Surgery in the year 2025

H. Feussner
## Agenda

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<td></td>
<td>Current state of interventional medicine</td>
<td>Future developments: Individualized procedures</td>
<td>Multimodal treatment</td>
<td>New therapeutic paradigms</td>
<td>Implants</td>
<td>New accesses</td>
<td>Challenges for science, research and development</td>
<td>visualization</td>
<td>navigation</td>
<td>robots / mechatronic assistant devices</td>
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The past century - three eras of evolution in surgery

Current state

Future develop:
- Indiv. proced.
- Multim. treatm.
- New paradigms
- Implants
- Access
- Visualisation
- Navigation
- Robots
- Cognitive syst.
- Interdisciplinary cooperation

Challenges:
- Navigation
- Visualisation
- Robots
- Cognitive syst.

1900
Mastering of the anatomy

1950
Reconstructive Surgery, Transplantation

2000
Reducing the trauma of the access
Towards less invasive therapy

Invasivity

open surgery

laparoscopic surgery

single port surgery

hybrid procedures

NOTES

transvascular interventions

percutaneous procedures

Surgery

Other disciplines
Just memories of glorious days?

How to make surgery even better and more competitive?
Individualized procedures: The balance between oncological requirements and trauma reduction

T1sm gastric cancer

Local excision?

Total gastrectomy/lymphadenectomy?
Individualized surgery

Less pain
Lower complication rate
Faster reconvalescence
„Oncological correctness“
Improved cosmesis
Reduced incidence of longterm Complications (adhesion, incisional hernia)

Cost reduction
Better quality of life
How to identify the critical 20% of cases?

Lymphnode

drainage:

Sentinel lymph node evaluation
Clinical evaluation

Dye

Nanotubes

Wilhelm et al COLONVIEW 2012
Why is it not yet clinical standard?

• Reliability is still too low!

  - specific markers?

  - precise localization?

  - uncertain pathophysiological behaviour

  - intraoperative assessment

> will 10 years be enough to close the gap?
Multimodal treatment: Surgery as a part of a comprehensive therapeutic strategy

Current state

Future develop: Indiv. proced.

Future develop: Multim. treatm.

Future develop: New paradigms

Future develop: Implants

Future develop: Access

Challenges: Visualisation

Challenges: Navigation

Challenges: Robots

Challenges: Cognitive syst.

Interdisciplinary cooperation

Center of excellence

Neoadjuvant Radiotherapy
Intraoperative Radiotherapy
Adjuvant Therapy

Pathology

Surgical staging incl. surg. laparoscopy

Imaging procedures

Neoadjuvant Chemotherapy
Intraoperative Chemotherapy
Palliative Therapy

Tumor-board

Surgery

Follow-up Therapy
Multimodal treatment: Improved prognosis

Kapiteijn et al. *NEJM* 2001

**Präop. RTX + TME vs. TME**

Local recurrence rate in colorectal cancer

Ychou et al. *J Clin Oncol* 2011

2-3×CF **OP** 3-4×CF

Longterm survival after gastric cancer
The happy few: Multimodal treatment does only work in a subgroup of oncological patients!

- Currently available agents are only efficient in a comparatively small number of cancer types
- It is still impossible to predict whether the individual patient is a „responder“ or not
- Ctx/RCtx is often accompanied by severe side effects with a significant reduction of QoL

> better knowledge of tumor biology and more efficient agents have to be elaborated!
New therapeutic paradigms I
An intelligent new approach to an old problem

**Achalasia:** The spincter between esophagus and stomach fails to open during swallowing
Therapeutic standard: Surgical myotomy
New therapeutic paradigms II
The end of: „if in doubt, take it out“

Cancer right liver

Conventional resection
Local tumor destruction in situ by thermo ablation
Percutaneous thermodestruction of a liver tumor under laparoscopic guidance

- Percutaneous radiofrequency ablation probe
- Laparoscopic ultrasound probe
- Liver tumor
Why is clinical penetration still low?

• How to hit the tumor precisely and save adjacent healthy structures?

• How to prove that the entire tumor is destroyed?
Functional implants
Regaining functional activities by implantable active devices

- Example I: Fecal incontinence
  The inability to control bowel movement dramatically deteriorates QoL!

Up to now, any conventional surgical approaches were highly demanding and less than really successful:
- Flaps
- Sphincter reconstruction
- etc
Where is the problem?

- Future indications for intelligent functional implants:
  Any kind of motility disorders, organ insufficiency etc.
  but:
  Limited knowledge about physiology/pathophysiology
  Mode of action often unclear
  Energy
  Interfaces between electrodes and tissue
  closed loop mechanisms

> further progress in biosignal processing, biomaterials etc. is badly needed
New accesses into the anatomy

Current state

Future develop: Indiv. proced.
Future develop: Multim. treatm.
Future develop: New paradigms
Future develop: Implants
Future develop: Access

Challenges: Visualisation
Challenges: Navigation
Challenges: Robots
Challenges: Cognitive syst.
Interdisciplinary cooperation

- Tracheobronchial System
- Gastrointestinal Tract
- Pancreatobiliary System
- Vascular System
Transvascular interventions
Accesses into the abdominal cavity

- Laparotomy
- Laparoscopy
- Mini – laparoscopy
- Single port surgery
- NOTES ("scarless surgery")
Potential barriers to clinical practice

- Access to peritoneal cavity
- Gastric (intestinal) closure
- Prevention of infection
- Visualization, Spatial orientation
- Development of suturing device
- Development of anastomotic (non-suturing) device
- Development of a multitasking platform to accomplish procedures
- Control of intraperitoneal hemorrhage
- Management of iatrogenic intraperitoneal complications
- Compression syndromes
- Training other providers

