Artificial Intelligence in Surgery

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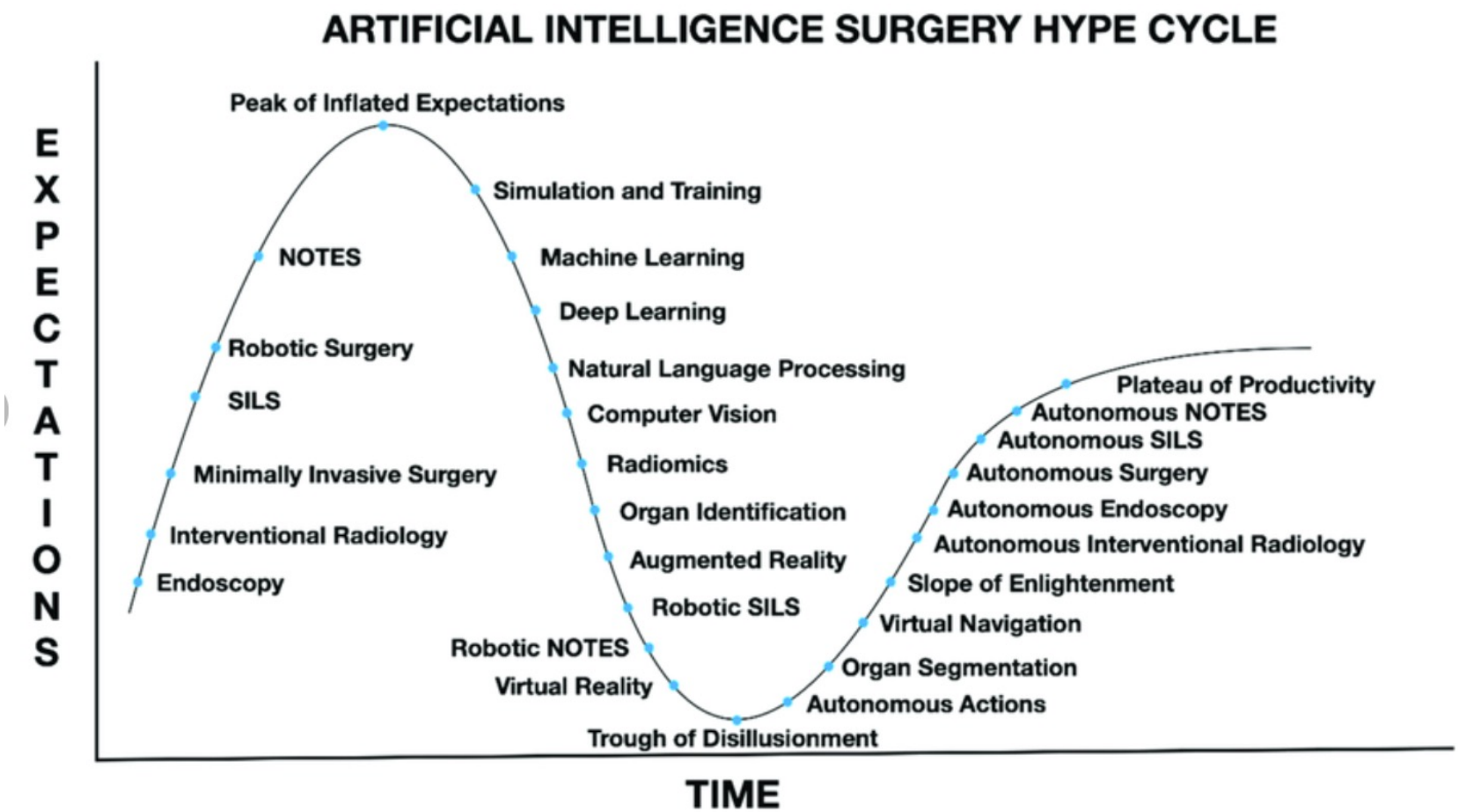
AI in Surgery



Computer-assisted surgery (**CAS**) represents a surgical concept and set of methods, that use computer technology for surgical planning, and for guiding or performing surgical interventions. CAS is also known as **computer-aided surgery**, **computer-assisted intervention**, **image-guided surgery**, **digital surgery** and **surgical navigation.**

Robot-assisted surgery or **robotic surgery** are any types of surgical procedures that are performed using **robotic systems**, using either a **tele-manipulator** or a computer.

A **telemanipulator** e.g. the da Vinci Robot is a system of remotely controlled manipulators that allows the surgeon to operate real-time under stereoscopic vision from a control console separate from operating table

In **Computer controlled systems** , the surgeon uses a computer to relay control data and direct the robotic arms and its end-effectors e.g. a telemanipulators for their input. This makes possible AI or autonomous procedures and telesurgery

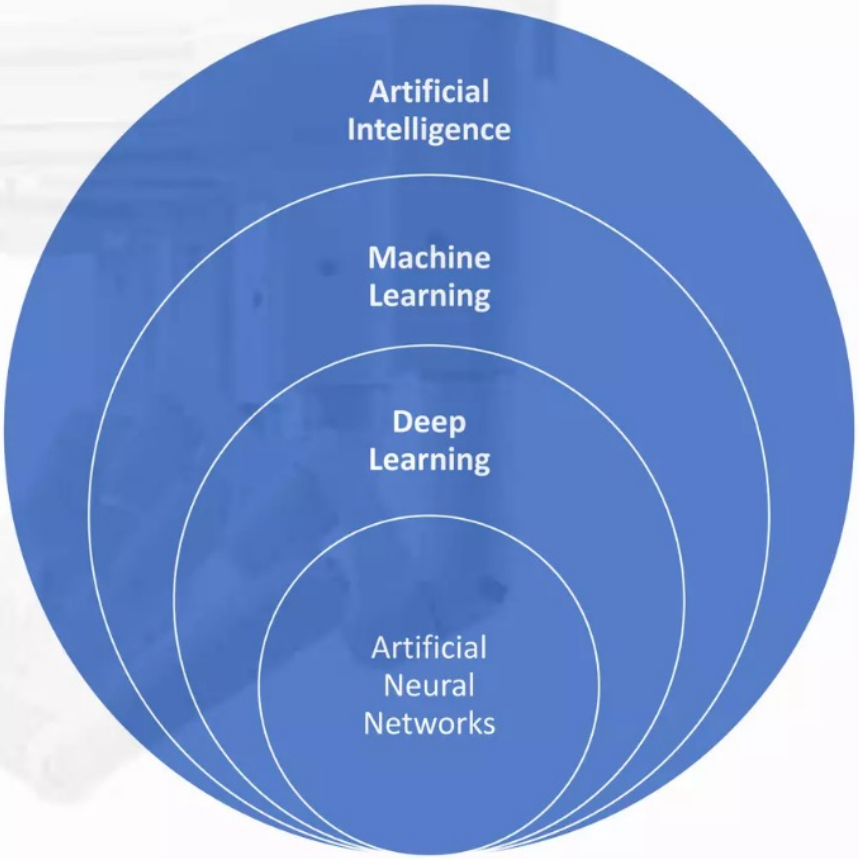
Image-guided surgery (**IGS**) is any surgical procedure where the surgeon uses tracked surgical instruments in conjunction with preoperative or intraoperative images in order to directly or indirectly guide the procedure. Image guided surgery systems use cameras, ultrasonic, electromagnetic or a combination or fields to capture and relay the patient's anatomy and the surgeon's precise movements in relation to the patient, to computer monitors in the operating room or to augmented reality headsets (augmented reality surgical navigation technology)

Artificial intelligence (AI) is intelligence—perceiving, synthesizing, and inferring information—demonstrated by machines, as opposed to intelligence displayed by non-human animals or by humans.

