Application of Artificial Intelligence in Ophthalmology

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AI: History

Alan Mathison Turing (1912-1954)
English mathematician, logician
Father of computer science. Founder of artificial intelligence.

Turing Test: developed by Alan Turing in 1950, is a test of a machine's ability to exhibit intelligent behavior equivalent to, or indistinguishable from, that of a human.

Turing Award - "the Noble Prize of Computer Science"

The chess-playing computer **"DEEP BLUE",** developed by IBM, defeated world champion Garry Kasparov in 1997.

Lin HT，2018

AI: Milestones

1943
neural network
mathematical model

1956
Dartmouth Conference

1980s
symbolic machine learning
e.g. decision tree(DT)

1986
Backpropagation(BP) algorithm, i.e. "the backward propagation of errors"

1990s
statistical learning
e.g. Support Vector Machine(SVM)

2006
Hinton
multilayer artificial neural network

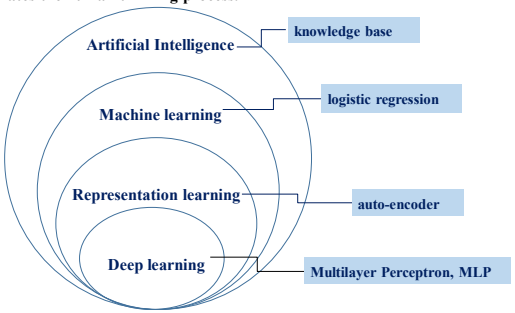
AI

Deep learning

Lin HT, 2018

AI: Basic Concepts

- AI simulates the human thinking process.



Goodfellow L, Deep learning 2017

Applying algorithms to medical data

- **Machine Learning: Analyzing Big Data**

  decision tree; random forest; neural network;

  Support Vector Machine (SVM); Boosting

- **Deep Learning: Processing Images**

  deep neural network; CNN…

  AlexNet (2012) ZF Net (2013) VGG Net (2014)

  GoogleNet (2015) Microsoft ResNet (2015）

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Applying algorithms to medical data

Neural Networks

Random Forest

Support Vector Machine

Deep Neural Network

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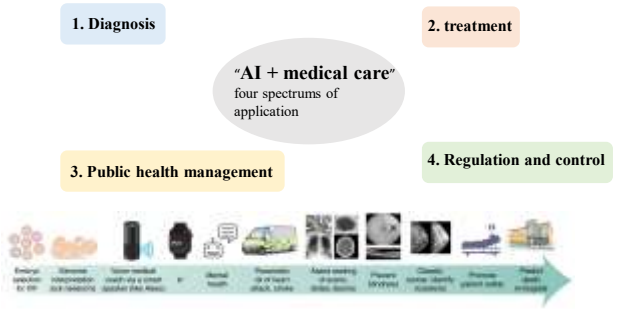
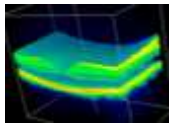
AI: Application



He JX, Nature Medicine 2019

Substantial AI-granted subject advantages in ophthalmology

- **The most important surface organ.**
- **Easy-to-collect ocular images and information.**



- **Big data as AI's infrastructure.**
- **Image recognition as its major objective.**

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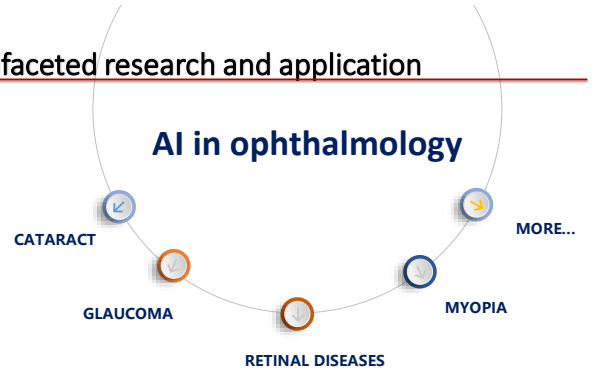
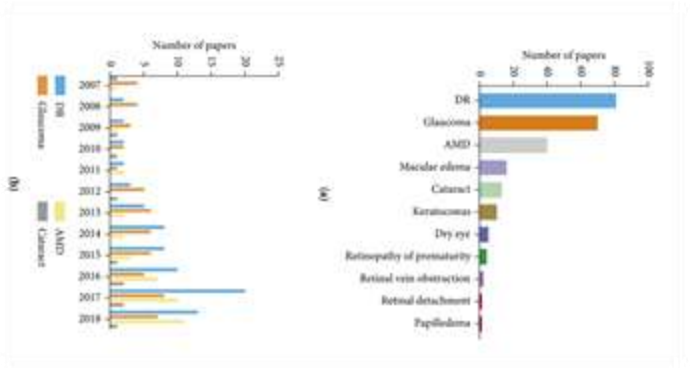
Multifaceted research and application

