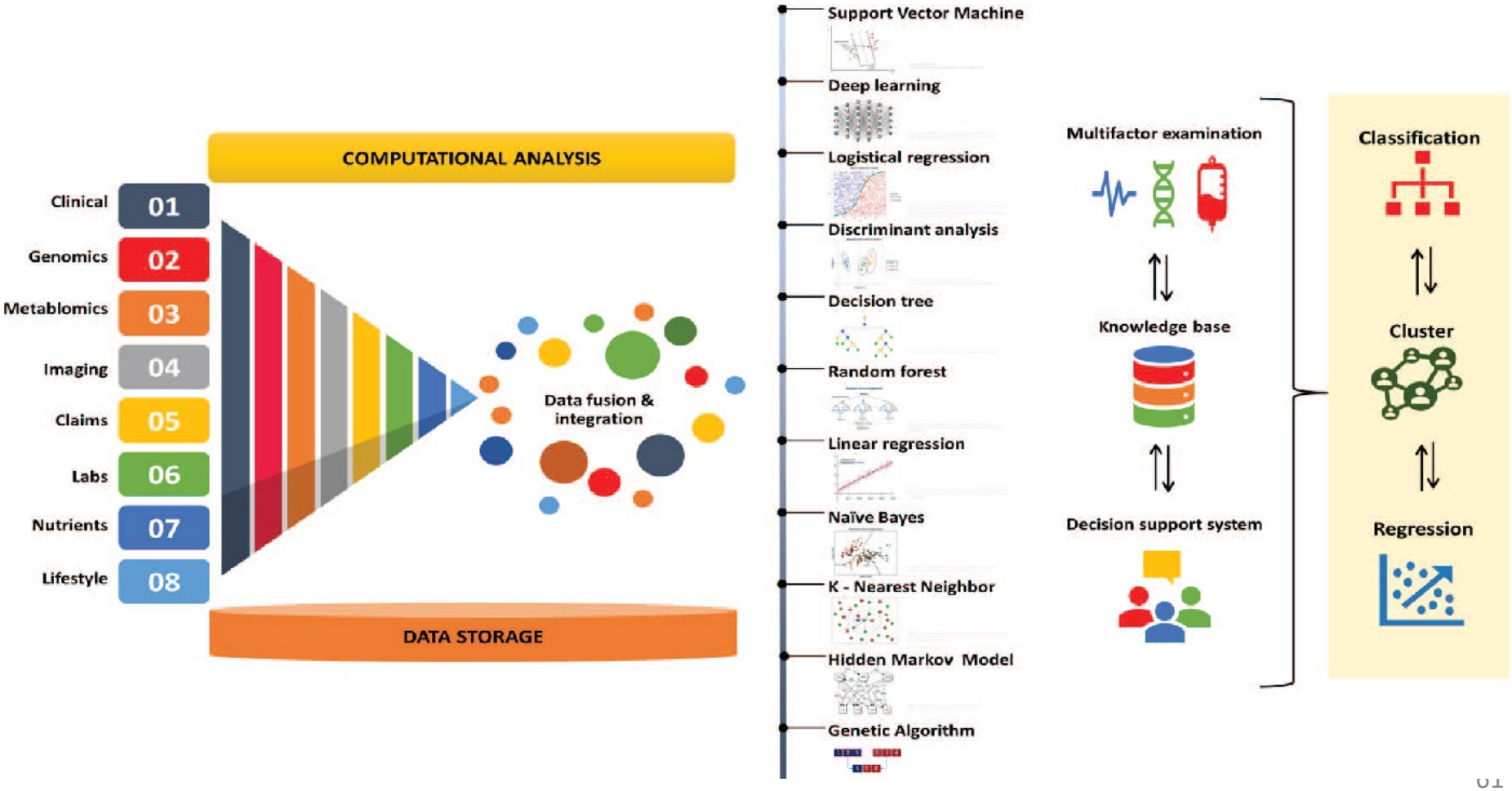
Walking naturally after spinal cord injury using a brain–spine interface



