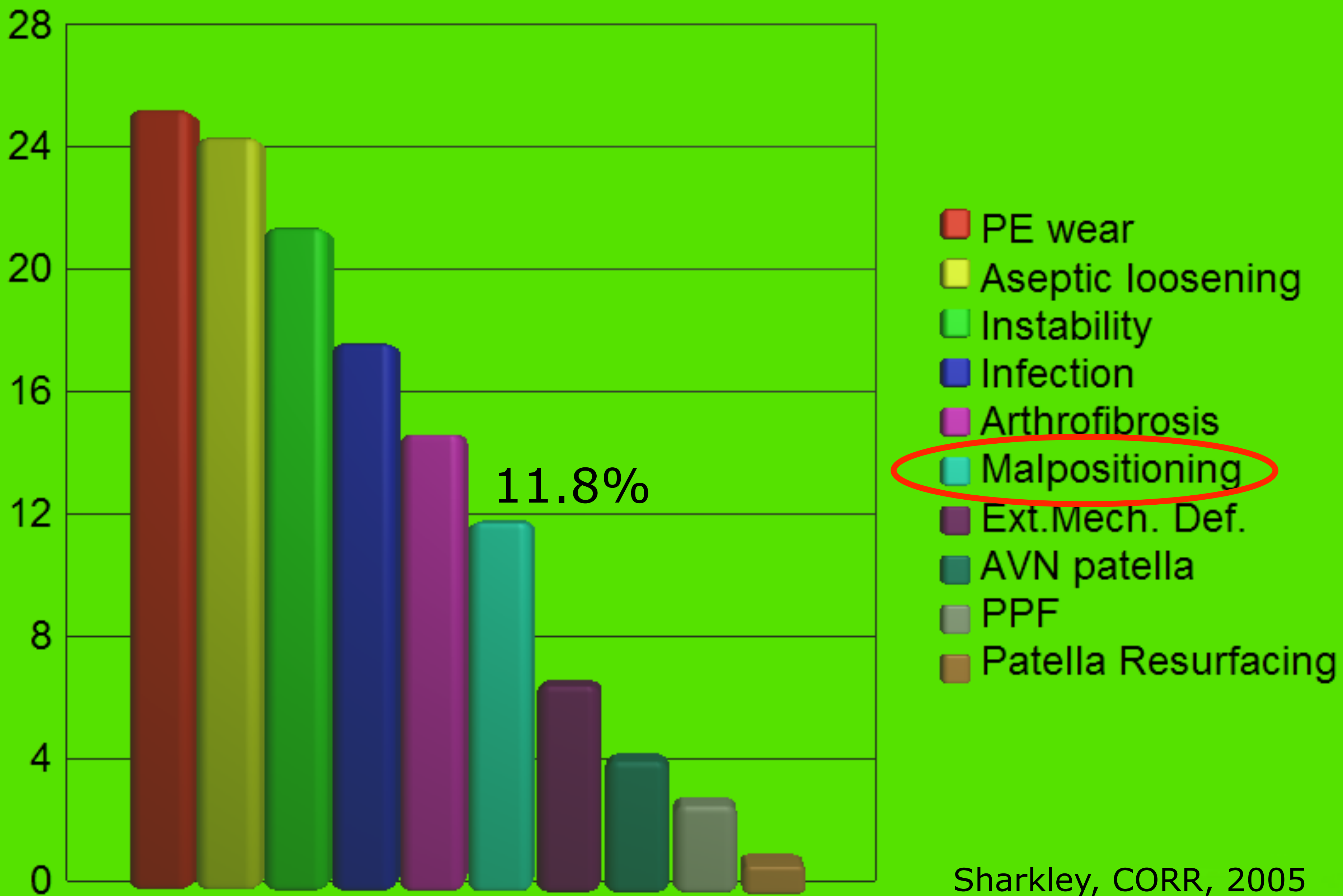
Computer Navigation in TKA

The role of Robotic Surgery

Christos Yiannakopoulos, M.D., Ph.D.