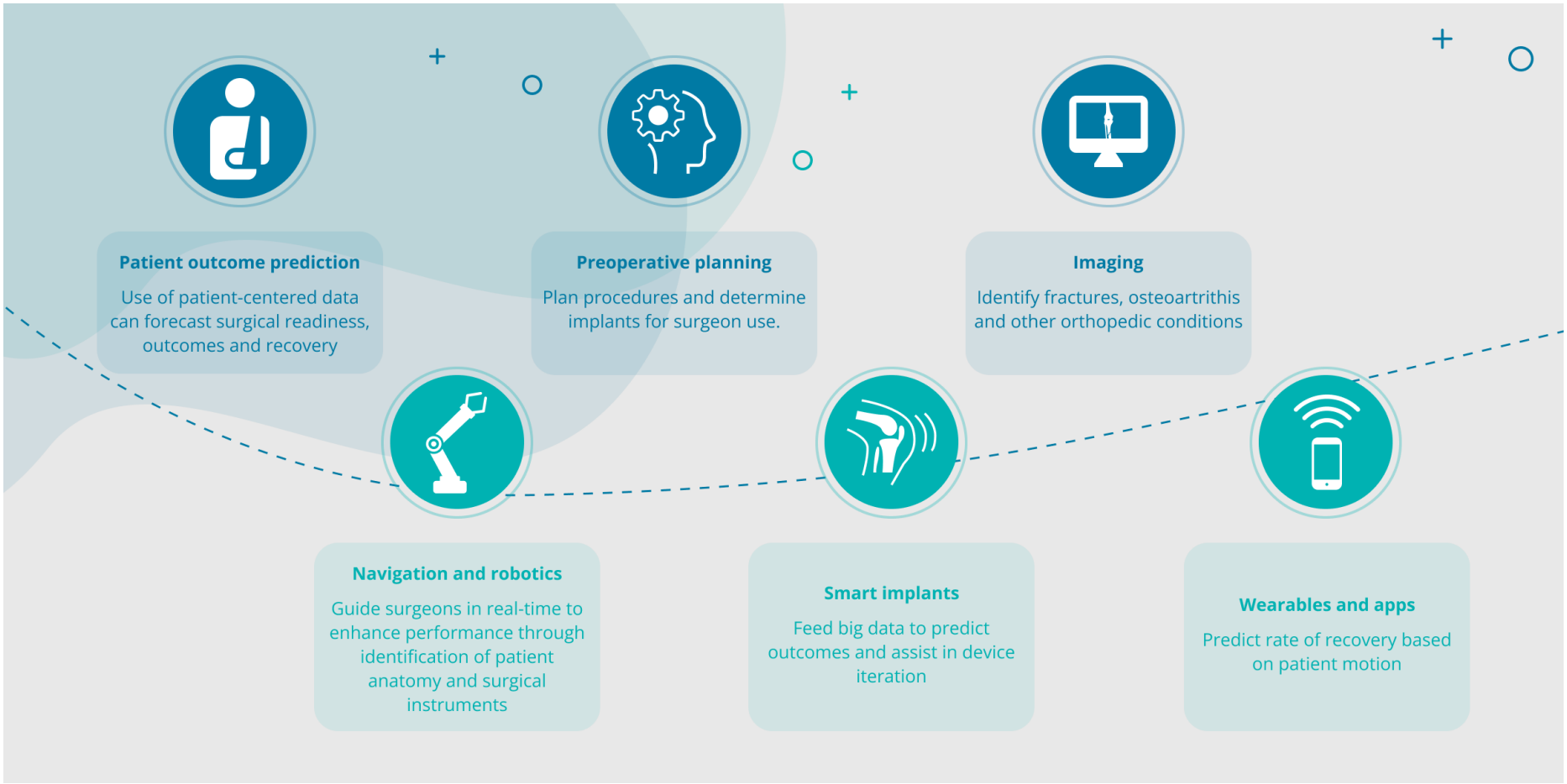
Machine learning (**ML**) is a field devoted to understanding and building methods that let machines "learn" – that is, methods that leverage data to improve computer performance on some set of tasks

Deep learning is part of a broader family of machine learning methods, which is based on artificial neural networks with representation learning . Learning can be supervised , semisupervised or unsupervised.

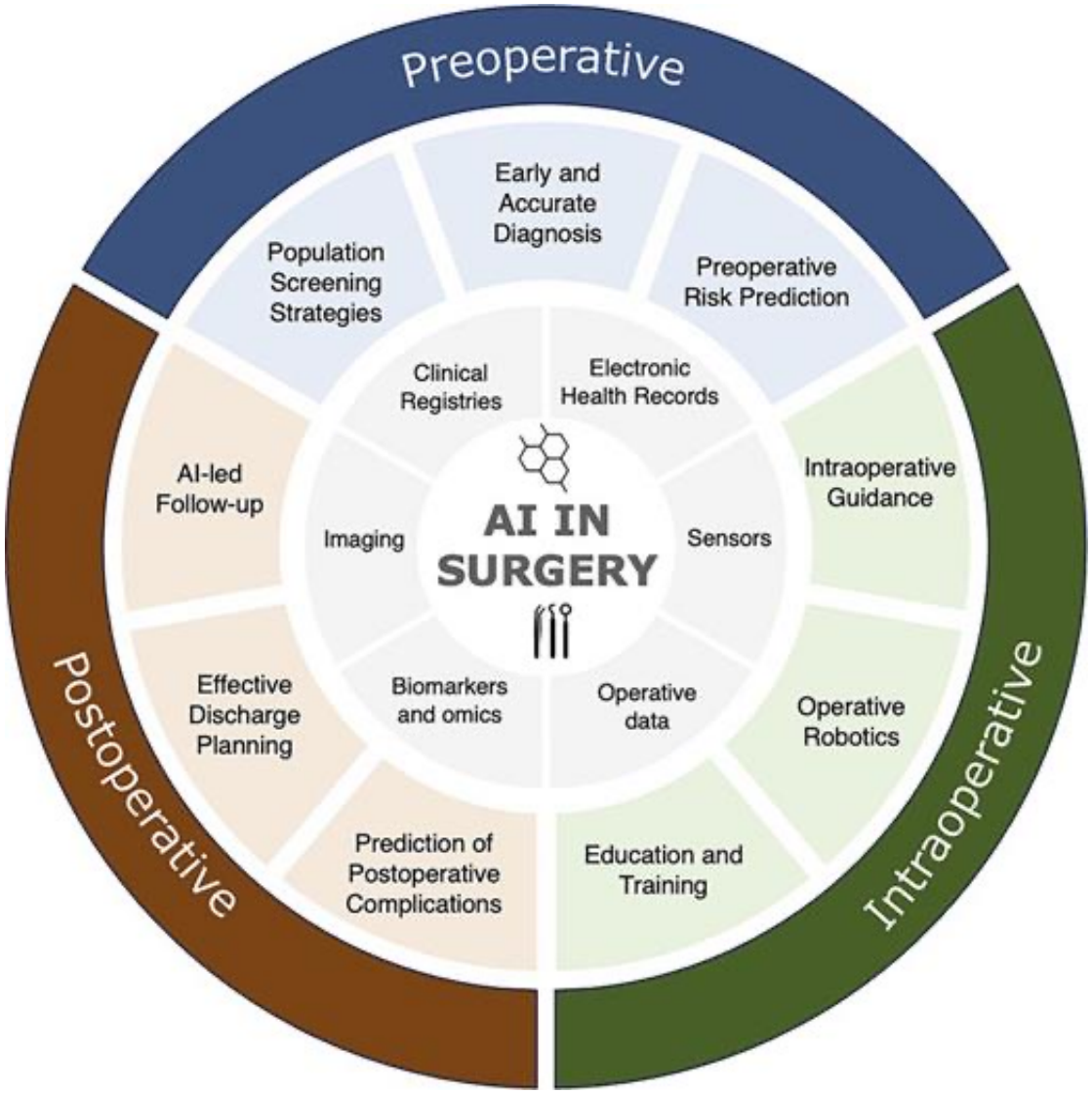
Artificial neural networks (**ANNs**), usually simply called neural networks (NNs) or *neural nets*, are computing systems inspired by the biological neutral networks that constitute animal brains.



AI in Surgery Applications



AI in Surgery Applications



- Scott Fisher (NASA) and Joseph Rosen gave the earliest conceptions of surgical robotics in 1980's - telepresence surgery in which surgeon works on computer assisted system to direct and manipulate robotic arms to perform the designated function.

- Open surgery → Laparoscopic surgery → Robotic

- The first robot to be used for surgery : Puma 560, a passive robot used to perform neurosurgical biopsies with greater precision.
- Neuromate 1997- steriotactic neuro surgeries.

- ROBODOC : first surgical robot approved by the FDA and also the first robot to perform automated procedure on humans.
- It was developed for primary/ revision THR, TKR.

- The US Army became interested in the possibility of decreasing wartime mortality by —bringing the surgeon to the wounded soldier—through telepresence.
- Funded computer motion which made AESOP, later they made Zeus system – 2 robotic arms and endoscope for vision.