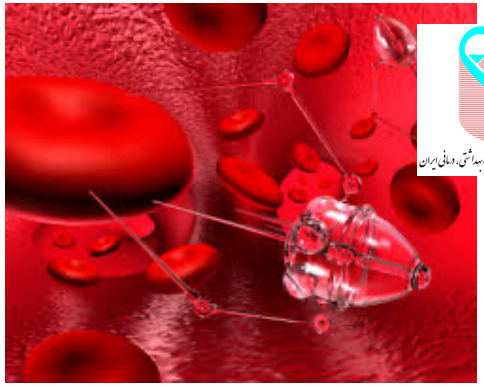
Walking naturally after spinal cord injury using a brain–spine interface, Nature volume 618, pages126–133 (2023)

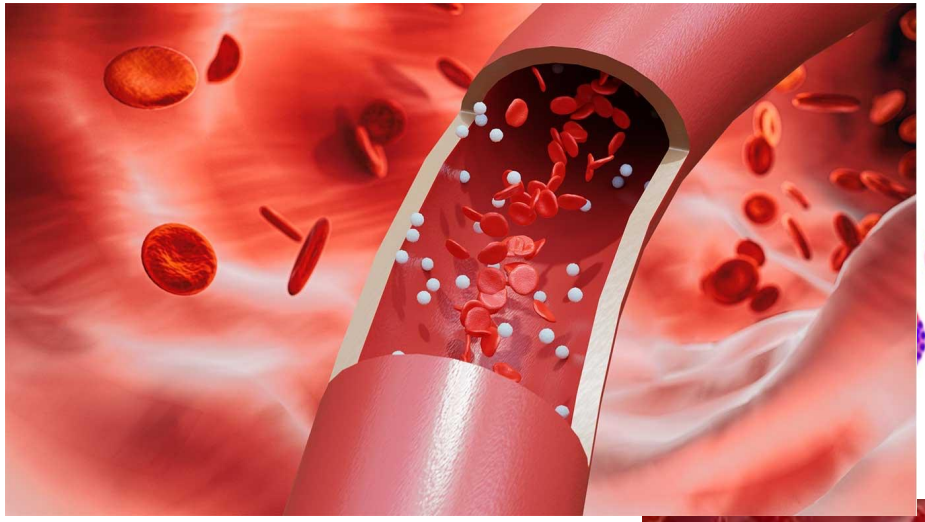
Artificial Intelligence in Medicine

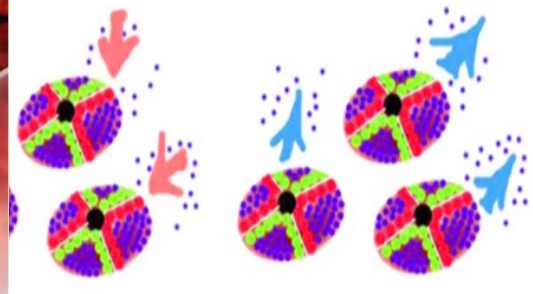
Artificial Intelligence = **Augmented Intelligence**

