30 Years of Robotic Surgery – Past, Present and Future

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Disclosures

- Proctor Da Vinci Surgical System - Intuitive
Objectives

• Review the inception & evolution of robotic surgery

• Discuss the driving forces for evolution
  » Telepresence
  » Technological advances
  » Minimally Invasive surgical movement

• Current day robotic surgery
  • Successes
  • Limitations and unmet surgical needs

• Future areas of advancement
The 80’s – Birth of Robotic Surgery

- Robotic Surgery - only 30 years old
  - Major strides have been made over the last decade
  - Coincided with developments in parallel technologies

- Other Technologies developed in the 80s
  - Personal computers, Graphical user interface
  - CDs, Walkmans
  - VCRs, Camcorders, Video game consoles
  - Cable television
  - Answering machines, Cell phones, Portable phones, Fax machines
The Beginning

Crude unguided articulating robotic arm
The early years – 1st Generation

- **Arthrobot - Vancouver, BC - 1983**
  - bone mountable hip arthroplasty surgery robot.
  - Small, didn't use CT data and showed fast registration.

- **PUMA 560 (Kwoh et al.)**
  - Goal - Increased Procedure Precision
  - 1985 – 1st case robotic case neurosurgical biopsy
    - non-laparoscopic
  - 1987 – 1st laparoscopic robotic surgery - cholecystectomy
    - Hybrid system with a flexible fiberoptic camera
  - 1988 – Davies et al. Imperial College London
    - 1st Transurethral Prostatectomy
    - Limitation – poor ultrasound imaging capabilities of prostate
Early Models

Machining the Femur
Inception of Telepresence

- **Telepresence Surgery**
  - National Air and Space Administration (NASA)
  - AMES Research Center
  - Provide remote access surgery

- **Partnership with Stanford Research Institute (SRI)**
  - Robotics & Virtual experts
  - Dexterous telemanipulation – hand surgery

- **Surgical Movement**
  - Next step – translation to minimally invasive surgery
Minimally Invasive Surgery

- Definition: requiring only a small incision or the insertion of an instrument into a body cavity; involving minimal damage of body tissue
- Small incisions – less pain
- Maximum efficiency – decreased operative time
- Direct access – overcome line of sight
- Minimal collateral damage – narrow dissection fields
- Decreased infection
- Decreased hospital stays
- Could we use robotics to enhance minimally invasive surgery
Evolution of Surgery

- SURGICAL MOVEMENT – Minimally Invasive Surgery

- GOLD STANDARD – Laparoscopic Surgery
  
  » Pros
  • Decreased pain
  • Better Cosmesis
  • Faster Recovery – Shorter Hospital Stay, less infection

  » Cons – difficult to do delicate surgery
  • Fulcrum effect
  • Two dimensional image
  • 4 degrees of motion (Hand/wrist – 7)
  • Transmission of Tremor
Key Parallel Advances in Technology

- **Endoscopes**
  - Smaller size
  - Improved optical resolution – 3D (paired scopes)
  - Angled scopes

- **Software**
  - Enhanced graphics
  - Improved Computer Processing

- **Improved hardware**
Military Influence

- **US Army inspired by work at SRI funds research**
  - Goal - decreasing wartime mortality by "bringing the surgeon to the wounded soldier-through telepresence."
  - Mobile Advanced Surgical Hospital (MASH)
  - Currently only studied in an animal model

- **Commercial Venture formed out of seed money from Army**
  - Computer Motion
  - Integrated Surgical Systems (Later - Intuitive Surgical)
Next Phase

Increased precision, multiple arms & guidance
Next Generation

- **1988 – PROBOT – Imperial College London**
  - Prostate Surgery
  - Image guided, model based, simulation
  - Online video monitoring.
  - Demonstrated success of soft tissue robotic surgery

- **1990 – AESOP system by Computer Motion**
  - 1st system approved by FDA for endoscopic surgery -1994
  - Coupled with HERMES – voice command