*Rattner et al Surg Endosc 2006*
**Where is the target? Visualization**

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**Challenges:**
- Visualisation
- Navigation
- Robots
- Cognitive syst.
- Interdisciplinary cooperation

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**Future development:**
- Individually processed
- Multimodal treatment
- New paradigms
- Implants
- Access

**Challenges:**
- Navigation
- Visualisation
- Robots
- Cognitive sys.
The problem of exposure
Highly dynamic optochips
Advanced visualisation: HDR photonic sensors
The problem of MIC and NOTES: the tunnel view
Spatial orientation

Endoscopic view

Re-establishment of the horizon
Intuitive understanding is facilitated by stabilization of the horizon!
Where is the target? Navigation

- Technologies for navigation:
  - depth maps: Time of flight
    - structured light
    - stereoscopic approaches
  - electromagnetic navigation
  - fiber braggs
Structured light

3D-MINC, BFS
Merging of pre- and intraoperative information
Reliable matching / referencing

Preoperative planning

Intraoperative sight

Augmented reality
Advanced visualisation: View extension
Mosaicing
„Forbidden zones“

Autonomes Zielerkennung
Vermeidung von Kollisionen
Natural-orifice transluminal endoscopic surgery (NOTES) in Europe: summary of the working group reports of the Euro-NOTES meeting 2010


Table 1 General requirements for platforms and robotics.

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<td>Size</td>
<td>Diameter of the shaft: ≤ 22 mm (preferably less).</td>
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<td>At least 2 functional channels (diameter 3 – 6 mm) and flexible vision.</td>
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<td>Image</td>
<td>Sufficient resolution and adequate illumination.</td>
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<td>Insufflation</td>
<td>High-flow insufflation with intraperitoneal pressure control.</td>
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<tr>
<td>Suction/irrigitation</td>
<td>High-volume suction and irrigation which is not impaired by the instruments in use (separate channel).</td>
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<td>Steerability</td>
<td>The tip of the device should have the ability to maneuver in all planes. The shaft should be capable of 180° retroflexion.</td>
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<td>Stability</td>
<td>Complete flexibility for insertion and positioning with subsequent rigidity of the shaft and continued flexibility of the tip.</td>
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<tr>
<td>Triangulation</td>
<td>The device should enable manipulation of tissue with traction and countertraction in all planes. Efficient grasping technique must be available.</td>
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<td>Controllability</td>
<td>Ergonomically sound interfaces with situational awareness.</td>
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“Highly Versatile Single Port System“ (HVSPS)
Requirements

- „Smart“ instrumentation
- Intuitive man-machine interface
- Enhanced visualization
- Integrated surgery
- Simulation
- Miniaturization
- True independent/autonomous robotic support
- Safety and documentation
- Surgical team robotic augmentees
- Operating room integration
- Acceptable cost/benefit ratio

Herron 2008, Wexner 2009, Feussner 2010
New Bending-Concepts

Horst/Ulbrich/Rixen, Applied Mechanics
Träger/Roppenecker/Lüth, MiMed
The first *in vivo* cholecystectomy using the HVSPS
The problem of the man-machine interface!
Team formation
Solo or duo: A medical question

CHIRURG

INTERVENTIONELLER GASTROENTEROLOGE

? [arrow]

ALLROUNDER?
First prototype of a NOTES cockpit

Dipl.-Ing. Nils Kohn
A cognitive/cooperative interventional environment

Model guided surgical workflow

Current state

Future develop:
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Challenges:
Visualisation

Challenges:
Navigation

Challenges:
Robots

Challenges:
Cognitive syst.

Interdisciplinary cooperation

J. Sutherland 2006
Model guided surgical workflow

Comprehensive real-time data acquisition!
Exact monitoring of the OR progress and possible discrepancies!

An autopilot is needed to guide process execution for routine healthcare events and warning lights and alarms need to be available just as they are for an aircraft pilot when an engine is overheating or a collision is immanent.

J. Sutherland 2006
Integrated OR
Workflow analysis and prediction

- Illumination
- Positioning of the team
- Intraabdominal pressure
- Instruments in use
- Tilt of the table
- Function of peripheral devices

Schneider et al, MITI
Modelling of a surgical intervention

- Modelling of a (laparoscopic) surgical intervention based upon workflows (scripts, finite state machines)
  - Definition of discrete states

- The actual state is defined by sensor variables
  - e.g. Location of different instruments on the mayo stand

- The actual state may lead to well defined actions

Kranzfelder/Schneider, IVAP 2025 BFS
Modelling of a (laparoscopic) surgical intervention based upon workflows (scripts, finite state machines)

- Definition of discrete states
  - The actual state is defined by sensor variables - e.g. Location of different instruments on the mayo stand
  - The actual state may lead to well defined actions

- Modelling of a surgical intervention
  - Which instrument is required next?
  - Which position of the support system is now optimal?
  - Which additional visual information is needed?
  - etc.

Kranzfelder/Schneider, IVAP 2025 BFS
Conclusions

- NOTES is the bridge between surgery and interventional gastroenterology, but it still waits for the adequate technology!

- Contributions are required from all fields of biomedical engineering

- The task is enormous: How to reach the goal is still unclear

- To avoid mistakes and failures and to speed up the R&D process, a closer cooperation between engineers and users is more essential than ever before

- Clusters should be established to promote an integrated approach to this unique challenge