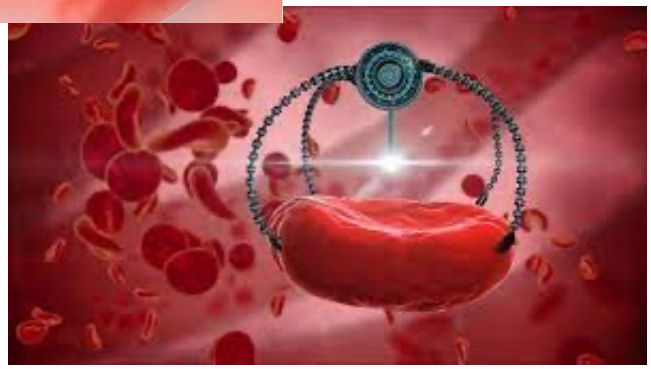


Nanomedicine







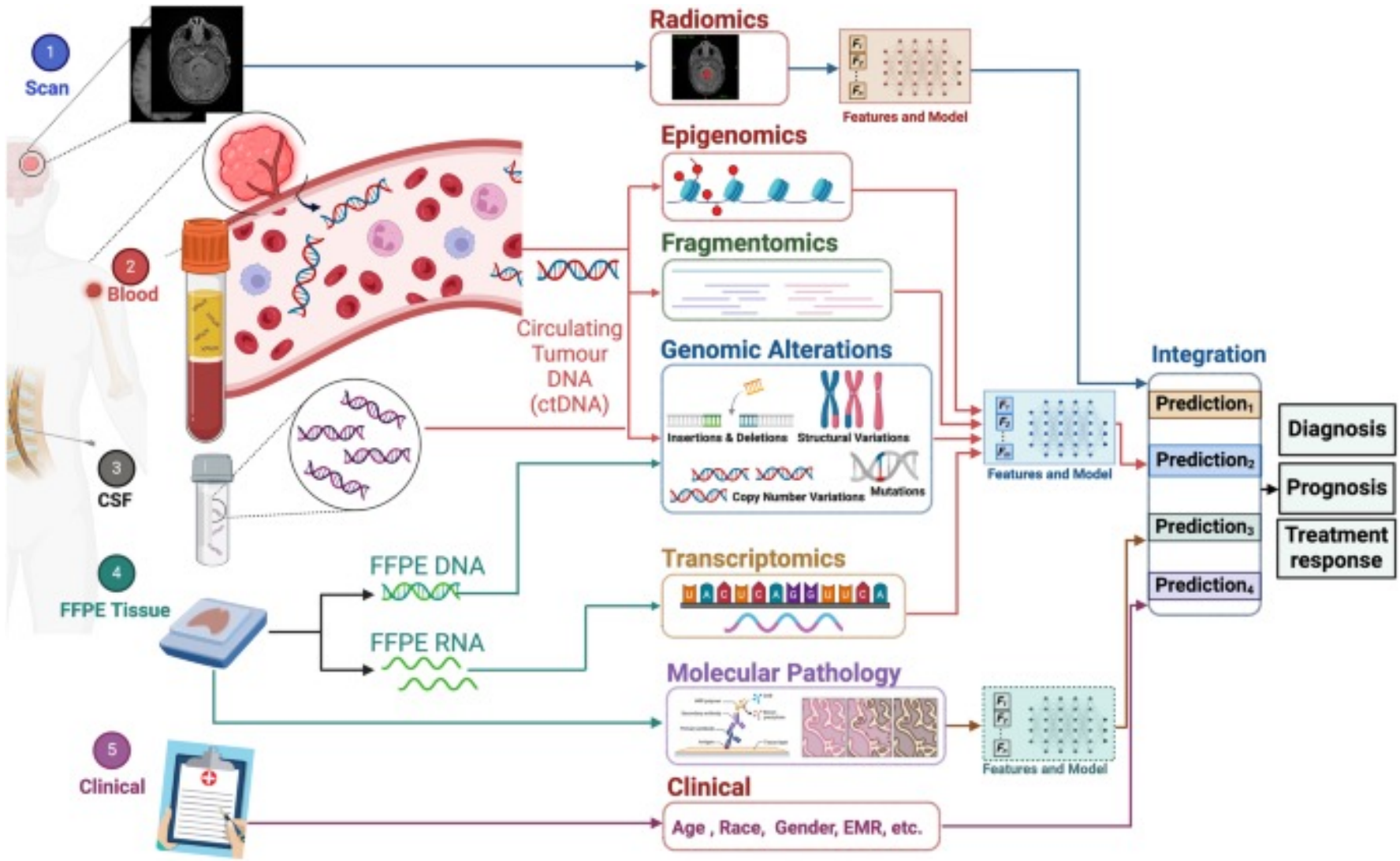


[1] N. Rady Raz, M. -R. Akbarzadeh-T and S. Setayeshi, "Influence-Based Nano Fuzzy Swarm Oxygen Deficiency Detection and Therapy," *in IEEE Transactions on Systems, Man, and Cybernetics: Systems*, vol. 53, no. 8, pp. 4994-5005, Aug. 2023, N. Rady Raz, M. R. Akbarzadeh T., "Target Convergence Analysis 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.

