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.
AI: Milestones

1943 neural network mathematical model
1956 Dartmouth Conference
1980s symbolic machine learning e.g., decision tree (DT)
1980s 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

Deep learning

AI: Basic Concepts

- AI simulates the human thinking process.

Artificial Intelligence
Machine learning
Representation learning
Deep learning

Lin HT, 2018

Goodfellow I, 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…
AI: Application

1. Diagnosis
2. Treatment
3. Public health management
4. Regulation and control

“AI + medical care”
four spectrums of application

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.

He JX, Nature Medicine 2019
Lin HT, 2018
Multifaceted research and application

AI in ophthalmology

- CATARACT
- GLAUCOMA
- MYOPIA
- RETINAL DISEASES
- MORE...

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%.

Largest Database of Congenital Cataract

- 1,000 training samples
- Label indices set by specialists
- Covers information on evaluation of Diagnosis, Severity, Treatment

- CCPMOR
  - 57 cases
- Collaborative Hospital
  - 53 cases
- Website-based Dataset
  - 936 cases

Deep neural network CNN-based AI training

Label indices
- Diagnosis (Normal or Cataract)
- Severity
  - Area (Extensive or Limited)
  - Density (Dense or Non-dense)
  - Location (Central or Peripheral)
- Treatment (Surgery or Follow-up)

Lin HT (co-corr.), Nature Biomedical Engineering 2017
AI: Serve Senile Cataract Patients

AI cloud

Specialist evaluation

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.

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.

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

<table>
<thead>
<tr>
<th>Step</th>
<th>Mean (Min) ± SD</th>
<th>Range</th>
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<tbody>
<tr>
<td>Capsulorhexis</td>
<td>4.60 ± 1.63</td>
<td>3.25, 9.62</td>
</tr>
<tr>
<td>Nucleus removal</td>
<td>7.36 ± 1.58</td>
<td>4.40, 11.853</td>
</tr>
<tr>
<td>Total procedure</td>
<td>26.44 ± 5.15</td>
<td>19.65, 46.28</td>
</tr>
</tbody>
</table>
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.

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.

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.

Using the Da Vinci Si HD robotic Surgical System


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.

• 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.

In Summary