  - 1st Robotic Total Hip Arthroplasty (THA)
  - Only FDA approved device for orthopedic surgery
  - Pre-operatively plan surgery in a 3-D virtual space
PROBOT

AESOP

ROBODOC
AESOP / HERMES
Integration Phase

Unite instrumentation, camera & endoscope
Next Generation

• 1998 – Zeus
  » Surgery Control Center
  » 3 Table mounted arms for endoscopic surgery
    • right and left robotic arms replicate the arms of the surgeon,
    • third arm AESOP voice-controlled robotic endoscope
  » 1st fully endorobotic surgery system
  » 1st total endoscopic coronary artery bypass graft

• 2001 – Socrates
  » Robotic Telecollaborative System
  » First transatlantic telesurgery
Robotic Revolution

• “Integrated System” and “Endo Wrist” technology
  » Intuitive Surgical revolutionized the industry

• 2000 – Da Vinci Surgical System
  » Revamped SRI telepresence surgery system
  » 1st fully integrated robotic surgical system approved by FDA
  » Integration of endoscopes, instruments & camera

  » 3 Components
    • Surgeon Console, patient-side cart and high definition video system
Da Vinci Surgical
Virtual Da Vinci Set up
Robotic Thoracoscopic setup
Robotic Hysterectomy
Advances

1. Visualization - 3D High resolution monitors
2. Reduced Instrument size (1cm diameter)
   » Decreased leverage on tissue – decreased infection
3. “Endo Wrist” Technology
   » 7 degrees freedom of motion
4. Digital zoom: 12 - 30x
5. Filters hand tremor
6. Ergonomic surgeon's console
Visualization

- High Resolution 3D Camera
- Improved visualization for surgeon and assistant
Patient-side cart and instruments
Greatest Advance – “Endo Wrist”
Current FDA Approved Robotic Surgery

- **Urologic Surgery**
  - Prostatectomy, Renal Surgery
- **General laparoscopic surgery**
  - Cholecystectomy, Colectomy, Low anterior resection
- **General non-cardiac thoracoscopic surgery**
- **Thoracoscopically-assisted cardiotomy**

- **Neurosurgical Procedures**
- **Gynecologic**
- **Throat/oropharynx and voice box**
- **Thyroidectomy and Parathyroidectomy**
Current Day Look at Robotic Surgery

Benefits
- Decreased Hospital stay
- Decreased Infection
- Decreased Pain
- Improved Cosmesis
- More rapid convalescence
- Reduced Operative Time
- Enhanced 3D Visuals
- Tremor Reduction

Disadvantages
- No Haptec Feedback
- Cumbersome size
- Accessibility
- Specialized Training
- Bulky
- 1 million dollar cumbersome fork lift
Surgical Advances Require Caution

• In the end, robotic surgery is a surgical tool and not an autonomous system, and as such, requires a skilled technician
  » 2002 death in Tampa during attempted kidney surgery

• Intuitive Surgical and Hospital Systems have since tightly controlled certification and maintenance of certification

• OB/GYN multicenter study 2009 – reported on learning curves and assessment of skills acquisition
Future of Robotic Surgery
"I'm closing up now. Can you go to the theatre and wake the patient up in ten minutes?"

Future remote robotic surgery.
Future of Robotic Surgery

• Compact/Mobile Units

• Tactile Feedback

• New Locations
  • Sinus/Skull Base
  • Tissue Harvesting
  • Neck Dissections

• Training Simulators
Future of Robotic Surgery

• The future is in size reduction – Compact units
  » Da Vinci – single port system
  » Competitive companies
    • Medrobotics – snake system
      • Surgeon back in front of patient - Loss of Telepresence

• Driven by market forces
  » Many surgical specialties are saturated
    • General Surgery / OB/GYN / Urology
  » Fields with room for expansion drawing attention
    • Otolaryngology / Neurosurgery / Cardiac

• Software and Hardware improvements
  » Greatest need and challenge – Tactile Feedback
Single Port System
Medrobotic Snake Technology
Thank you