Multimodal integration for enhanced diagnosis, prognosis, and treatment response prediction in brain tumors



Brain Tumor Diagnosis during Surgery

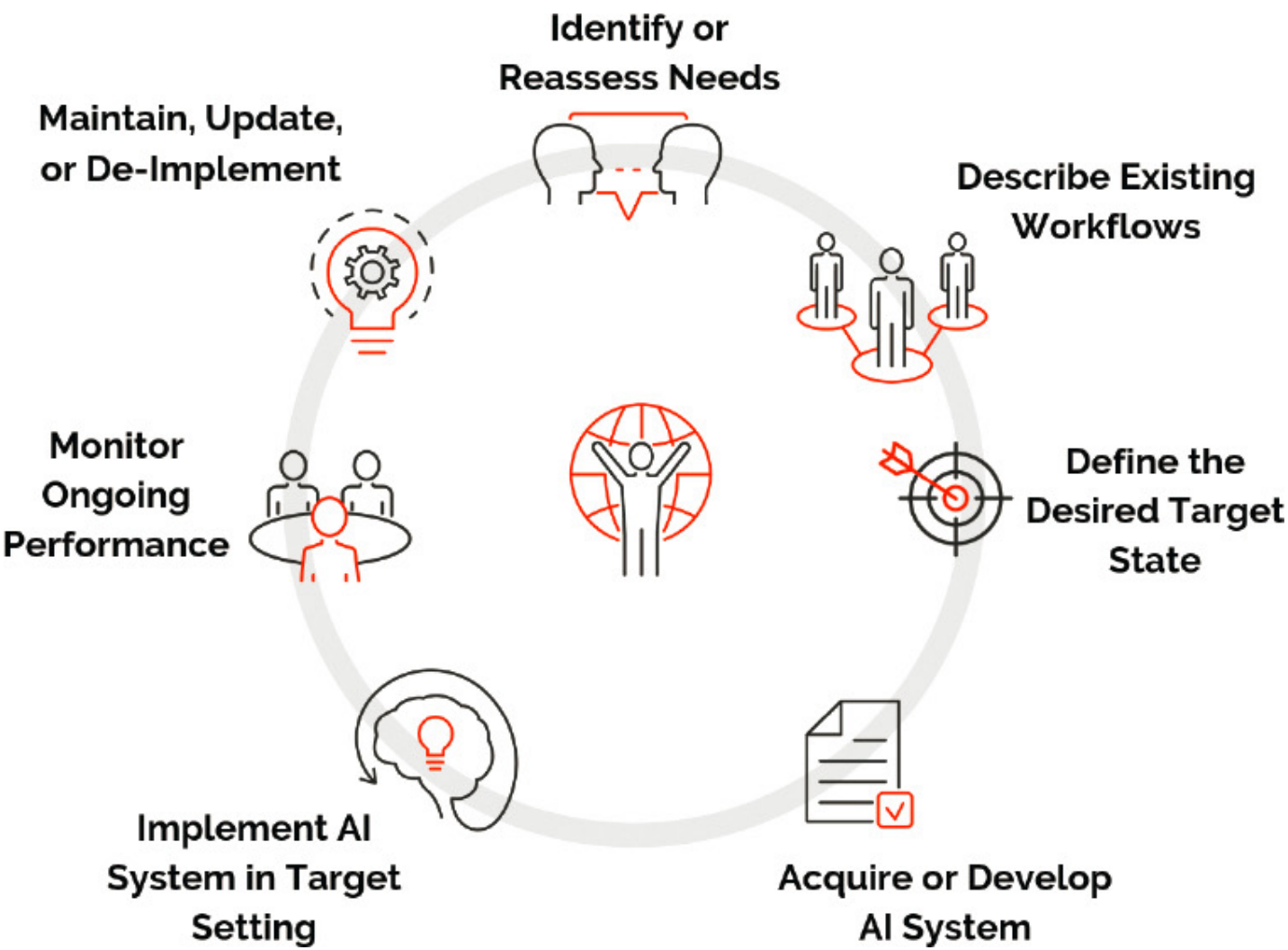
combine an imaging technology called stimulated Raman histology (SRH) with the predictive power of AI to improve current intraoperative pathology practice