- Mountain system introduce Da vinci.

da Vinci Si
da Vinci Xi
da Vinci S
da Vinci SP

da Vinci Si

- 1st telesurgical Lap. Cholecystectomy in humans – 1997 (Da Vinci)

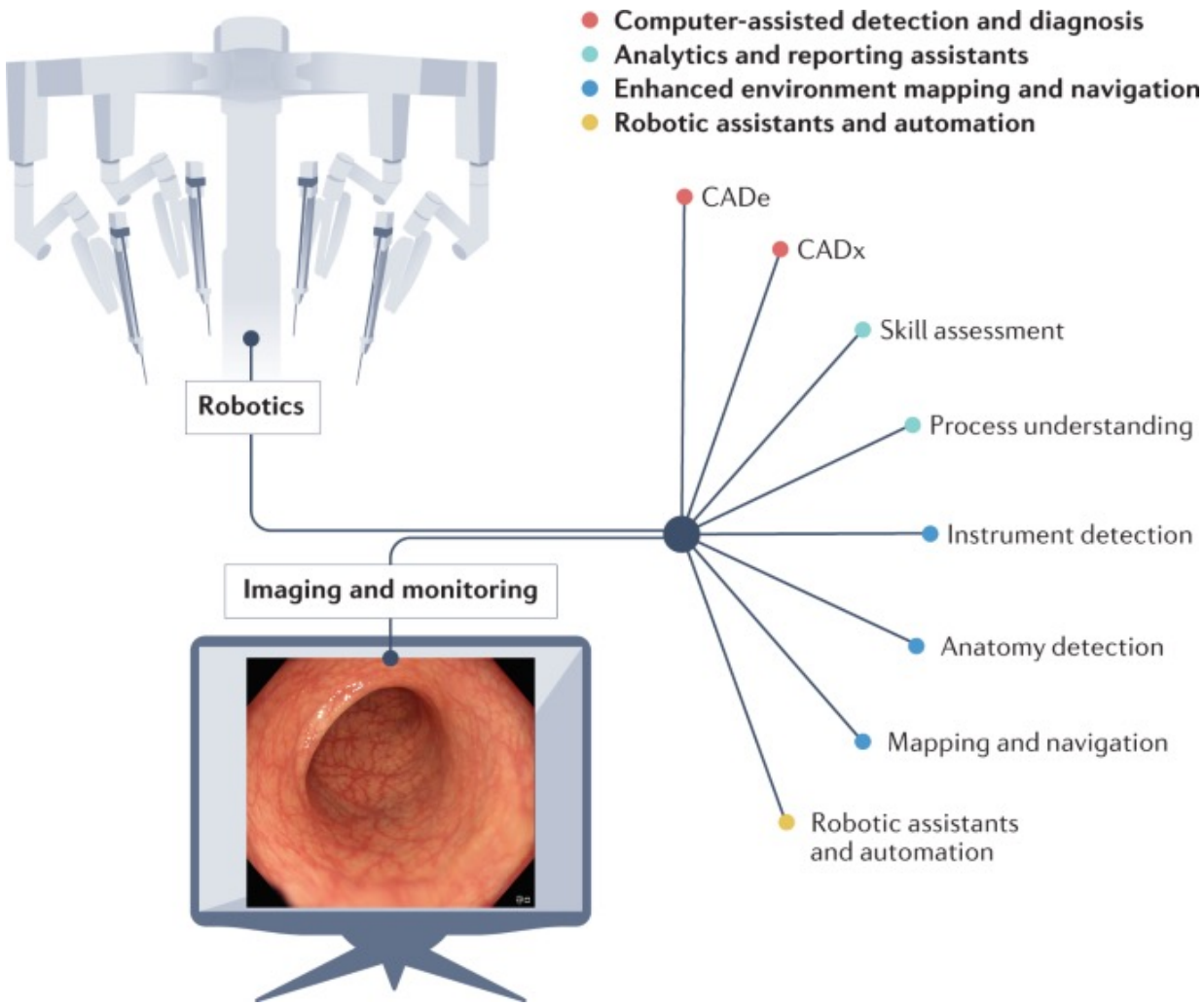
Da Vinci System

Master console, Patient cart, Vision cart.

- **Master console:**
- Place where the surgeon sits comfortably outside sterile field and controls the EndoWrist instrument movements at the surgical site via hand manipulators.
- It is the control unit.

- The console is provided with a Stereo Viewer that translates the image of the surgical site acquired by the endoscope and displays it in front of the surgeon's eyes in 3d (surgical immersion).

AI and Robotic Surgery



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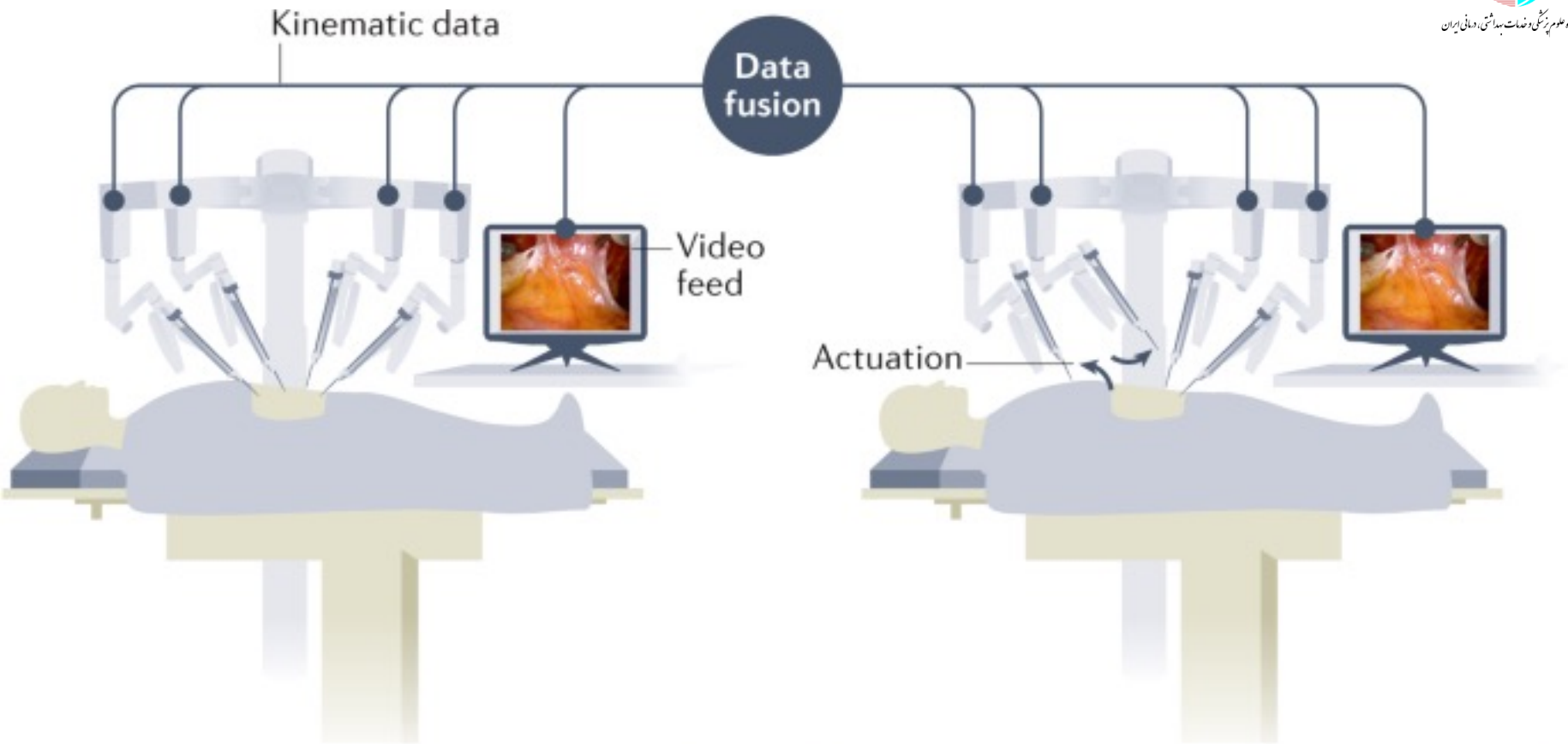

Major challenges
- Costs
- Practitioner learning curve
- Limited surgical tools and imaging modes
- Operative time

AI capabilities
- Enhanced visualization, for example, scene segmentation, lesion detection, surgical tool pose estimation
- Guided navigation and tool actuation
- Surgical workflow analysis

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- ENDOWRIST INSTRUMENTS:
- The instrument tips are designed to mimic the dexterity of the human hand and wrist.
- It allows 7 degrees of freedom and 90 degrees of articulation (5 degrees freedom in conventional laprascopy are called endowrist function).
- These instruments allows for greater precision when operating, help in the most rapid and most precise suturing, dissection and tissue manipulation available with any surgical platform.
- These instruments are multi-use instruments. Available in 8mm and being developed in 5mm diameters.

