A.R.A.K.N.E.S.
Array of Robots Augmenting the KiNematics of Endoluminal Surgery

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Scuola Superiore Sant'Anna
di Studi Universitari e di Perfezionamento

**Scuola Superiore Sant'Anna, Pisa (Italy)**

# Robot positioning and fixing: chemical anchoring strategy


**Selene Tognarelli**


**Summer School in Surgical Robotics**

**Montpellier, September 9-16 2009**


The ARAKNES (Array of Robots Augmenting the KiNematics of Endoluminal Surgery) Project has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement num. 224565.

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# Miniature in-vivo robots

**Laparoscopy has revolutionized the methods used by surgeon in many general surgery operations -> new frontier of even less invasive approach**

- *limiting the number of abdominal incisions*
  - single port laparoscopy (SPL)
  - laparoendoscopic single-site surgery (LESS)
- *eliminating abdominal incision*
  - natural orifice translumenal surgery (NOTES)

***By reducing the number of trocars**, and thus introducing the current endoscopes and instruments together at a single site, **several technical restrictions**, such as limited triangulation, limited visual axis and field, and internal and external collision of instruments, were imposed.*

***Miniaturized advanced system exploiting magnetic fixation and positioning***

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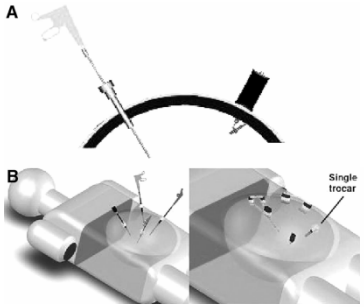
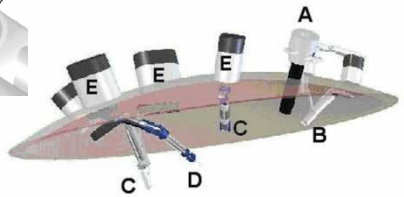
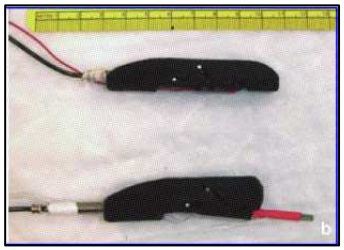
# For example....

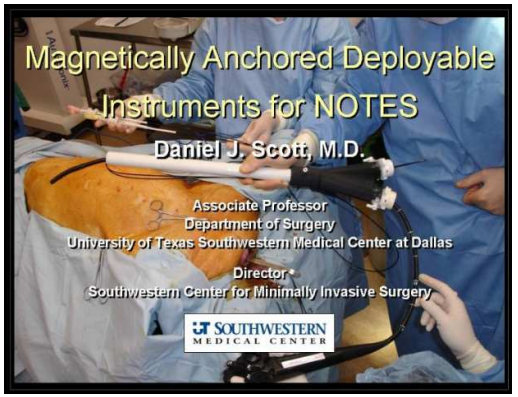
- Trans-abdominal magnetic anchoring and guidance systems (MAGS)



