

# Robotic Bone Drilling Assessment

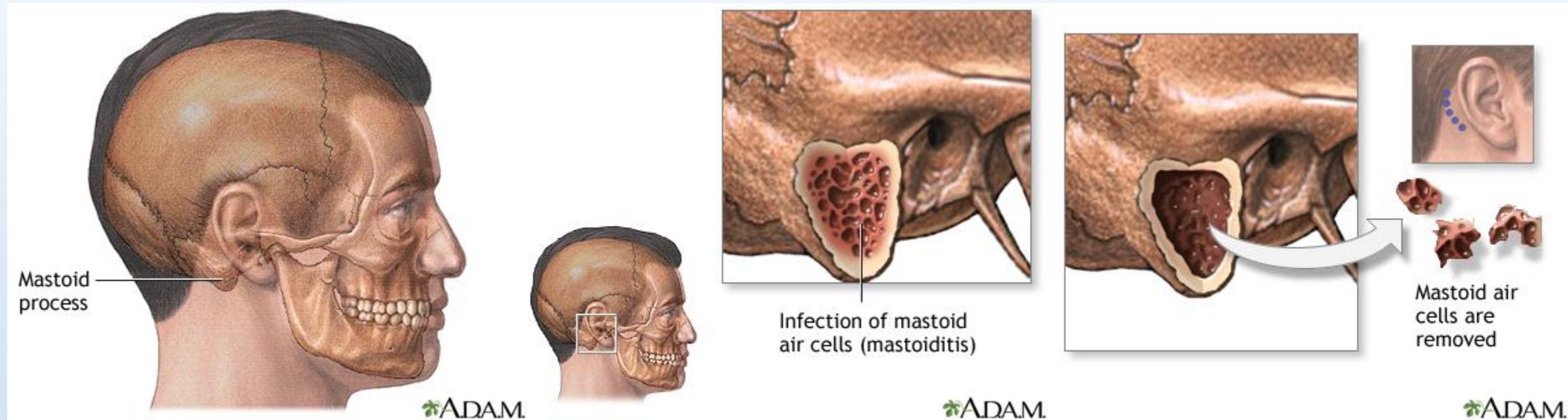
Seminar Review:

Revision Surgery, Microsurgical Robots, and Neuromonitors

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# Mastoidectomy



# What's a Mastoidectomy?

- Removal of tissue from the mastoid process
- Two reasons for mastoidectomies
  - Mastoiditis (for clearing infection)
  - Cochlear implant (for rehabilitation)
- Probability of damaging the facial nerve
  - 1-4% first surgery<sup>[1]</sup>
  - 4-10% next surgeries<sup>[1]</sup>

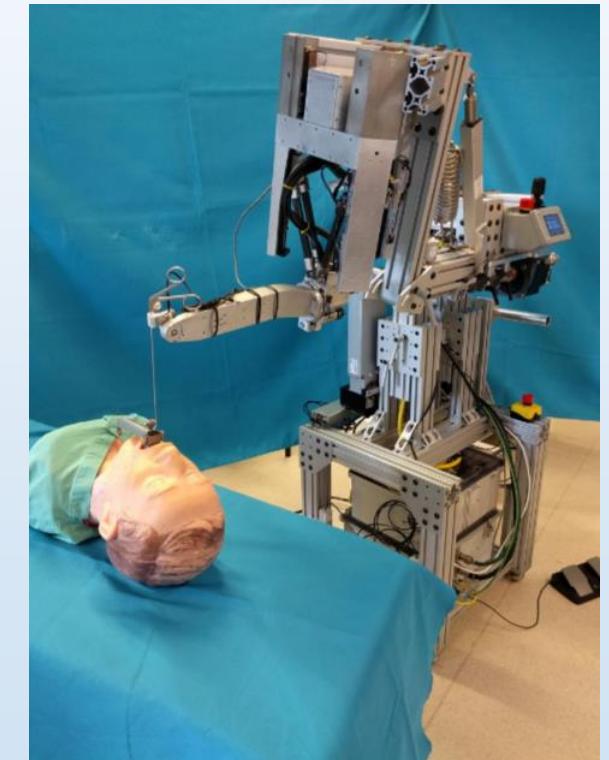
How Bad can it Be?