ADVANTAGES

LAPAROSCOPIC SURGERY	ROBOTIC SURGERY
Well developed technology	3 D visualisation – Dual camera
Affordable & ubiquitous	Improved Dexterity - endowrist
Proven Efficacy	Seven degrees of freedom
Easy to work in large spaces like peritoneal cavity	Ergonomic position
Can be done with less experienced assistant	Shorter learning curve
	Elimination of physiologic tremors
	Elimination of fulcrum effect
	Ability to scale motion
	Telesurgical Ability
	Micro anastomosis possible

DISADVANTAGES

LAPAROSCOPIC SURGERY	ROBOTIC SURGERY
Loss of touch sensation	Absence of touch sensation
Loss of 3 D visualisation	Expert assistant required by patient side
Longer learning curve	Requires re-docking if patient position is changed
Compromised dexterity	High start up cost
Limited degrees of freedom	Newer technology
The fulcrum effect	Increased time for OT set up
Amplification of physiologic tremors	Bulky equipment

USES

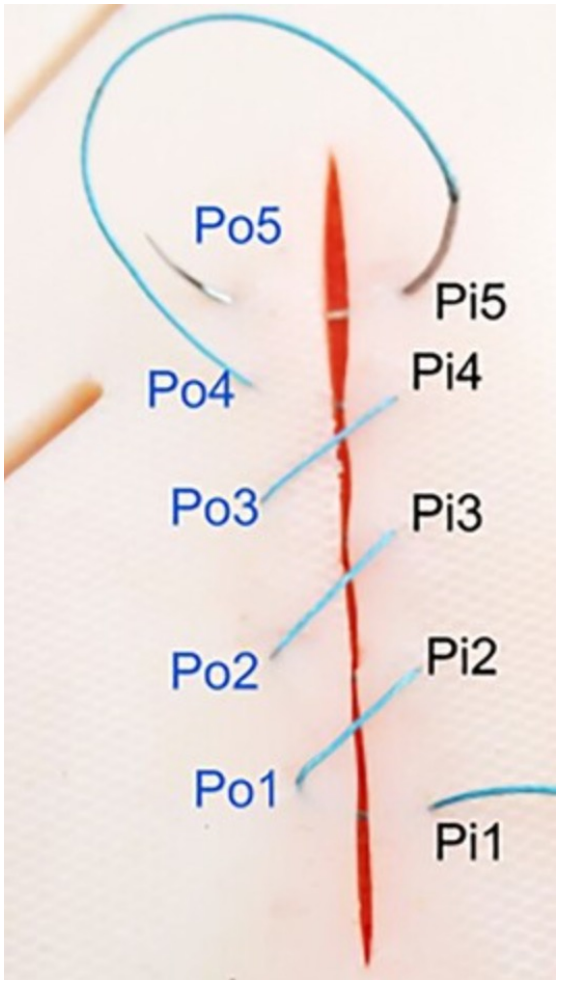
- Utilized in a wide variety of minimally invasive surgical procedures- general, urological, gynecologic, and cardiothoracic surgery.
- GI : cholecystectomy, Hellers myotomy, Fundoplication, bariatric surgery, colorectal surgery.
- Urology: There are multiple large series of robotic prostatectomies published in the literature. Better on comparision to open prostatectomy.
- Shorter hospital stay, less pain, less blood loss and fewer transfusions, and even better erectile function outcomes than conventional open nerve-sparing prostatectomy.
- Thoracic surgery: thymectomy, lobectomy, esophagectomy, and resection of mediastinal tumors.

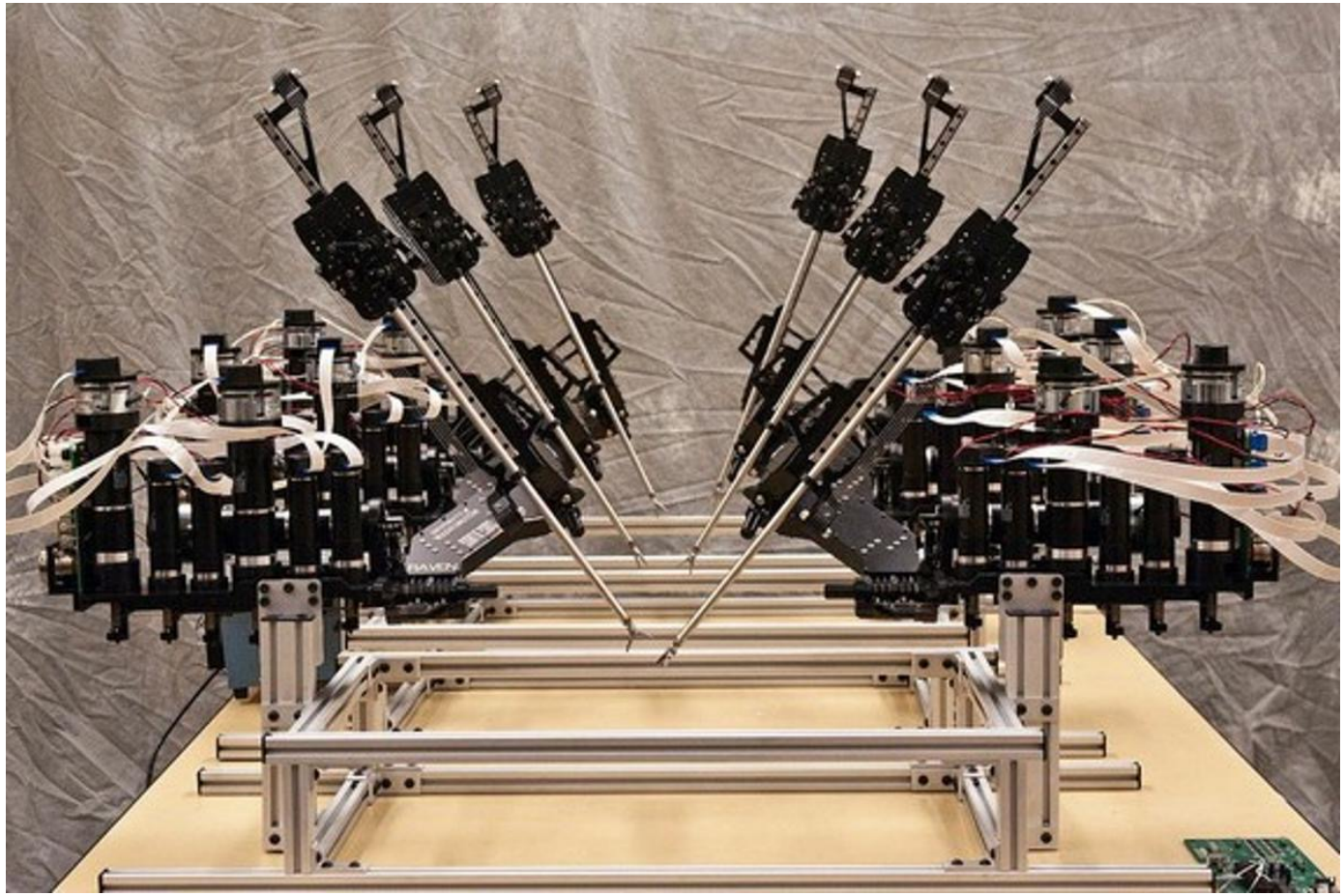
- Cardiac surgery :
- Davinci system was originally designed for use in closed chest cardiac surgery, but is now mostly used in other areas. Its used in minimally invasive mitral valve repair and replacement with good results, including a shorter length of stay and fewer blood transfusions than in open surgery.
- In the future, it is likely that multi-vessel or off-pump totally endoscopic robotic coronary artery bypass will be possible.

