Endoscopic Imaging
History of Endoscopy

• 400 BC: Hippocrates observes the anus using a speculum

• The first real endoscope that was developed was made by Phillip Bozzini in 1805 to examine the urethra, the bladder and vagina.
History of Endoscopy

• 1867 Desormeaux used an open tube to examine the genitourinary tract

• Adolf Kussmaul in 1868 used a straight rigid metal tube over a flexible obturator to perform the first gastroscopy.
History of Endoscopy

• Building on the work of others, Rudolph Schindler constructed the first practical gastroscope in 1932.
History of Endoscopy

• In 1957 Basil Hirschowitz developed his prototype fiberscope.
Endoscopy

- **Endoscopy**
  - A minimally invasive diagnostic medical procedure
  - The examination of internal body cavities using a specialized medical instrument called an endoscope.
  - Gives visual evidence of the problem (e.g. cancer, ulceration or inflammation)
  - Can be used to collect a sample of tissue or remove problematic tissue
  - Used to take photograph of the hollow internal organs
  - Performed under
    - Conscious sedation
    - Total Anesthesia
Endoscopy

- Physicians use endoscopy to diagnose, monitor, and surgically treat various medical problems.
- A surgeon introduces the endoscope into the body either through a body opening, such as the mouth or the anus, or through a small incision in the skin.
Endoscopy

• Risks of Endoscopy
  • Sedation
  • Damage to dentition
  • Aspiration
  • Perforation or hemorrhage after endoscopic dilatation
  • Perforation, infection, and aspiration after percutaneous endoscopic gastrostomy insertion
  • Perforation or hemorrhage after flexible sigmoidoscopy / colonoscopy with polypectomy
  • Pancreatitis, cholangitis, perforation or bleeding after ERCP
Endoscopy

• The endoscope
  • A slender, flexible or rigid tube
  • Equipped with lenses and a light source.
  • CCDs are used to feed a video to the monitor
  • Through the accessory channels of the endoscope water and air is supplied to wash and dry the surgical site.
  • Also has a channel through which surgeons can manipulate tiny instruments, such as forceps, surgical scissors, and suction devices.
    • A variety of instruments can be fitted to the endoscope for different purposes.
The Flexible Endoscope

- **Fiberoptic instruments**
  - Based on optical viewing bundles
  - 2–3·mm in diameter and contains 20,000–40,000 fine glass fibers, each close to 10·μm in diameter
  - Each individual glass fiber is coated with glass of a lower optical density to prevent leakage of light from within the fiber
    - The space between the fibers causes a dark ‘packing fraction’ → fine mesh frequently apparent in the fiberoptic image
- **Advantages**
  - Fiberoptic bundles are extremely flexible, and an image can be transmitted even when tied in a knot.
  - Small diameter
  - Direct view (monitor not necessary)
- **Limitations**
  - The image quality of a fiberoptic bundle, though excellent, can never equal that of a rigid lens system or a video-endoscope
    - Limited number of “pixels”
The Flexible Endoscope

- **Video-endoscopes**
  - Mechanically similar to fiber-endoscopes,
  - A CCD chip and supporting electronics mounted at the tip
  - To and fro wiring replacing the optical bundle
  - Further electronics and switches occupying the site of the ocular lens on the upper part of the control head.

- **Advantages**
  - Improved image quality
  - View through a monitor
    - Removing any need to hold the instrument close to the endoscopist's eye has hygienic advantages (avoidance of splash contamination)
    - Improved instrument design and handling techniques

- **Limitations**
  - No direct viewing
  - Can not be made < 5 mm
The Flexible Endoscope

- Parts of the endoscope
  - Connector Section
  - Control Section
  - Insertion Section
The Flexible Endoscope

• Control section
  • Held in the operator's left hand
  • Has two stacked angulation control knobs
    • direct up/down and left/right deflection of the endoscope tip.
  • Has air/water and suction valves
  • Has remote switches to modify or capture the video image.
  • Has entry port to the instrument channel(s) is (are)
  • Fiber optic instruments have an eyepiece located at the top of the control section for direct image viewing.
The Flexible Endoscope