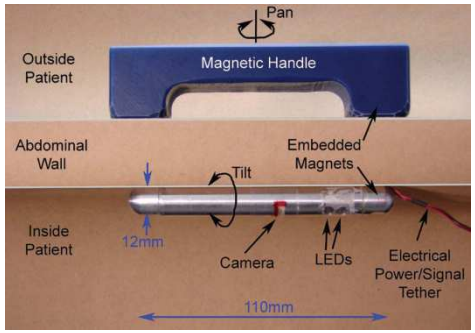



*Scott et al.*

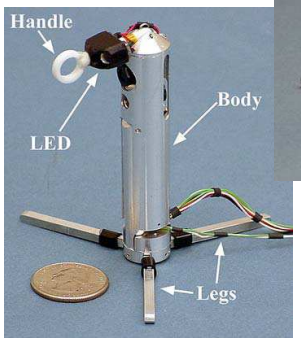


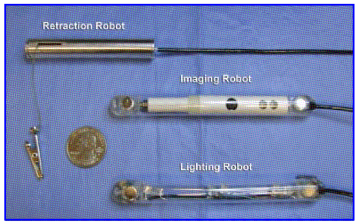

http://www.eats.fr/lectures/viewer.php?doi=lt01enscott001&start=1&redim=1

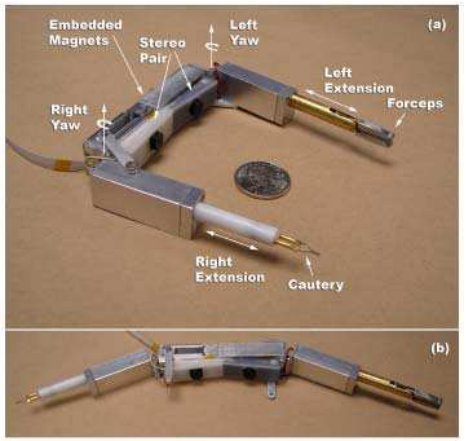
- Miniaturized imaging/camera robot




***Nebraska group***

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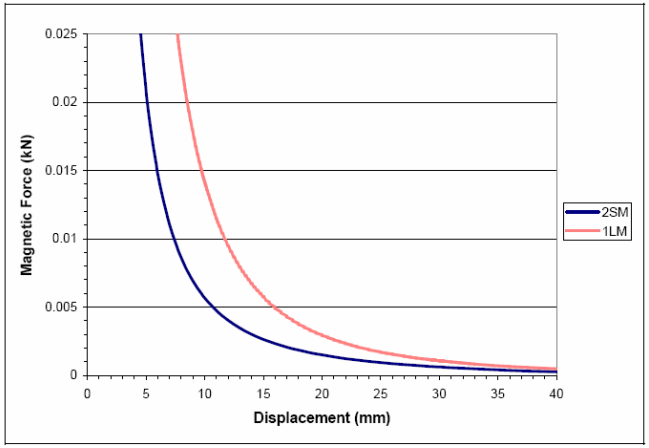
# Magnetic limitations

***However, magnetic technology must address current limitations:***

✓ The coupling strength of magnets decreases exponentially with respect to the distance between the source magnet and its target
✓ The maximum number of external magnets in the operating area is theoretically limited to avoid magnet-magnet interference and operator-magnet collisions
✓ Like MRI, magnetic technology would be absolutely contraindicated in patients with peacemakers; and it would be relatively harmful for patients with known metal foreign bodies or recently implanted metal orthopedic prostheses.

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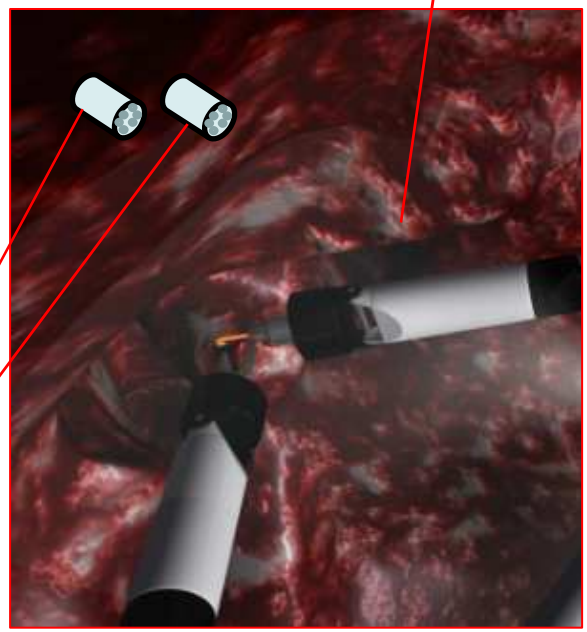
# Chemical anchoring strategy

- **How developing good adhesion between the assistive surgical instrumentations and abdominal wall?**