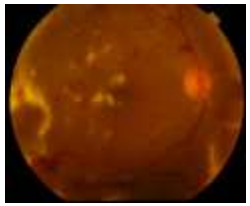




Lin HT，2018

AI: Diabetic Retinopathy

- Gulshan et al. first reported DL for DR
  Used large fundus image data- deep CNN;
  AUC 0.99 for detecting referable DR;
  High sensitivity and specificity.
- EL Tanboly et al. DL-based computer aided system
  52 OCT to detect DR;
  AUC 0.98.
- OCTA to automatically diagnose nonproliferative DR (NPDR)
  High accuracy and AUC.

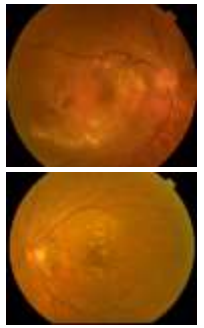


AI: AMD

Fundus images and SD-OCT using ML
AUC >80%;

Agreement for the models and specialists
~90%;

DL algorithms used to automatically detect exudates, macular edema, drusen, and CNV.



AI: Glaucoma

C / D diagnosis at early stage by AI;
ML methods detects preperimetric glaucoma VFs from healthy VFs;

Fundus images, VFs, and OCT used to construct DL-based glaucomatous diagnostic models;

DL detects preperimetric OAG;
AUC 0.8384

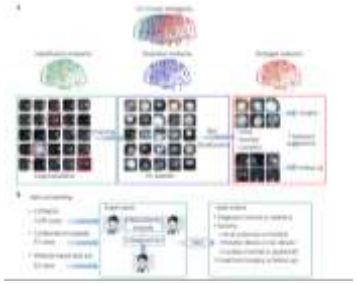
AI: Cataract

CNN-based computer-aided diagnosis framework to classify and grade pediatric cataract;

Software to realize clinical application for doctors and patients.

AI: Congenital Cataract Diagnosis

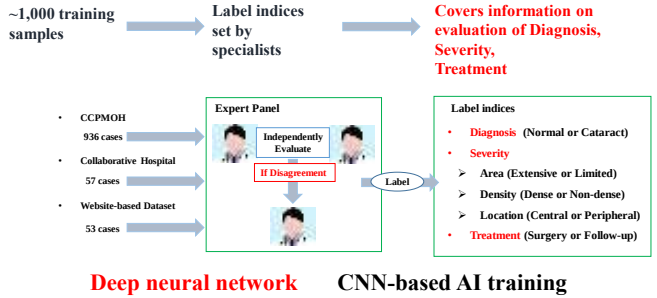
Infantile cataract



- **Based on 1,239 images, diagnosis accuracy > 93%.**

Lin HT(co-corr), Nature Biomedical Engineering 2017

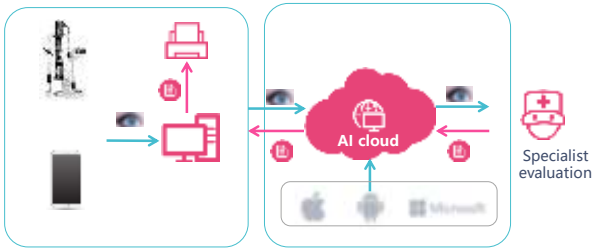
Largest Database of Congenital Cataract



Deep neural network **CNN-based AI training**

Lin HT(co-corr), Nature Biomedical Engineering 2017

AI: Serve Senile Cataract Patients



Lin HT，2018

AI: Serve Patients with Retinal Diseases

Lin HT，2018

In Summary

- This is AI era.
- Its huge potentials are being explored by all walks of life.
- Its application in the medical field, especially in ophthalmology, is of high significance.
- It is blooming.