Why are TKA failing?



Sharkley, CORR, 2005

- 55.6% of revision occurred early (< 2 years)

- 32% of patients have >1 reason of failure

- ✓ Approximately 8 to 10 percent of knees are malaligned outside a safe zone using intramedullary instrumentation.

- ✓ These knees may have early failure.

✓Colwell, CORR, 1995

Accurate alignment of knee implants is essential for the success of TKA

- ✓ But not sufficient for a perfect TKA
- ✓ Soft tissue balancing
- ✓ Restoration of knee kinematics

Not all clinical studies relate tibial lucencies and alignment errors

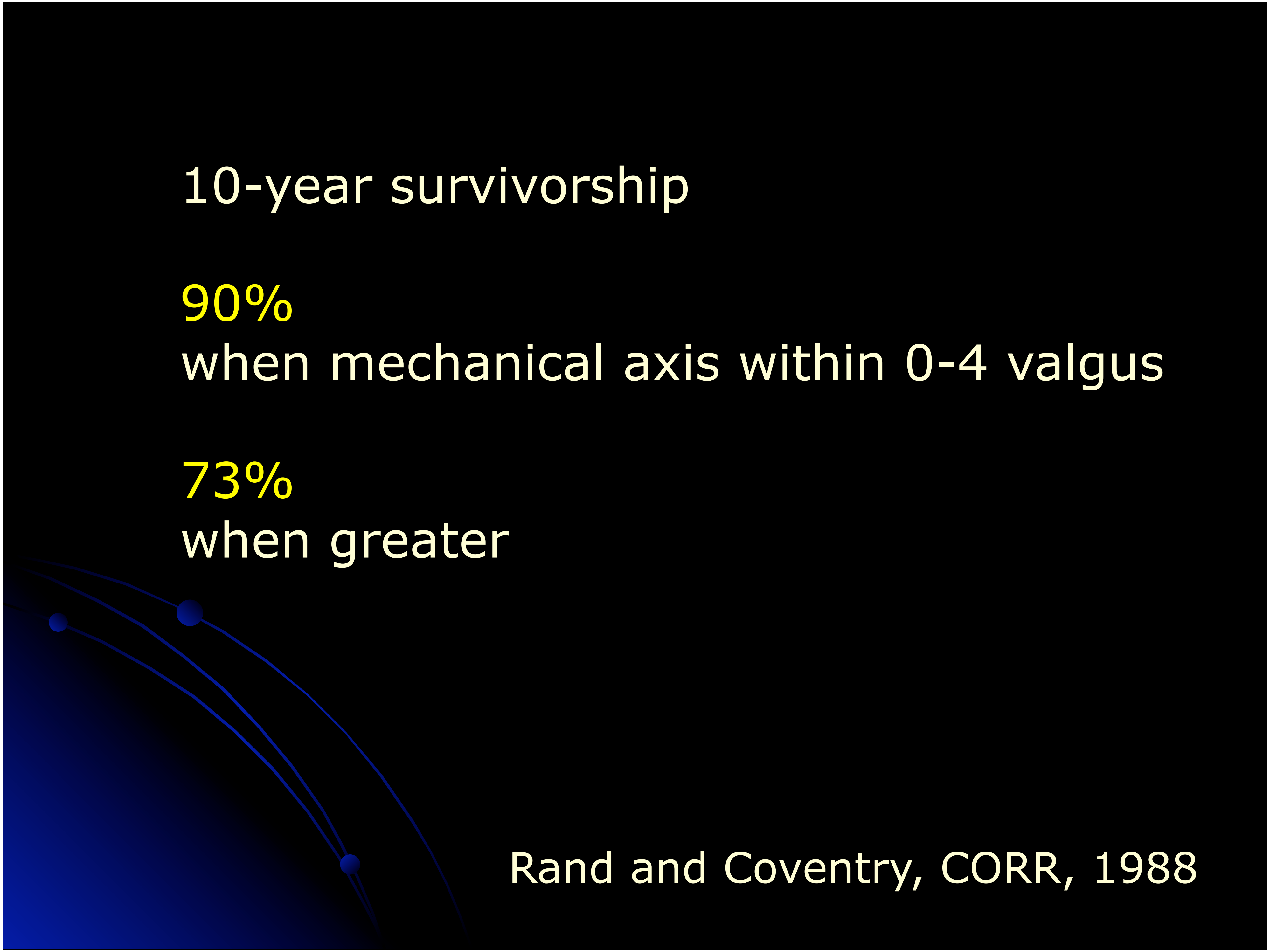
Smith et al., J Arthroplasty, 1989

Banks et al., Knee, 2003

Ranawat, CORR, 1988

- Good positioning of the implants is achieved in only 75% using standard instrumentation.
- Varus positioning of the tibial implant the commonest error.

Mahluxmivala et al. Arthroplasty, 2001


10-year survivorship
90%
when mechanical axis within 0-4 valgus
73%
when greater
Rand and Coventry, CORR, 1988

Malalignment in the coronal plane remains a major technical complication of TKA

Component Malalignment/Malposition

- Better instrumentation
- Navigation

- ✓ alignment guides are designed based on standardized bone geometry
- ✓ optimal placement of the components may not be achieved when the patient's bones differ from the bone geometry that was assumed by the instrument designer

Visual Navigation

Vs

Computer Navigation

CAOS

1) increasing the accuracy with which TJA is performed

2) reducing the need for direct visualization of critical surgical anatomy

3) decreasing the dependency on fluoroscopy in minimally invasive approaches that use it.