Innovation through collaboration

How to get started with AI for hospital and clinic management systems

1. Identify your needs. What are the biggest challenges that your hospital or clinic is facing? What areas do you think AI could have the biggest impact?
2. Research AI solutions. There are a number of different AI solutions available for hospital and clinic management systems. Do some research to find solutions that are tailored to your specific needs.
3. Implement AI solutions carefully. It is important to implement AI solutions carefully and to monitor their performance closely. AI solutions should be integrated with your existing systems and workflows in a way that minimizes disruption.
4. Perform the task in a collaborative manner.

What to do then?



Challenges and Questions

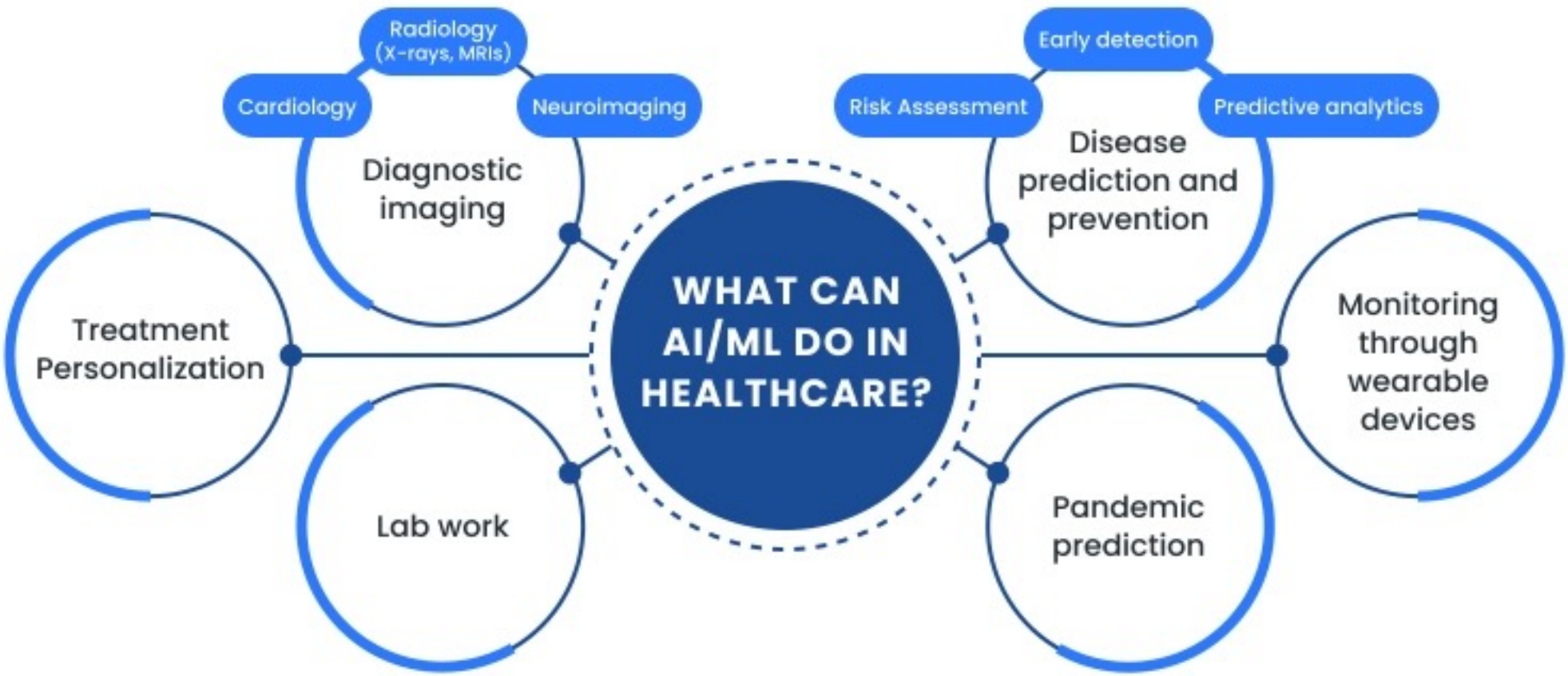
- How do we ensure the ethical use of AI in healthcare?
- What are the regulatory frameworks that need to be in place for the safe and effective use of AI?
- How do we measure the quality and accuracy of AI in healthcare?