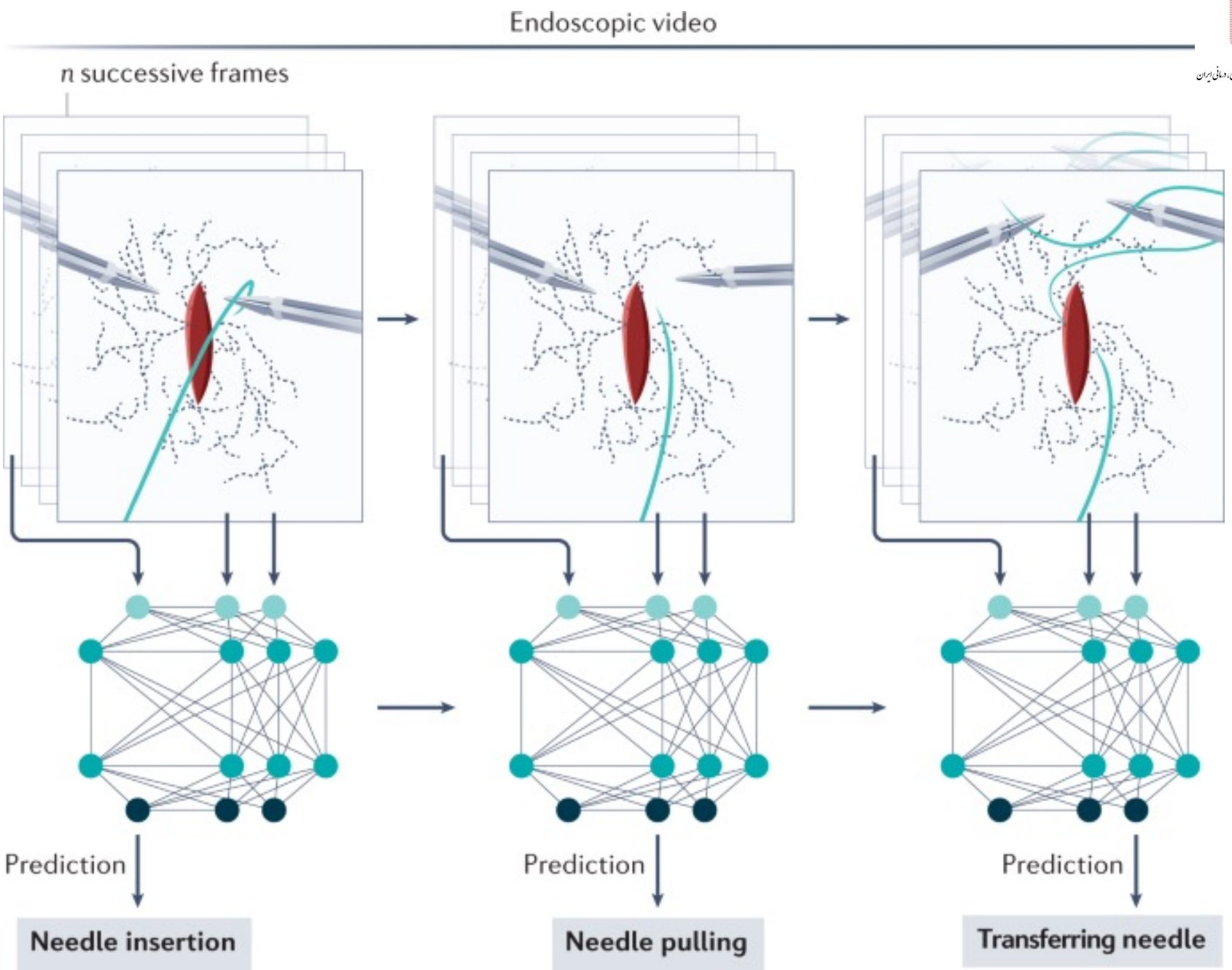
- Gynaecologic Surgery: radical hysterectomy, Tubal anastomosis etc.

- Other departments: Neurosurgery, Transplantation surgeries, Vascular surgeries (slovania-2000) , orthopedics, paediatric surgery.

Suturing Robotic







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Deep Learning Models & Robotic Surgery

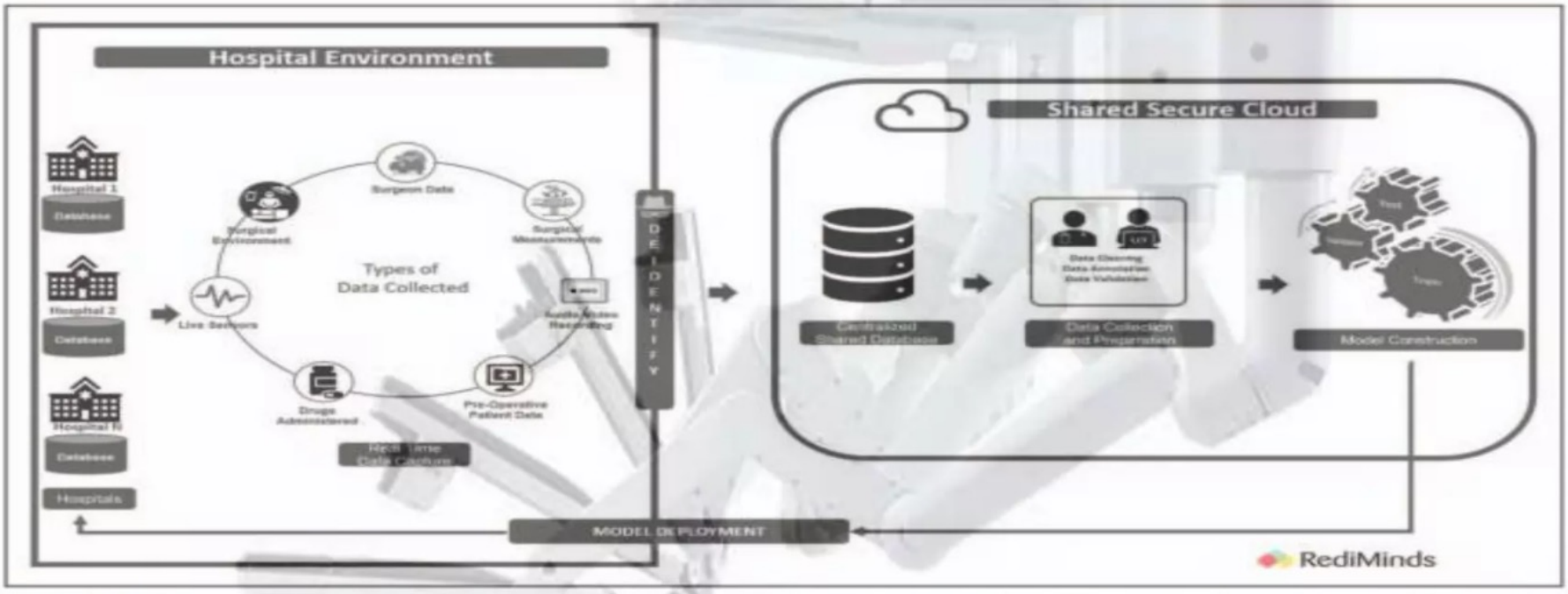
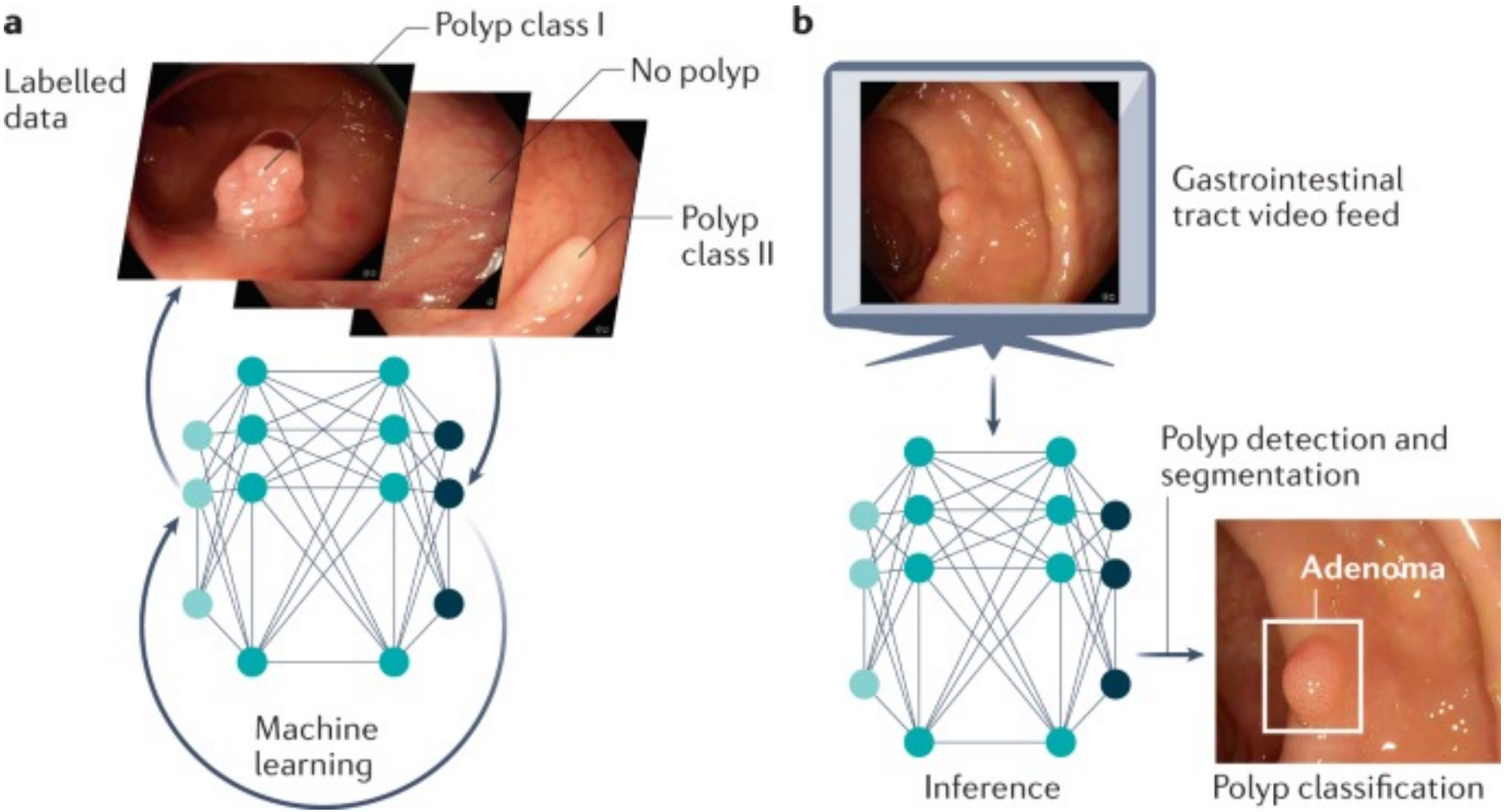