Components of a GPS system

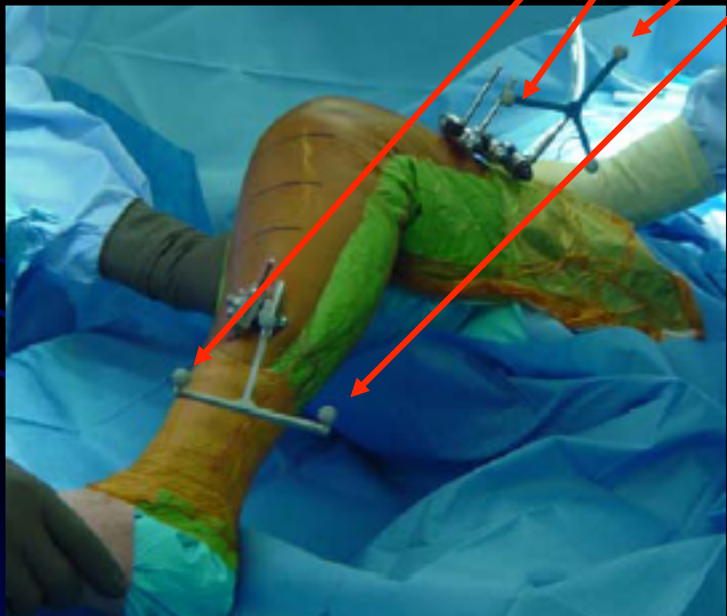
Satellite

Receiver

Map

Basic setup and components of a CAOS system

End-effector



Surgical object

Position sensor

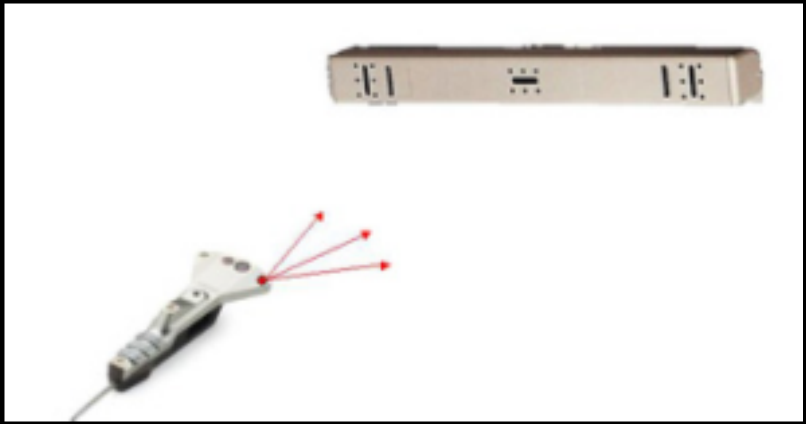
Monitor

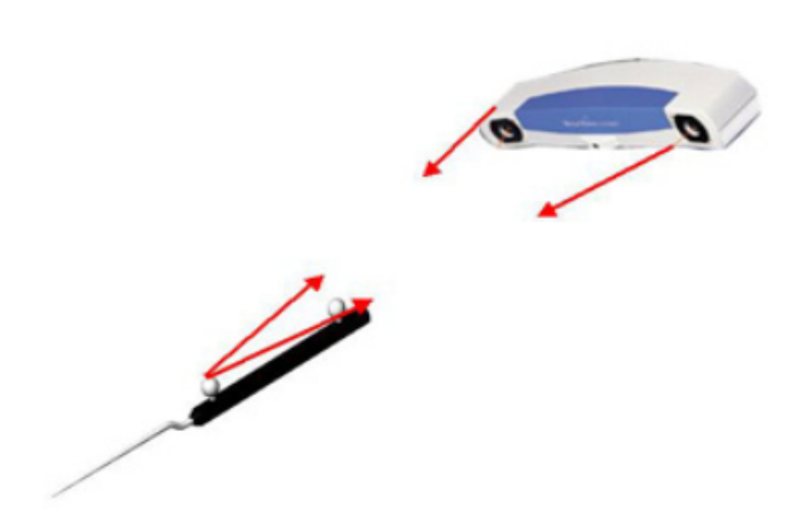
Components of a Navigation System

- Localizer (infared camera)
- Instruments with infared LED’s (light emitting diodes)
- User interface
- Computer

Localizer (detect infrared light)

- Active
- Passive
- Magnetic





Computer Assisted Arthroplasty

- Passive Systems

Image-free navigation systems

Image-based (CT, MRI, Fluoro)

- Active Systems

Robotic systems (Passive, Active, Synergistic)