Cover Your Eyes



# Experimental Design

- Surgical phantom simulating mastoid
  - Healthy and diseased regions
  - Facial nerve
- 3 Subject groups
  - Laymen
  - Training surgeons
  - Resident surgeons
- 3 Levels of robotic assistance (Galen)
  - Freehand (no assistance)
  - Hand tremor elimination
  - Hand tremor elimination + virtual fixtures



# Assessment Criteria

- Safety
  - First priority
  - Facial nerve damage = lower quality of life
  - Metric: minimum distance between drill and nerve
- Effectiveness
  - Complete removal of diseased tissue
  - Evaluated using postoperative scans
- Speed
  - Total surgical time

# Revision Surgery

Bercin S; Kutluhan A; Bozdemir K; Yalciner G; Sari N; Karamese Ö,  
“Results of revision mastoidectomy.” *Acta Oto-Laryngologica* 129.2  
(2009): 138-41. Web.



# Objectives & Methods

- Restore hearing in infected ear (chronic otitis media)
- Avoid damaging neurovascular structures
- Report revision surgery results
- Identify and mitigate factors for additional surgery
- 35 patients were studied
  - Before & after revision surgery

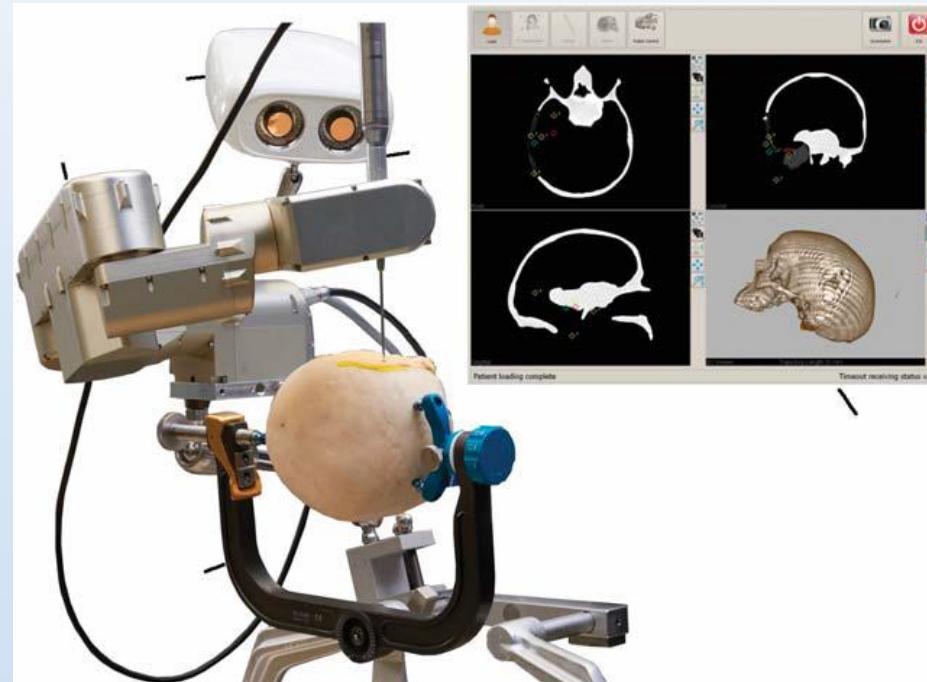
# Results

**Table I.** Causes of failure of previous surgery.

Cause	CWD (n = 21) (%)	ICW (n = 14) (%)	Total (n = 35) (%)
Persistent sinodural angle air cells	15 (71.4)	8 (57.1)	23 (65.7)
High facial ridge	14 (66.7)	—	—
Persistent tegmental air cells	12 (57.1)	6 (42.9)	18 (51.4)
Recurrent or persistent cholesteatoma	17 (80.9)	11 (78.6)	28 (80)
Persistent mastoid apex air cells	11 (52.4)	8 (57.1)	19 (54.3)
Narrow meatoplasty	17 (80.9)	—	—
Closed supratubal recess	15 (71.4)	9 (64.3)	24 (68.6)
Open eustachian orifice	11 (52.4)	—	—
Inadequate canalplasty	14 (66.7)	8 (57.1)	22 (62.9)
Anulus or tympanic membrane remnant	12 (57.1)	—	—