FIGURE 1. A schematic for data capture, and construction of deep-learning models. The process for multicenter data capture, building, testing, and validating deep-learning models, the precursors of autonomous robots. (a) Individual center data capture; (b) merged data engineering and model building in the secured cloud environment; and (c) feedback loop for model deployment and validation.



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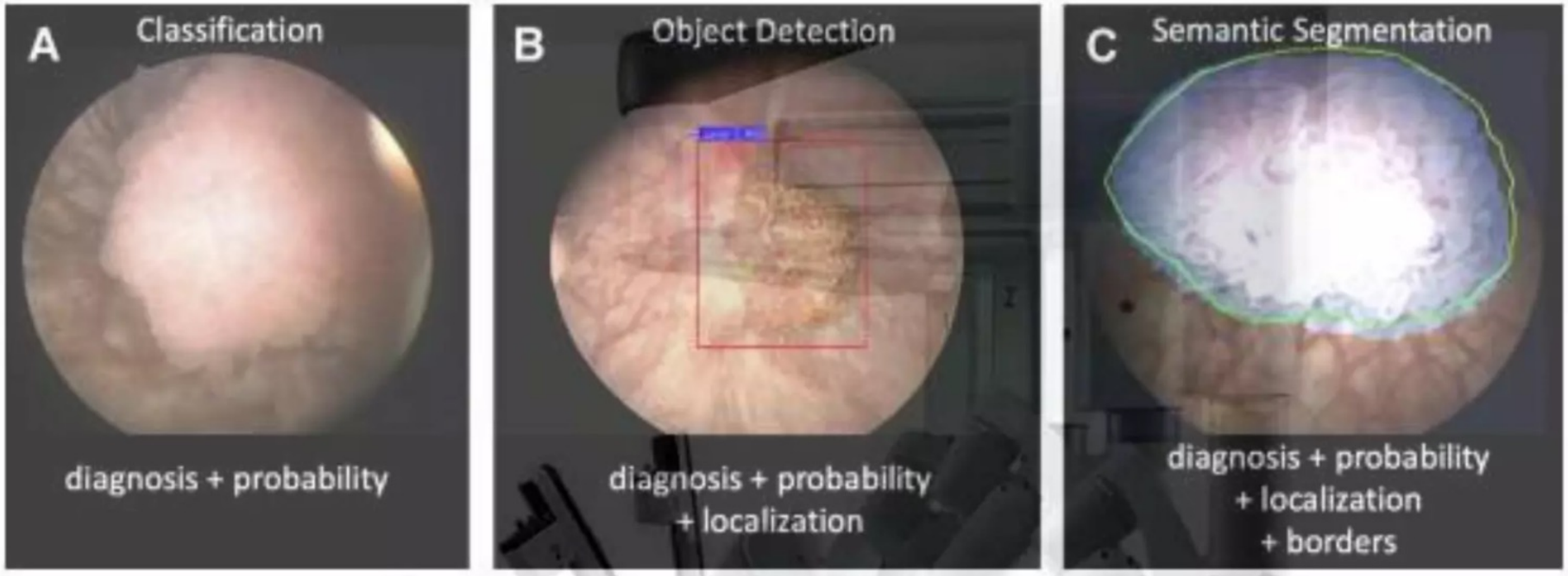
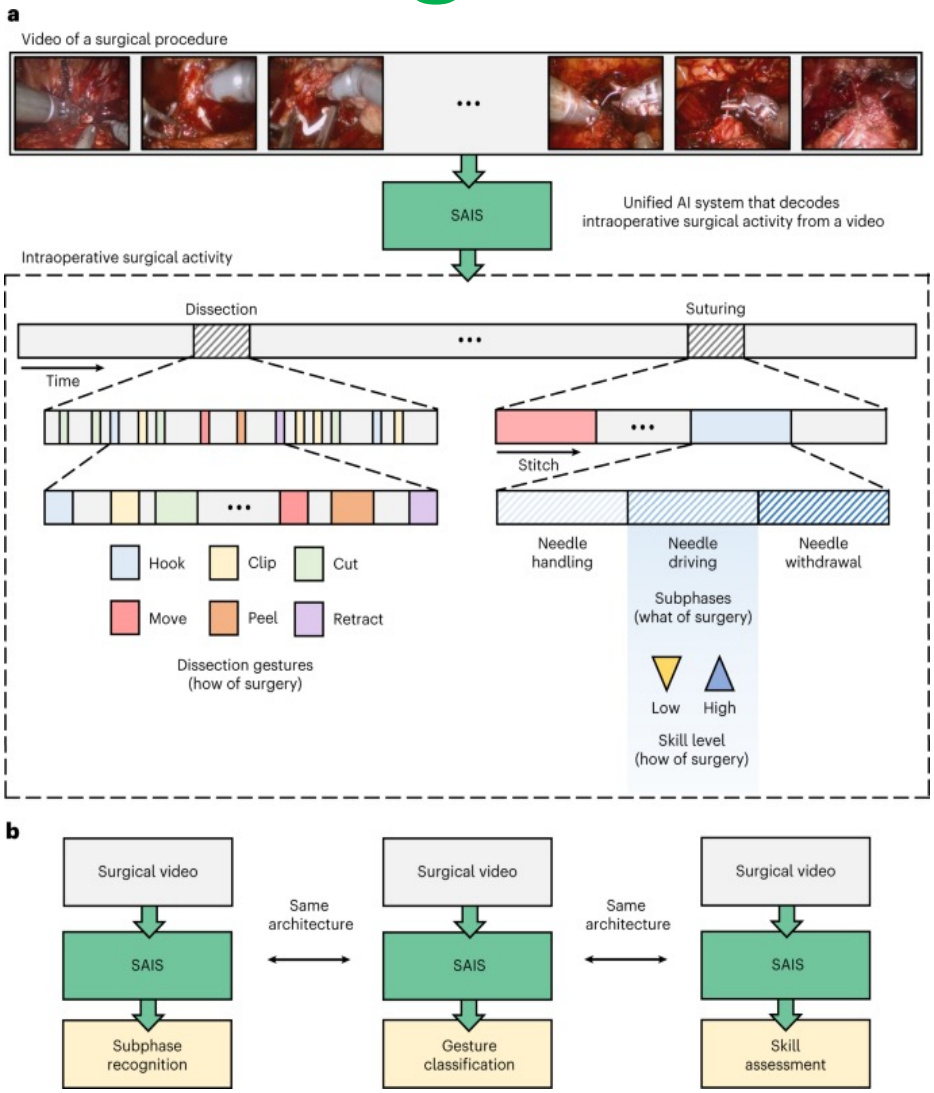


Image Analysis With Artificial Neural Networks (ANN)