Most CAS systems used for knee surgery

are either image free of fluoroscopy based

Open or closed systems

Specific for implant type

Can be used with any implant

Operational process of navigational TKA

Kinematic determination of hip rotation centre

↓

Measurement of anatomic landmarks

↓

Mounting of navigated alignment and cutting gauge

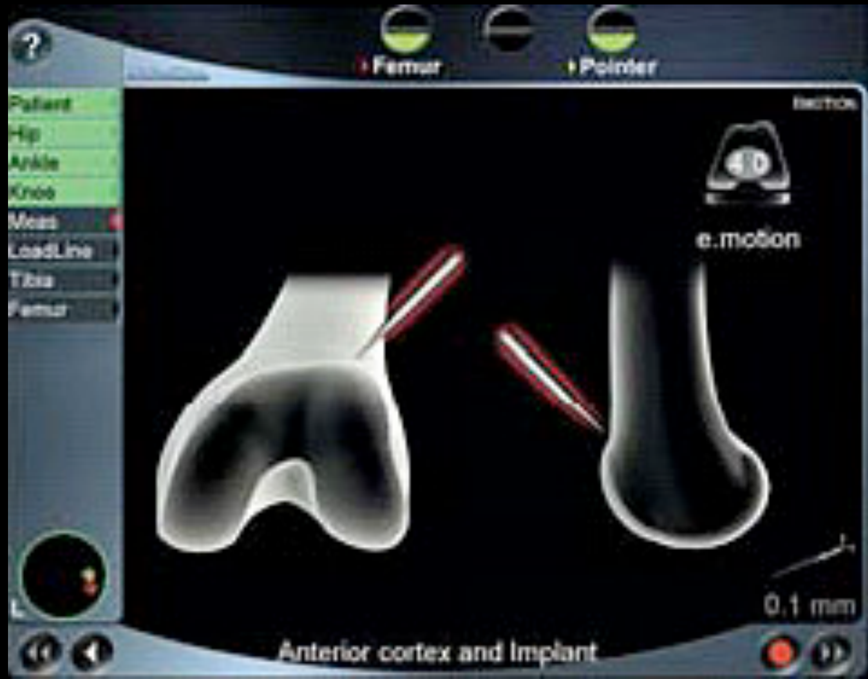
↓

Bone cutting

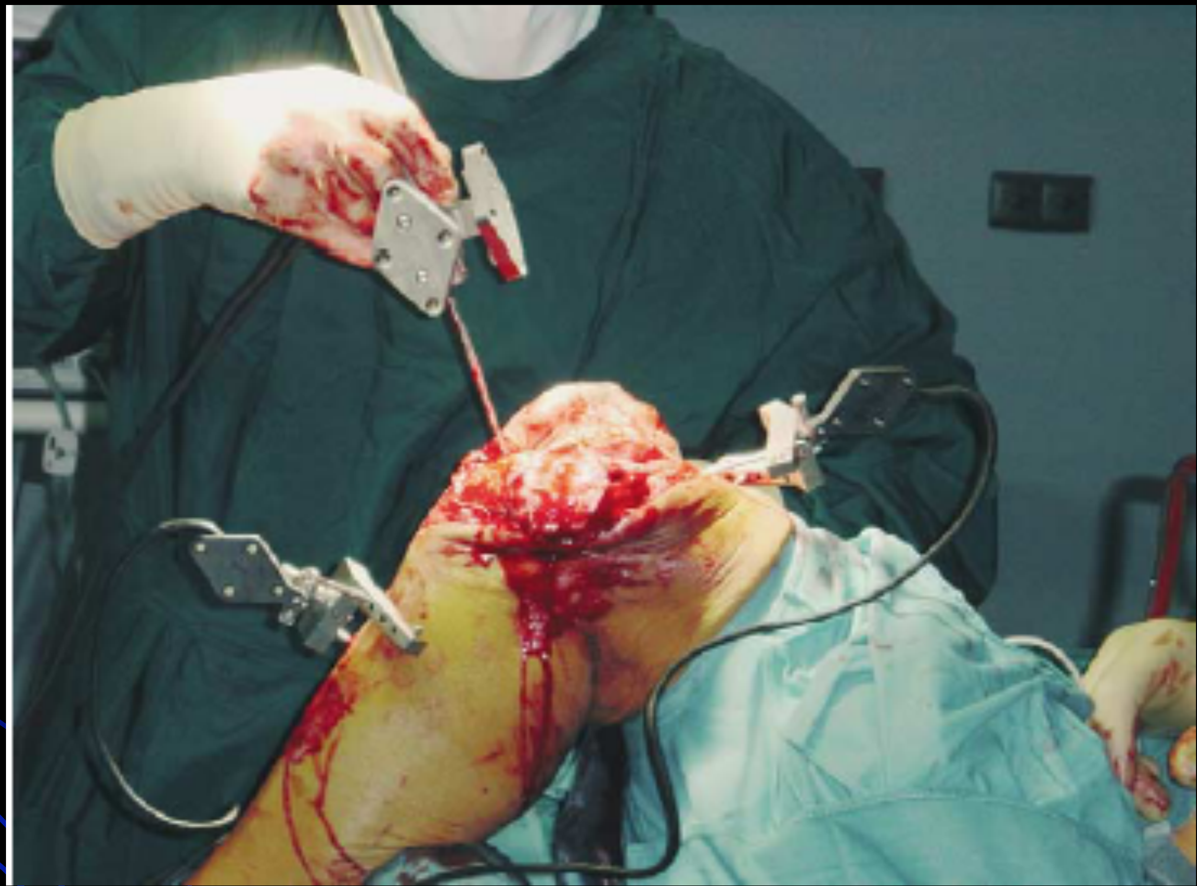
↓

Implant insertion

Fig. 10-B



Anatomic Landmark Registration



The surgeon uses an instrumented palpation hook to collect information on the patient anatomy