# Microsurgical Robots

Bell, Brett, Christof Stieger, Nicolas Gerber, Andreas Arnold, Claude Nauer, Volkmar Hamacher, Martin Kompis, Lutz Nolte, Marco Caversaccio, and Stefan Weber. "A Self-developed and Constructed Robot for Minimally Invasive Cochlear Implantation." *Acta Oto-Laryngologica* 132.4 (2012): 355-60. Web.



Bell, Brett, Christof Stieger, Nicolas Gerber, Andreas Arnold, Claude Nauer, Volkmar Hamacher, Martin Kompis, Lutz Nolte, Marco Caversaccio, and Stefan Weber. "A Self-developed and Constructed Robot for Minimally Invasive Cochlear Implantation." *Acta Oto-Laryngologica* 132.4 (2012): 355-60. Web.

# Objectives

- Perform minimally invasive mastoidectomy
- Create direct cochlear access tunnel (DCA)
  - As small as possible
  - Directly to cochlea for cochlear implant
- 0.5mm accuracy required!

# Robot & Study Specifications

- Arm has 5 degrees of freedom
  - Mountable on operating room table
  - Has haptic feedback (feels hand's force)
- 
- 8 human heads as subjects
  - Registration done visually by human
  - 2mm starter hole followed by DCA

# Results

Table II. Comparison of DCA accuracy results.

Reference	Model	Error at target (mm)	Method
Schipper et al. 2004 [5]	Cadaver	1.6	Hand-guided
Labadie et al. 2005 [6]	Temporal bone	Not reported	Hand-guided
Labadie et al. 2009 [9]	Temporal bone	$0.36 \pm 0.18$	Template
Majdani et al. 2009 [10]	Temporal bone	$0.78 \pm 0.29$	Kuka KR3
Klenzner et al. 2009 [11]	Temporal bone	0.25 (virtual)	Staeubli RX90CR
Baron et al. 2010 [12]	Phantom	$0.62 \pm 0.25$	Kuka KR3, Mitsubishi RV-3S
This work	Cadaver	$0.56 \pm 0.41$	Custom built

DCA, direct cochlear access.

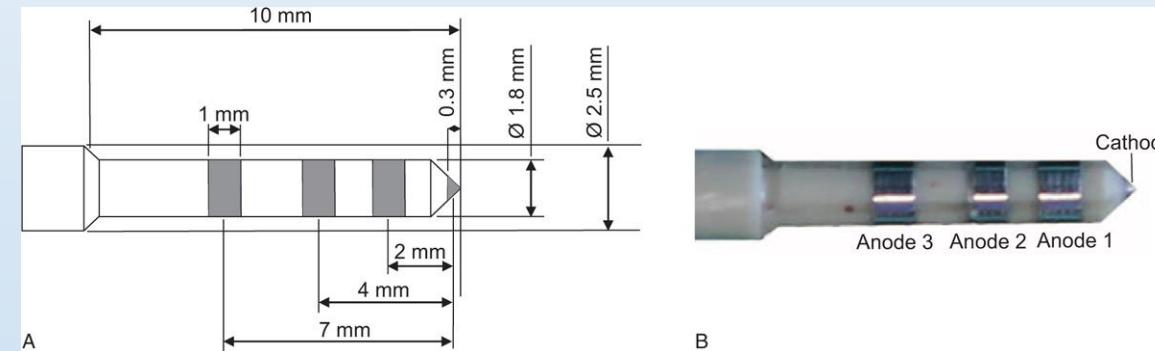
Robot failed!