(A) ANNs are capable of classifying images to provide a diagnosis and a measurement of its probability.
(B) Object detection provides localization of a diagnosed object within an image and also provides a measurement of its probability.
(C) Semantic segmentation provides outlining of the borders of a given object in addition to the diagnosis, probability, and localization

A vision transformer for decoding surgeon activity from surgical videos

Capture surgeon tasks during surgery for recording and post-operative treatment



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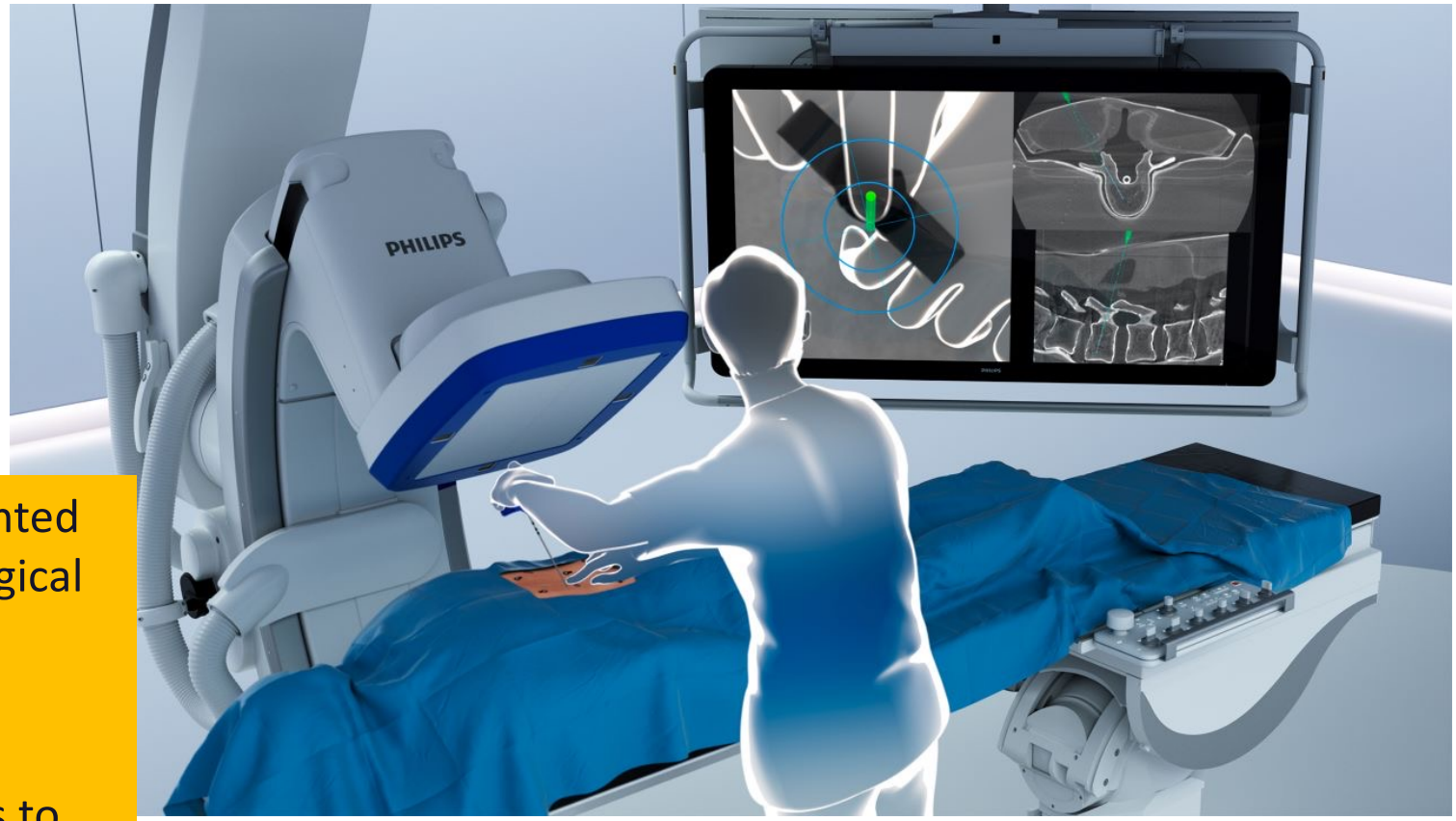
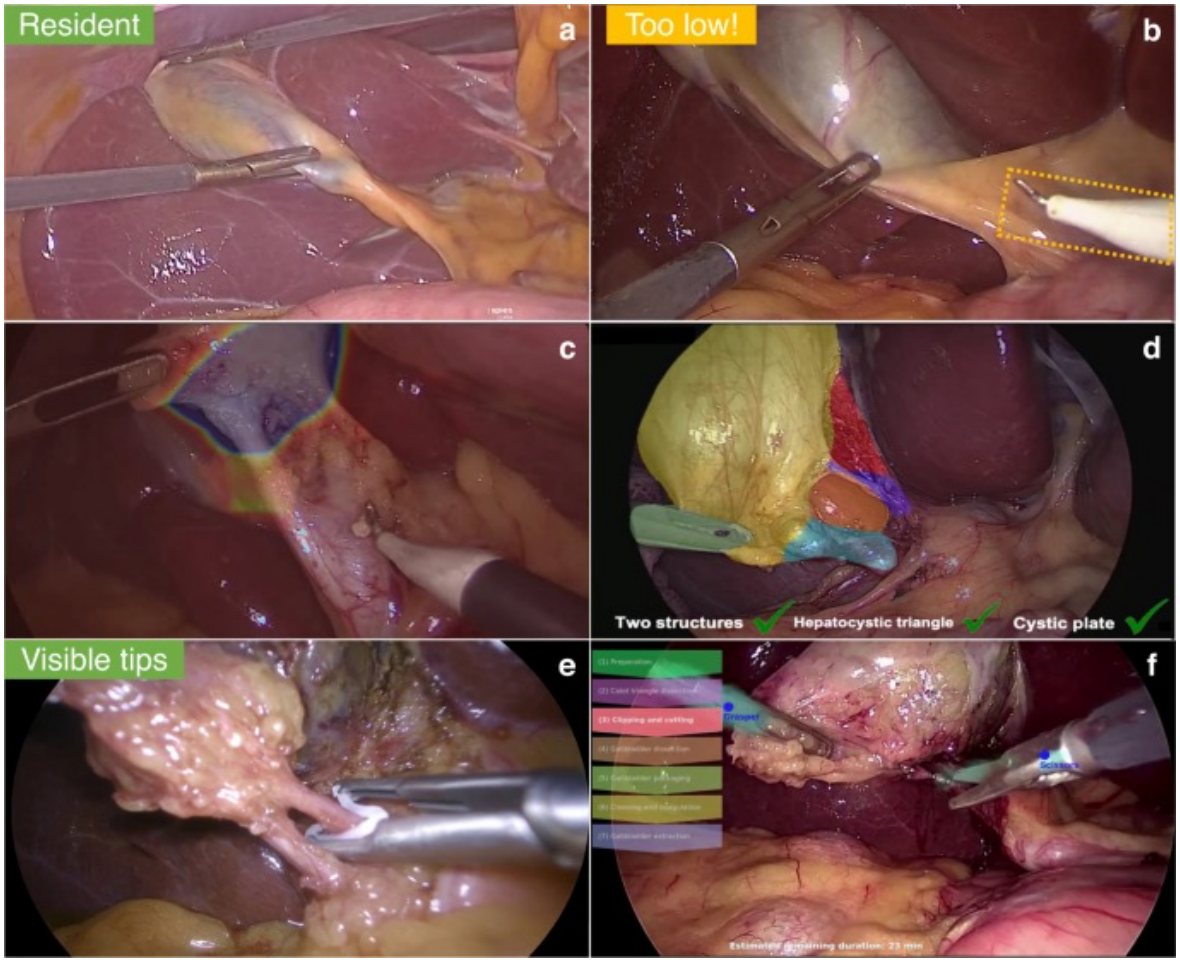
Augmented Reality and Surgical Navigation