Robotic Surgery in Ophthalmology

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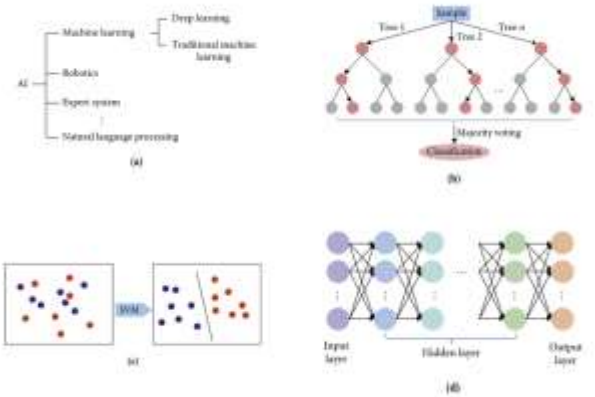


Potential Benefit of Robotic Surgery

increased precision and dexterity

elimination of tremor

task automation

shortening of learning curve

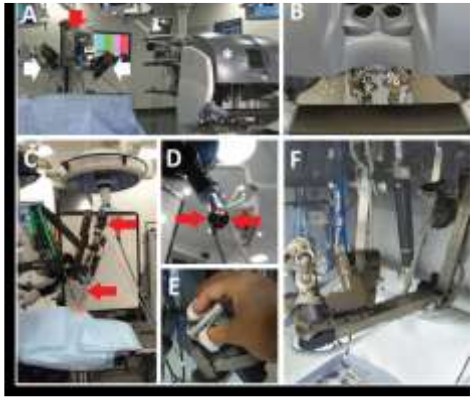
Cornea Transplantation

Da Vinci system (Intuitive Surgical, Sunnyvale, California)

3 freshly harvested porcine eyes
Frozen human cadaver head

Each step of the penetrating keratoplasty procedure can be achieved.

Bourges J-L, et al. Br J Ophthalmol 2009;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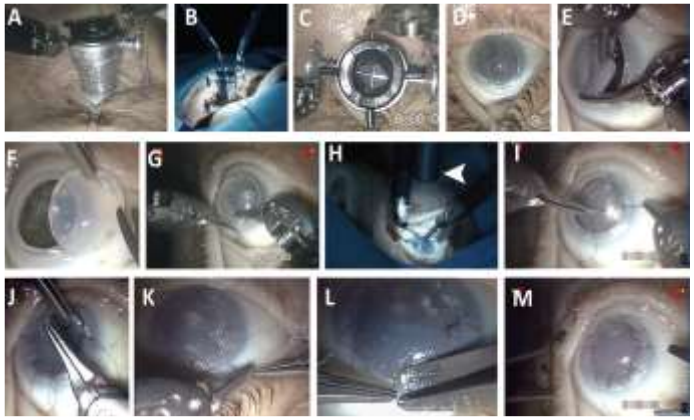
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Cataract Surgery

Using the Da Vinci Xi robotic surgical system.

This is a new step toward robotic anterior segment surgery.

Fully robotic computer-aided automated cataract surgery where surgeons assist robots.

Bourcier T, et al. J Cataract Refract Surg 2017

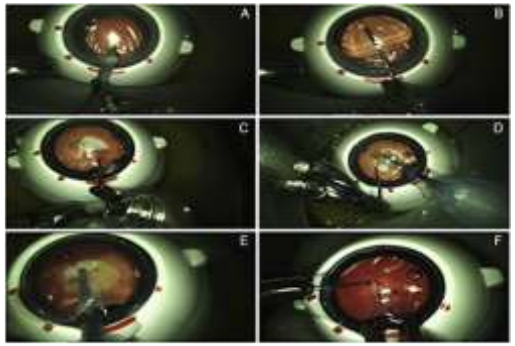


Table 1. Duration of certain surgical steps and the entire procedure.

Step	Mean (Min) ± SD	Range
Capsulorhexis	4.60 ± 1.63	3.25, 9.62
Nucleus removal	7.36 ± 1.58	4.40, 11.8.53
Total procedure	26.44 ± 5.15	19.65, 46.28

Retinal Surgery

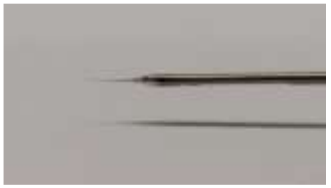
18 eyes from domestic pigs

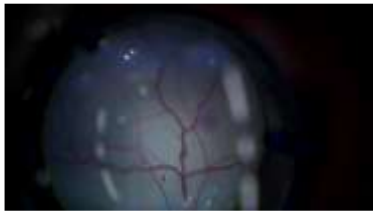
Cannulation was successful in 15 eyes.
Prolonged retinal vein cannulation is possible and safe.