# Next Version

- Two sources of error
  - Human registration
  - Calibration errors in robot
- Planned modifications
  - Digital human-free registration
  - Additional fiducials
  - Neuromonitoring
  - Visual tool tracking

# Neuromonitors

Ansó, Juan, Cilgia Dür, Kate Gavaghan, Helene Rohrbach, Nicolas Gerber, Tom Williamson, Enric M. Calvo, Thomas Wyss Balmer, Christina Precht, Damien Ferrario, Matthias S. Dettmer, Kai M. Rösler, Marco D. Caversaccio, Brett Bell, and Stefan Weber. "A Neuromonitoring Approach to Facial Nerve Preservation During Image-guided Robotic Cochlear Implantation." *Otology & Neurotology* 37.1 (2016): 89-98. Web.

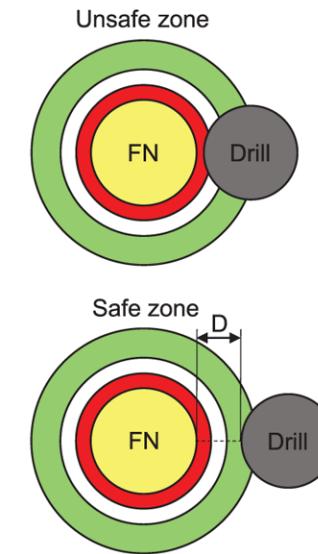
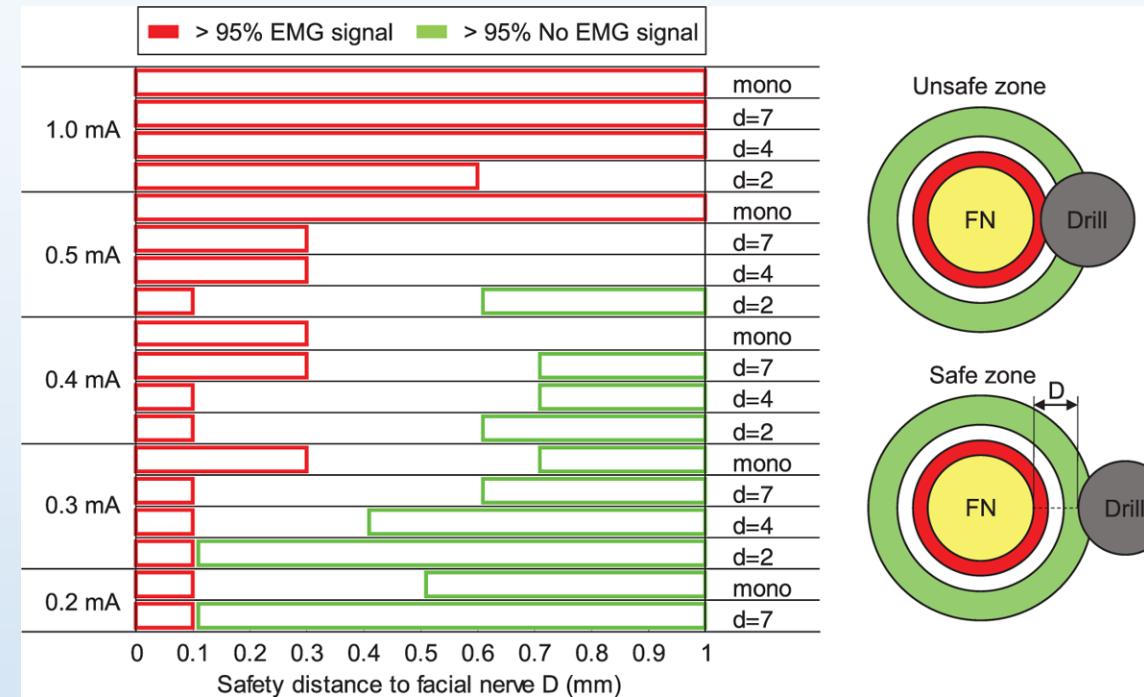


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# Objectives & Probe Design

- Compare monopolar and bipolar probe designs
  - Used for detecting facial nerve
- Monopolar design – 1 electrode
  - High sensitivity (detects facial nerve far away)
  - Low specificity (can't tell how far away)
- Bipolar design – 2 electrodes
  - Low sensitivity (detects facial nerve really close)
  - High specificity (knows exactly where facial nerve is)

# Results



# Takeaways