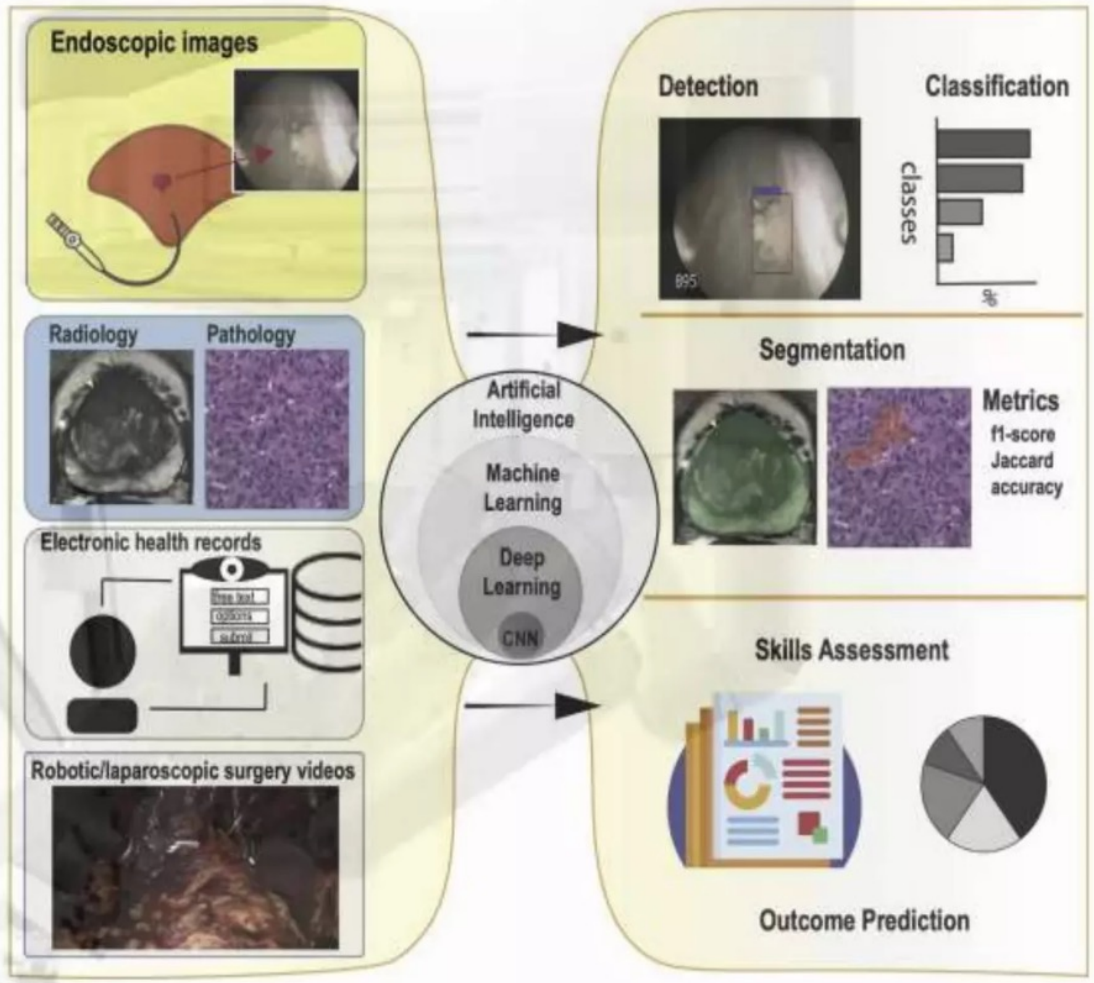
ClarifEye is an augmented reality (AR)-based surgical navigation system developed by health technology solutions company Royal Philips to assist minimally invasive spine surgeries in a hybrid operating room.

Computer vision - based real-time assistance in laparoscopic cholecystectomy

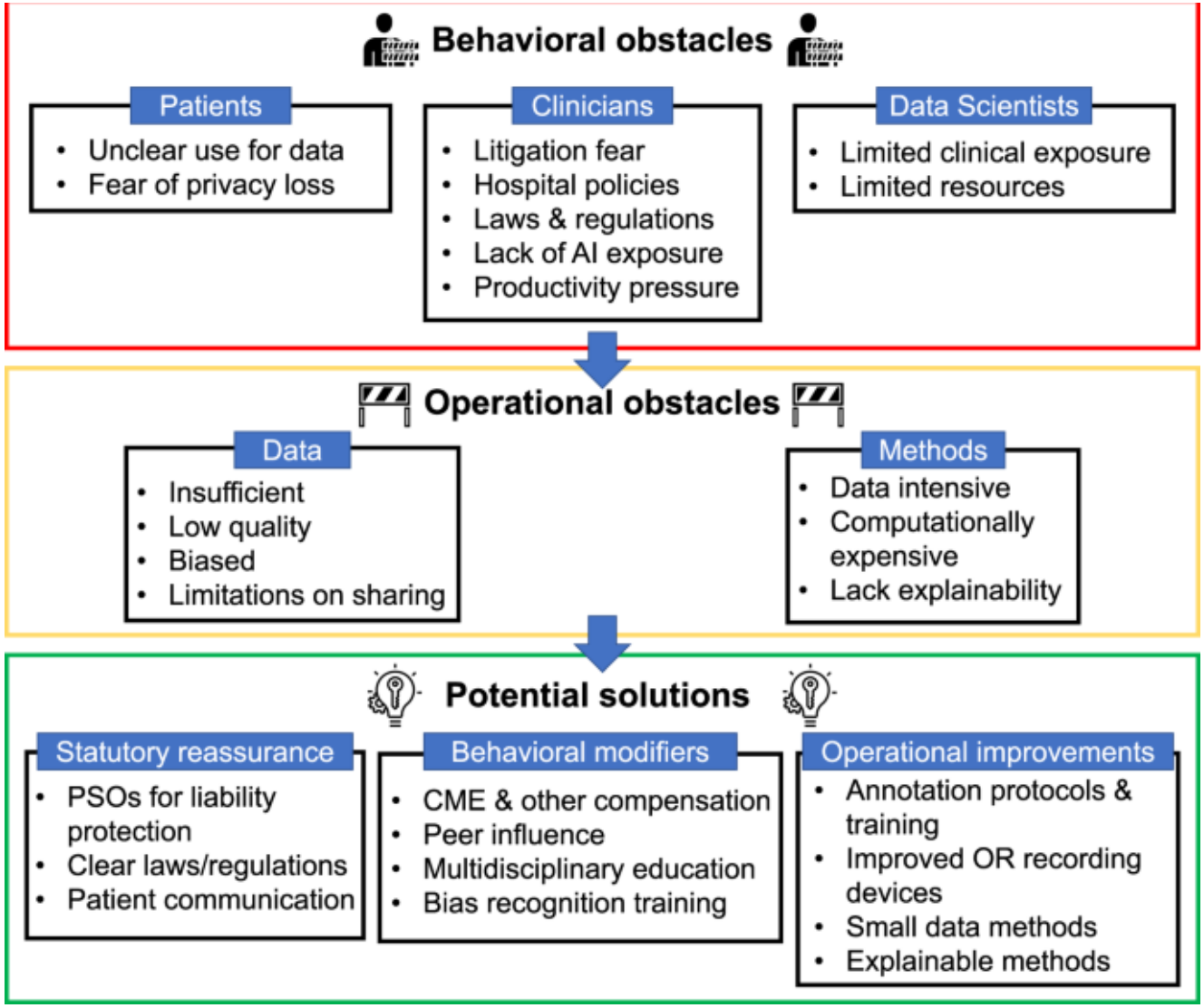


Artificial Intelligence & Health Care Data

1) Object Detection
2) **Image Classification**
3) Segmentation
4) Skills Assessment
5) Outcome Prediction



Obstacles and possible solutions for AI in surgery.



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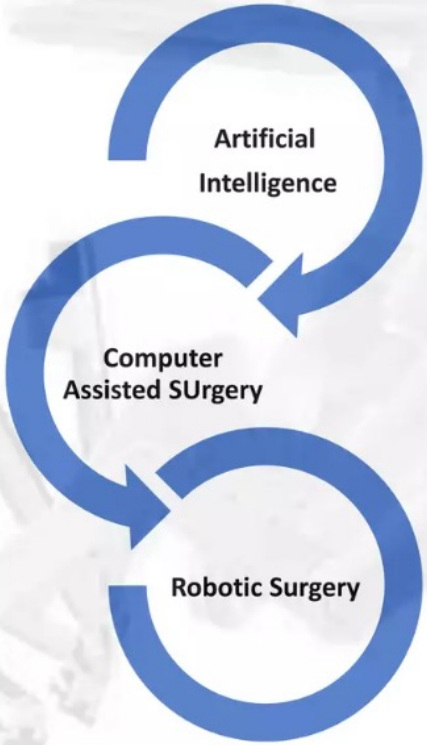
Conclusion: the future belongs to AI & Robotics!