***Chemical strategy*** ***Magnetic strategy***

***Muco-adhesive films***

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# Chemical anchoring strategy

- Muco-adhesive films ⇨ chemical anchoring strategy

**Mucoadhesive polymers**, like Carbopol® (**CP971**), are natural or synthetic hydrophilic macromolecules, which contain numerous hydrogel bond-forming groups. These polymers hydrate and swell in contact with an **aqueous medium**, and as a result, adhere to the mucosal surface. **Therefore, mucoadhesive system would allow stable anchoring of surgical devices during surgical interventions**

| Ingredients | Sample1 (S1) | Sample2 (S2) | Sample3 (S3) | Sample4 (S4) |
|---|---|---|---|---|
| Carbopol | 0,3% | 0,3% | 1% | 1% |
| PPG | 3% | | 3% | |
| PVP | 10% | 10% | 10% | 10% |
| PEG | | 2% | | 2% |
| PF127 | 1% | 1% | 1% | 1% |

**In order to select the best mucoadhesive formulations, *ex-vivo* measurements of adhesion forces and *in-vivo* adhesion tests were performed**

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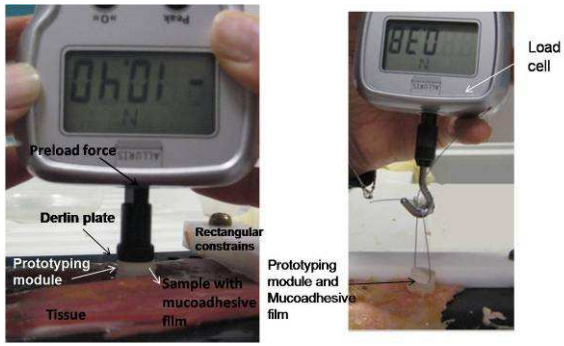
# Chemical anchoring strategy

- *Ex-vivo* test: force detachment.
  - force required to detach the polymeric films from gastric mucosal tissue ($F_D$);
  - pre-load force (5N - 10 N)
  - effect of varying mucoadhesive-tissue contact time (3-5 min);

**Results**

| Preload condition / Formulation | Preload Force: 5N | | Preload Force: 10N | |
|---|---|---|---|---|
| | 3 minutes | 5 minutes | 3 minutes | 5 minutes |
| S1 | $F_D$=1,41 N±0,11 | $F_D$=1,62 N±0,28 | $F_D$=1,68 N±0,11 | $F_D$=2,05 N±0,15 |
| S2 | $F_D$=1,33 N±0,05 | $F_D$=1,53 N± ,16 | $F_D$=1,54 N±0,35 | $F_D$=1,73 N±0,07 |
| S3 | $F_D$=2,59 N±0,09 | $F_D$=2,60 N±0,10 | $F_D$=2,58 N±0,10 | $F_D$=2,87 N±0,09 |
| S4 | $F_D$=1,64 N±0,11 | $F_D$=1,69 N±0,08 | $F_D$=1,60 N±0,10 | $F_D$=1,78 N±0,11 |




- *Animal experiments:* to assess the anchoring mechanisms of modules in real operative conditions on the stomach wall

*S3 formulation (1% Carbopol, 3% PPG)*

  - the mucoadhesive films were attached to the same cylindrical passive modules (12 mm in diameter) used during the ex-vivo test;
  - the mucoadhesive films were attached to a miniaturized vision system.

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# Chemical anchoring strategy

- *Animal experiments*

**Results**

- stable anchoring of surgical assistive instruments to the stomach wall;
- these films possess the benefits of being biocompatible, non-toxic and safe.

**However, the mucoadhesion force couldn't anchor and sustain a robotic module equipped with several degrees of freedom during complex surgical tasks.**

**Mucoadhesive films** could be used for anchoring auxiliary devices, such as **cameras, biosensors, and assistive tools** directly onto the abdominal tissues.

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