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Mini Review

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Robotic Surgery in Eye Care: A Comprehensive Review

Author (Escientific Publishers)*

Hindu Rao Hospital and NDMC Medical College Delhi

History

The term “robotics” originates from the Czech word “robota,” meaning “servant” or “worker.” Karel Čapek introduced it in his

It had four movable axes and a fast-rotating blade. [3,4] Computer Motion, started in 1989, became a top provider of surgical robots as their Automated Endoscope System for Optimal Positioning (AESOP) robotic arm got FDA approval in 1994, making it the first

telepresence surgical robot. AESOP evolved into the ZEUS system with three remotely controlled arms. In the early 1990s, Integrated Surgical Solutions and IBM developed ROBODOC®. It was used for hip replacements in 1992. [4] In 1999, Intuitive Surgical launched the da Vinci "Standard" surgical robot. Robotic surgery is now used

- Features include remote-control instrument manipulation and multi-arm configurations.

3. KU Leuven Robotic System

- Offers stabilization for high-precision tasks like retinal vein cannulation.
- Combines manual handling with robotic support for tasks requiring sustained precision.

4. Medineering Robotic Endoscope Guiding System

- Originally designed for endoscopic applications, this system stabilizes visualization during orbital surgeries.

We will cover the common systems like the Da Vinci Surgical System and the Precevus Surgical System as examples of current uses

through a combination of robotic arms, 3D visualization, and remote-controlled manipulation.

Components and Design

The Da Vinci Surgical System consists of three primary components:

1. Surgeon Console:

- The console allows the surgeon to operate the robotic arms from a remote station.

2. Enhanced Visualization:

- The stereoscopic imaging system allows better visualization of microscopic structures, such as corneal layers or orbital tis-

- Robotic arms provide steady control, reducing the risk of excessive tissue damage.
- Pterygium Surgery:
- The system facilitates meticulous removal of pterygium tissue, particularly in recurrent cases.

Advantages

1. Precision and Stability:

- The robotic arms filter out physiological tremors, providing unprecedented stability for delicate maneuvers.
- In a case series on pterygium surgeries, the system demonstrated high surgical success rates with minimal complications. However, the procedural time was significantly longer than traditional methods.
- Orbital fat decompression surgeries performed with the Da Vinci system reported reduced intraoperative bleeding and improved cosmetic outcomes. [6,7]
- Future Directions
- Enhancing the system's miniaturization and flexibility for ophthalmic applications is a priority.

- Integrating advanced imaging technologies, such as intraoperative OCT, can further refine surgical precision.
- Demonstrates the potential for advanced treatments like targeted drug delivery to occluded retinal veins.

- Subretinal Drug Delivery:
- Used for injecting tissue plasminogen activator (tPA) in cases of subfoveal hemorrhage.
- Offers consistent injection volumes and reduces the risk of over- or under-dosing.
- Epiretinal and Internal Limiting Membrane Peeling:
- Facilitates precise membrane removal for macular holes and ERM.
- Reduces the risk of iatrogenic retinal trauma.
- Retinal Vein Cannulation:

Preceyes-assisted surgeries for ERM peeling, outcomes were comparable in terms of surgical success and retinal thickness improvement. However, robotic procedures took significantly longer.

- Subretinal tPA delivery using the Preceyes system showed superior precision and consistency compared to manual injections, though not statistically significant in overall efficacy. [8,9]

Future Directions

- Expanding the system's capabilities to anterior segment surgeries, such as corneal transplantation, could broaden its utility.
- Incorporating AI-driven automation for specific tasks, like retinal vein cannulation, could further enhance its efficiency.
- Efforts to reduce costs and improve accessibility will be crucial

The Da Vinci Surgical System has been tested for corneal transplantation and amniotic membrane grafting. However, procedural durations were longer due to the setup and learning curve associated with the system.[11,12,13]

Cataract

Robot-assisted cataract surgery using phacoemulsification was

- Membrane peeling for conditions like macular holes and ERM.

Although outcomes in terms of retinal thickness and visual acuity were comparable to manual techniques, robots provided superior consistency and reduced surgeon strain during prolonged procedures.[8] Corneal and Ocular Surface Procedures

- Robotic systems can enable remote surgery, providing access to patients in underserved areas.

4. Innovative Training Tools

- Virtual reality simulators and robotic-assisted training platforms enhance skill acquisition and procedural confidence.

Limitations and Challenges

Procedural Duration

Robotic-assisted surgeries consistently require longer operation times compared to manual techniques. This is attributed to:

- Extensive setup and calibration.
- Future robotic systems should focus on miniaturization for compatibility with ophthalmic procedures.
- Autonomous features, such as automated suturing or membrane dissection, could reduce reliance on manual inputs.

The lack of patient-reported outcome measures (PROMs) and long-term follow-up studies further restricts our understanding of the broader impact of robotic systems on patient care.[6,8-11]

Current Evidence and Research Gaps

Technological Innovations

1. Miniaturization and Autonomy

wide.

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