• **Insertion Section**
  - The portion of the endoscope that is inserted into the patient
  - The length, diameter, and degree of stiffness of the insertion tube vary among models.
  - The insertion tube contains
    - One or two instrument channel(s)
    - One or two light guide bundles (incoherent fiber optic)
    - An air channel, a water channel
    - Either an image guide bundle or a CCD chip with wire
    - Connections, and angulation wires.
The Flexible Endoscope

• **Endoscopic Accessories**
  - Biopsy forceps
  - Graspers
  - Baskets
  - Injectors
  - Dilators
  - Knives
  - HF endo-therapy accessories
  - . . . too many types of accessories.
The Flexible Endoscope

• Connector section
  • A light guide,
  • An air-pipe
  • Electrical contacts compatible with the processor/light source.
  • Side connectors for a water container, suction, CO2, insertion tube venting
  • An S (safety)-cord connecting mount, which grounds the endoscope, reducing the electrical shock hazard to the operator.
The Rigid Endoscope

• A lens system transmitting the image to the viewer
  • Typically a relay lens system
  • Rod lenses provide for better image quality and light efficiency

• Different diameters and viewing angles
Flexible Endoscopy

- Depending on the body part, each type of endoscopy has its own special term, such as:
  - laryngoscopy (vocal cords)
  - bronchoscopy (lungs)
  - colonoscopy (colon)
  - Esophagoscopy (esophagus)
  - gastroscopy (Stomach)
  - Hysteroscopy (uterus)
  - etc
Bronchoscopy

A bronchoscope is used to view the airways and check for any abnormalities.
Esophagoscopy
Surgical or Rigid Endoscopy

- Laparoscopy
- Arthroscopy
- Endo-Urology
- Gynecology
- E.N.T-applications
- Proctoscopy
- And many other surgical applications (gastrectomy, neurosurgery, ...etc).
Arthroscopy can be used to repair a tear of the lateral meniscus of the knee. The arthroscope allows the surgeon to see and repair the tear inside the knee joint.
Urethrocytoscopcy
Laparoscopic Surgery

• Laparoscopy is minimal access surgery
  • Accomplish surgical therapeutic goals with minimal somatic and psychological trauma.

• A rigid endoscope is introduced through a sleeve into the peritoneal cavity.

• The abdomen inflated with carbon dioxide

• Further sleeves or ports are inserted to enable instrument access and their use for dissection.
Laparoscopic Surgery

• Examples
  • Laparoscopic cholecystectomy has become the standard of management of uncomplicated gallstone disease.

• With improved instruments and more experience it is likely that other advanced procedures, previously regarded as controversial, will also become fully accepted
  • E.g. laparoscopic colectomies for malignancy,
Benefits of Laparoscopic Surgery

• Smaller incision
• Improved cosmetics
• Reduced possibility of infection
• Reduced post op pain
• Reduced blood loss
• Return home quicker
• Return to work quicker!
Limitations of Laparoscopic Surgery

• Reliance on remote vision and operating
• Loss of tactile feedback
• Dependence on hand–eye coordination
• Difficulty with haemostasis
• Extraction of large specimens
• Reliance on new techniques
Da Vinci Surgical System

• Not really a robot!
  • Master-slave system – the surgeon directly initiates all the movements of the robotic instruments in real time

• The prototype was developed by Stanford Research Institute in 1980s, funded by US Army, to perform battlefield surgery remotely by a surgeon in the safe rear

• FDA approved in human operations in 2000
Da Vinci Surgical System

**Imaging**
- Double lenses laparoscope
- 3D, high definition, binocular view
- 10-15X magnification

**Dexterity**
- Endowrist instruments have 6 degrees of freedom
- Filtering off hand tremor
- Scaling down movements 1-5X
Da Vinci Surgical System

• **DaVinci Offers**
  • Improved dexterity
  • Better control
  • Better precision
  • Improved ergonomics – decreased fatigue and strain

• **Advantages**
  • Reduced hospital stay
  • More high risk patients can be treated
  • Less staff required

• **Limitations**
  • Cost of equipment $1 million
  • Steep learning curve for surgeons
  • Doctors training on device felt hindered by lack of ability to feel the tissue they’re working on
  • Surgery with this system takes 40-50 minutes longer than standard procedure
Limitation of Fiberoptic Endoscopy