Challenges and Ethical Considerations

data privacy,

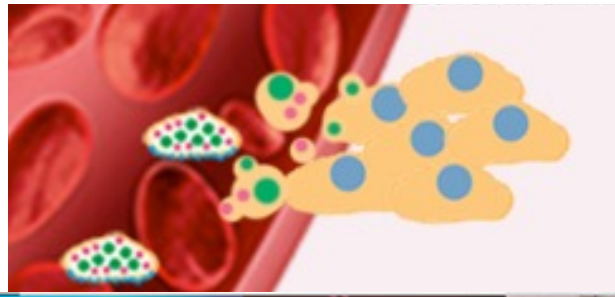
potential biases in datasets

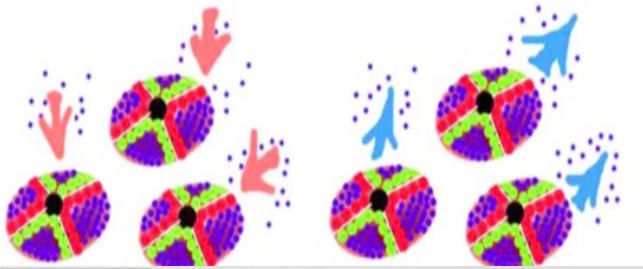
interpretability of algorithms,

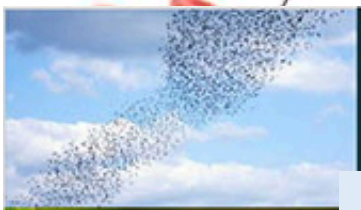


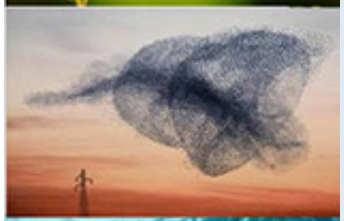
Note that!!

- 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.









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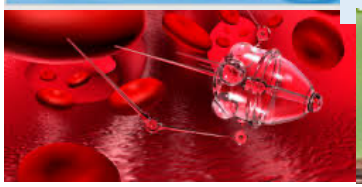
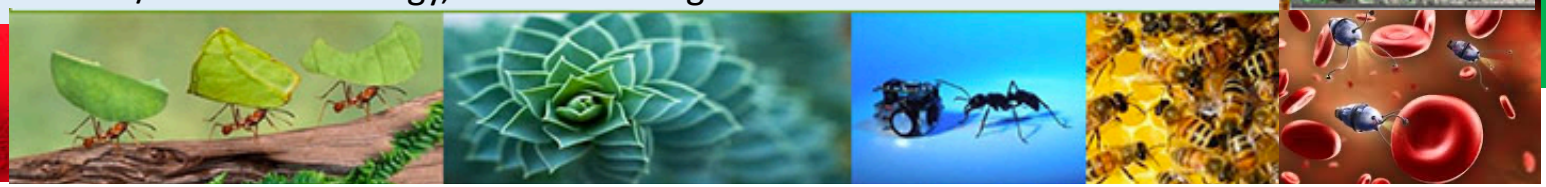
Research Interest:

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)