Single access robots for surgery

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Outline

- The evolution of robotic surgery: state of the art
- From external robots to endoluminal robots
- Concluding remarks
The Evolution of Surgery

Traditional Techniques

Laparoscopic Surgery

Robotic Surgery
History of laparoscopy and robotic surgery

- 1985: Erich Mühe
  1st laparoscopic cholecystectomy
- 1985: Kwoh, Young et al.
  1st robot (Puma 560) in neurosurgery
- 1987: 1st video-laparoscopic cholecystectomy
- 1989: Benabid, Lavallée et al.
  1st patient in neurosurgery (Neuromate)
- 1991: Davies et al.
  1st patient for TURP (Puma 560)
- 1992: Integrated surgical systems
  1st hip surgery with ROBODOC
- 1994: Computer Motion Inc.
  1st FDA clearance: AESOP laparoscope holder
- 1998: Intuitive Surgical, Inc.
  1st st totally endoscopy CABG using the daVinci ROBOTIC SYSTEM
A success story in surgical robotics: the “daVinci” system

The main reasons for success:

- VERY HIGH SURGICAL PRECISION
- Minimal invasiveness
- Intuitive control
The DaVinci System

- External arms with Remote Center of Motion: the movement is mechanically constrained around a pivot point;
- 3 DOFs moved by the external arms (2 orientations and 1 translation considering the roll as internal DOF);
- 3 DOFs internal, actuated by a cable-driven system:
  - 1 Roll
  - 1 Pitch
  - 2 coaxial yaw (used also for open-close of the gripper)
da Vinci® Prostatectomy Procedure Growth
* Figures based on Company estimates.
Installs by Country and Region

- Installed sites: >900 academic and community hospitals
- Installed systems: >1500
- Employees: >1400

- USA: 968
- Europe: 229
- Asia: 61
- Middle East: 19
- Latin America: 11
- Canada: 9
- Brazil: 4
- Venezuela: 3
- Argentina: 3
- Mexico: 1
- Saudi Arabia: 8
- Turkey: 5
- Qatar: 3
- Israel: 2
- Pakistan: 1
- Austria: 2
- Finland: 2
- Ireland: 2
- Bulgaria: 1
- South Korea: 23
- China/Hong Kong: 13
- Singapore/Malaysia/Thailand: 8
- Japan: 7
- India: 5
- Taiwan: 5
Recent trends: Intuitive’s heuristic expression of patient value

New instrumentation

Patient Value = \( \frac{\text{Efficacy}}{\text{Invasiveness}^2} \)

Limiting incisions

SPL robotic system by Intuitive Surgical

- Integrated Energy Instruments
  - Monopolar Energy
  - Bipolar Energy
  - Advanced Bipolar
  - Harmonic
  - Advanced Graspers
  - Laser

Tissue Spectroscopy

- Using da Vinci Si system with 8.5mm 3D HD endoscope.
- Curved Instrument Cannulae.
- 5mm, non-wristed, semi-rigid instruments.
How to improve current robots for surgery

- Training of users (importance of simulators)

- Tuning the robot features based on the environment where it has to operate (tissue biomechanics)

- Limiting the invasiveness and overall robot size still preserving (and augmenting!) functionalities
Why only LARGE robots?
Could we obtain the same advantages (precision, early diagnosis and therapy, accuracy) with smaller, friendly, scarless robots?
The CyberKnife (towards no incisions...)

Image-Guidance System + Multi-Jointed Robotic Arm

- Robotic targeting precision <0.2mm
- Overall precision of treatment
  - <0.95mm for cranial and spinal lesions
  - 1.5mm for moving targets with respiratory tracking

6MV linear accelerator for X-ray tumor ablation

6 d.o.f.s
KUKA KR 210-2
Endoluminal Therapy and Surgery

Endoluminal procedures consist of bringing a set of advanced therapeutic and surgical tools to the area of interest by navigating in the *lumen* of the human body, such as the gastrointestinal tract, the urinary apparatus, the circulatory system, etc.

**Instrumentation for endoscopic surgery and NOTES (Natural Orifices Transgastric Endoscopic Surgery):**

- PillCam for GI tract endoscopy
- Clip for endoscopic surgery

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*Endoluminal Therapy and Surgery*
The vision: reconfigurable robots for the exploration and operation of the human body
The vision (long term)

1: Swallowing the capsules
2: Passing through the esophagus
3: Assembly in the stomach
4: Diagnosis/Intervention in the stomach
5: Reconfiguration for passing the pyloric sphincter
Example of a multi-module robot integrating a grasping tool

12 Modules
- Camera X1
- Forceps X1
- Storage X1
- Central X1
- Structural X8

The ARAKNES Project has received funding from the European Community’s Seventh Framework Programme (FP7/2007-2013) under grant agreement num. 224565.
from the “vision” to the patient

Additional Displays

Autostereoscopic Display

User Console

Bimanual Controller

Patient Support System

ARAKNES robotic unit for transabdominal access

ARAKNES robotic unit for esophageal access
ARAKNES Hybrid Configuration

Umbilical Access Port

ARAKNES robotic unit for transabdominal access

Bimanual ARAKNES Robot for Abdominal Procedures

ARAKNES robotic unit for intra-gastric assistance

ARAKNES robotic unit for esophageal access

Araknes deployment Araknes sensor
General overview of the ARAKNES Platform and high-level control architecture (by Philippe Poignet, LIRMM UMR 5506 CNRS UM2)
The ARAKNES *mini*-Robotic Arm

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Elbow (1 dof)</td>
<td>Ext. motors</td>
</tr>
<tr>
<td>Shoulder (2 dof)</td>
<td>Int. motors</td>
</tr>
<tr>
<td>Wrist (3 dof)</td>
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</table>

- **Robot maximum diameter:** 18-20 mm
- **Tip force needed:** 5 N
- **Joint rotational speed needed:** 360-540 deg/s
- **Total length:** 130 mm

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Bi-manual manipulator control
(in collaboration with STMicroelectronics and CNRS-LIRMM)
From mini to micro: the top-down approach

Example of miniature platform to be used in Single Port Laparoscopy and NOTES surgery

1 robot + Video ICRA2011 = 2 robots
Robotic Surgery: Lessons Learned

Problems to be solved for full acceptance of robots in surgery:

- Real application domains and procedures that benefit: finding the unmet clinical needs among the 6301 currently performed surgical procedures
- Time of intervention
- Time and complexity for set up
- Cost/benefit clearly proved