• Double Balloon (Push-and-Pull) Endoscopy
  • Fiberoptic method to visual the entire small bowel
  • Two balloons are inflated and deflated in sequence to move the endoscope through the bowel

• Advantages
  • Complete visualization of the entire small bowel to the terminal ileum
  • Can do therapeutic interventions
  • Allows for sampling/biopsying of small bowel mucosa
  • Allows for resection of polyps
  • Placement of stents or dilation of small bowel strictures

• Disadvantages
  • Technically difficult procedure
  • Very time consuming (Procedure can take > 3 hours)
  • Patient may need to be admitted to the hospital
  • Higher risk of small bowel perforation
  • Case reports of pancreatitis and intestinal necrosis
  • Reported incidents of aspiration and pneumonia
Capsule Endoscopy

- Capsule endoscopy was first used in humans in 1999.
- First publication on capsule endoscopy was published in Nature in 2000:
- Two major companies have capsule endoscopy products.
  - Given Imaging has the PillCam
  - Olympus has the EndoCapsule
- The latest pill camera
  - Sized at 26x11 mm
  - Capable of transmitting 50,000 color images during its traversal through the digestive system of patient.
Inside a Capsule Camera

1. Optical Dome
   - This shape results in easy orientation of the capsule axis along the central axis of small intestine and so helps propel the capsule forward easily.
   - The Optical Dome contains the Light Receiving Window.

2. Lens Holder
   - The Lens Holder is that part of the capsule which accommodates the lens. The lens is tightly fixed to the holder so that it doesn’t get dislocated anytime.

3. Lens
   - The Lens is an integral component of the capsule.
   - It is arranged behind the Light Receiving Window.
Inside a Capsule Camera

4. Illuminating LED’s
- Around the Lens & CMOS Image Sensor, four LED’s (Light Emitting Diodes) are present. These plural lighting devices are arranged in donut shape.

5. CMOS Image Sensor
- CMOS (Complementary Metal Oxide Semiconductor) Image Sensor is the most important part of the capsule. It is highly sensitive and produces very high quality images.
- It has 140° field of view and can detect objects as small as possible.
Inside a Capsule Camera

6. Battery
- Two batteries
- Silver Oxide primary batteries are used (Zinc/Alkaline Electrolyte/Silver Oxide). Such a battery has a even discharge voltage, disposable and doesn’t cause harm to the body.

7. ASIC Transmitter
- The ASIC (Application Specific Integrated Circuit) Transmitter is arranged behind the Batteries as shown. Two Transmitting Electrodes are connected to the outlines of the ASIC Transmitter.
- These electrodes are electrically isolated from each other.

8. Antennae
- As shown, the Antennae is arranged at the end of the capsule. It is enclosed in a dome shaped chamber.
How does Capsule Endoscopy Work?

- Capsule is swallowed by the patient like a conventional pill.
- It takes images as it is propelled forward by peristalsis.
- A wireless recorder, worn on a belt, receives the images transmitted by the pill.
- A computer workstation processes the data and produces a continuous still images.
Advantages of Capsule Endoscopy

- **Uses**
  - Crohn's Disease.
  - Malabsorption Disorders.
  - Tumors of the small intestine & Vascular Disorders.
  - Ulcerative Colitis
  - Medication Related To Small Bowel Injury.

- **Advantages**
  - Painless, no side affects or complications.
  - Miniature size, so can move easily through the digestive system.
  - Accurate, precise and effective.
  - Images taken are of high quality are sent almost instantaneously to the data recorder for storage.
  - Made of bio-compatible material, doesn’t cause any harm to the body.
Limitations of Capsule Endoscopy

• Anatomical Limitations
  • Slow Gastric/Intestinal Motility.
  • Narrowing or obstruction
  • Potentially obstructed views
  • Morbidly obese patients

• Technical limitations
  • Poorer quality of images as compared to Fiberoptic scopes
  • The position of the capsule can not be accurately controlled
  • Interpretation of results are very observer dependent
  • Findings may be of unknown significance or relevance.
  • Inability to biopsy or treat any pathology seen.

• Overcomes
  • Smaller devices
  • Bi-directional telemetry camera?