Kinematic Registration

Mechanical axis calculation

Robots have manipulative advantages over humans

- Indefatigable
- Reliable
- Extremely precise
- Impervious to biohazards
- Telecapable
- Possess near-absolute geometric accuracy

Types of Robotic Systems

- General surgery (Zeus, da Vinci)
- Orthopedic Surgery
- Neurosurgery

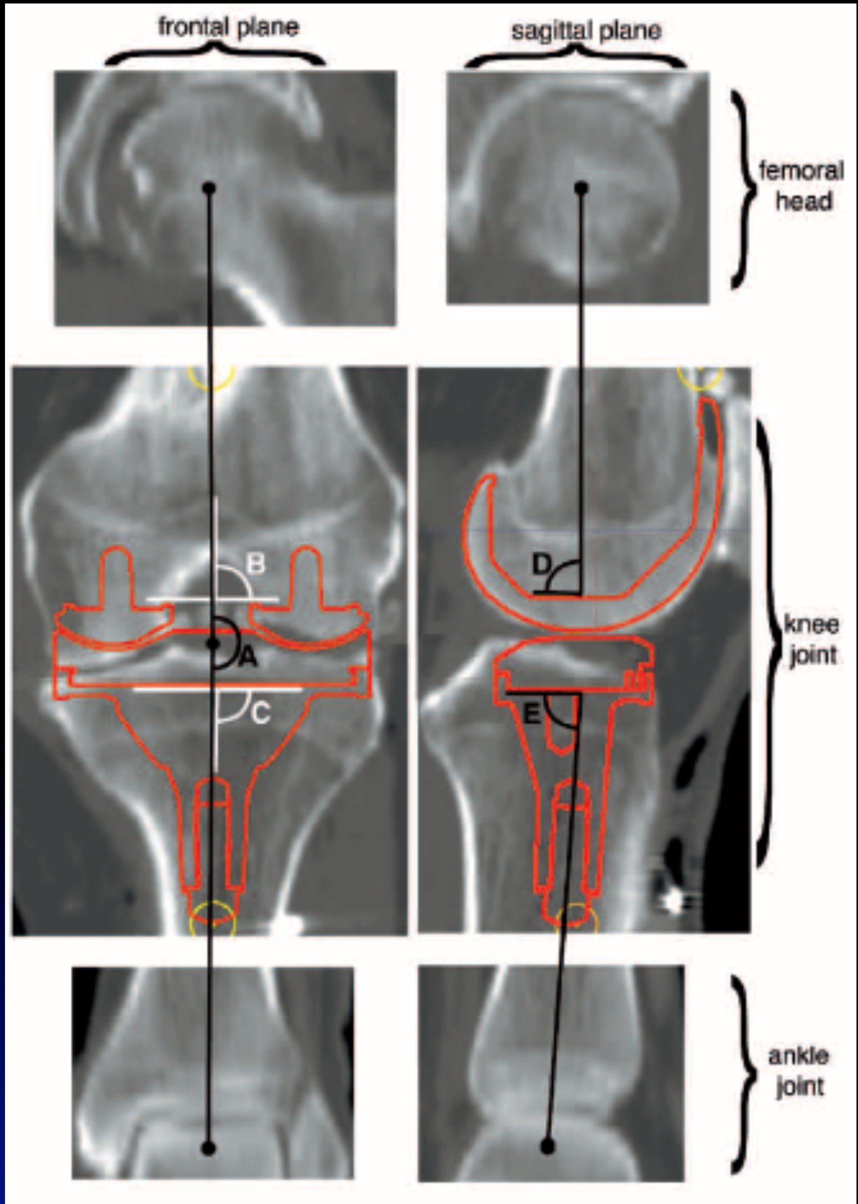
Acrobot Robot

The Acrobot system

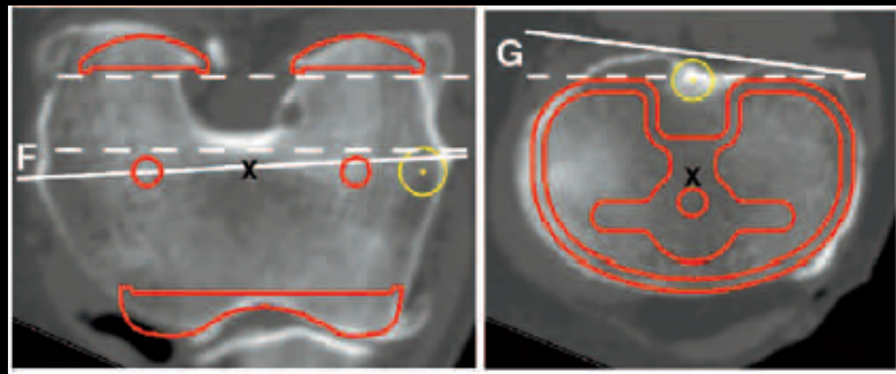
Caspar Robot

CASPAR

Decking, AOS 2004



CT-based preop planning



Decking, AOS 2004

Requirements of CAOS

- Safe
- Accurate
- Efficient
- Cost-effective
- Adaptable to the various approaches and instruments

Image-guided TKA

- ✓ improves alignment
- ✓ assists ligament balance
- ✓ provides immediate feedback to the surgeon
- ✓ reduces the learning curve
- ✓ contributes to teaching
- ✓ provides documentation

Advantages of Knee Navigation

- Rotational alignment correction
- Axial alignment correction
- Individual kinematics of the patient
- More accurate
- More information
- Dynamic intraoperative feedback

With navigation we can avoid outliers

- ✓ Approximately 30% of the German Hospitals have a navigation system.

- ✓ 20.000 TKA in Europe with CAOS

Is Navigation Necessary?