The possibility of exposing the thrombus for a longer time to an active thrombolytic agent might increase the chance of successfully removing the clot in patients suffering from recent RVO.

Robot-assisted retinal vein cannulation with prolonged infusion time is technically feasible.

Willekens K, et al. Acta Ophthalmol. 2017





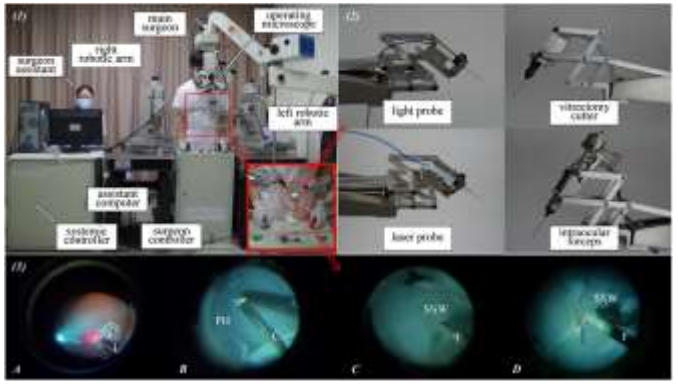
Retinal Surgery

9 rabbit eyes, 25 porcine eyes

Robot-assisted vitreoretinal operations
Maneuverability, accuracy and stability
Without any iatrogenic complication,
Such as retinal tear or retinal detachment

First time for development of the
robotic-aided system for vitreoretinal microsurgery in China.

Chen YQ, et al. Graefes Arch Clin Exp Ophthalmol (2017)



Retinal Surgery

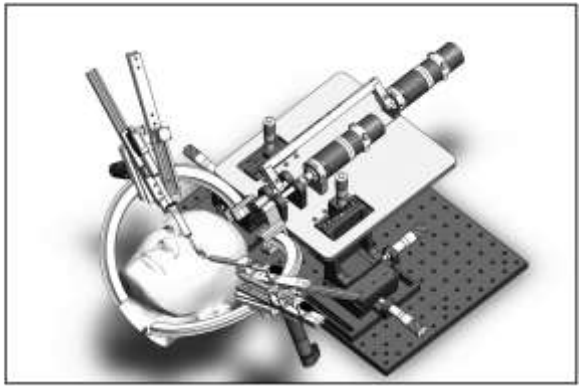
16 porcine eyes

Simulation of microcannulation of a temporal retinal vein was successfully achieved in 4 eyes.

IRISS(Intraocular Robotic Interventional and Surgical System) may be technically feasible in humans.

Capable of performing both anterior and posterior segment intraocular surgery.

Rahimy E, et al. Eye (2013).



Pterygium Surgery

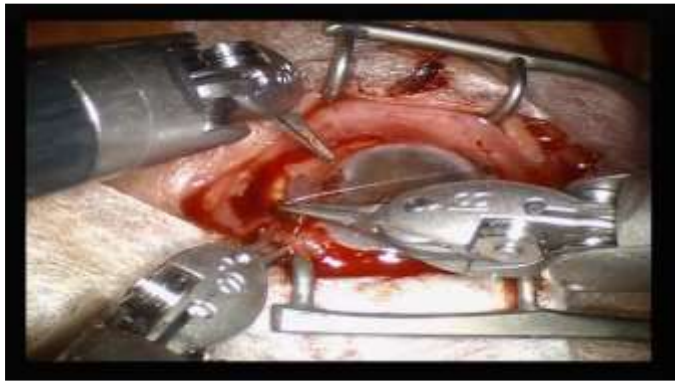
Using the Da Vinci Si HD robotic Surgical System

First human case of robot-assisted pterygium removal surgery (2015)

3 patients with robotically assisted amniotic membrane transplant surgery, All patients acquired a smooth corneal surface without infection or ulceration.

Many kinds of ocular surface surgery can be performed with the Da Vinci surgical system.

Bourcier T, et al. Cornea 2015.



In Summary

- Robotic surgery is now a clinical reality in ophthalmology.
- It improves the accuracy and stability of operations. It is void of hand tremors unavoidable in human operations, which makes intraocular surgeries safer and more stable.
- The largest impediment to the development of robotic surgery is large expenditure and patients' doubts.


THANKS