- Is it Cost Effective?

Not necessarily

- Is it Necessary?

Surgeon's experience, valgus, revision

- Does it Work?

Financial Burden of Robotic Surgery

- OR time
- Time and machinery
- Preop CT scan
- Complications

Is CAOS cost-effective?

- In the US 250.000 TKA annually
- Failures due to malpositioning= 500
- Cost of Revision TKA= 40.000$
- Financial Burden of Malpositioning=20.000.00 $

Surgical Time & TKA
Laskin 2002

	Non Infected		Infected	Incidence
Primary	93	vs	120	0.39%
Revision	96	vs	160	0.97%

In infection the operating times are longer in both primary and revision cases.

The longer the wound is open, the more likely the risk of infection.

Navigation

- Not faster
- Not cheaper
- Better?

8% of tibial cuts are malaligned by more than 4° in the coronal plane when an extramedullary alignment guide is used.

Teter et al. CORR, 1995

Not All CAS patients are in the 0-2^{o} margin

61.7%

Mielke et al. 2001

Author	N	Navigation System	Error Margin	Outliers CAS	Outliers Conventional	Major (> 5°) Outliers CAS	Type of Trial
Saragaglia et al[26]	25/25	Orthopilot	0–3°	16%	25%	8%	Prospective randomized
Mielke et al[23]	30/30	Orthopilot	0–3°	38%	43%	6,7%	Matched groups
Jenny and Boeri[16]	40/40	Orthopilot	0–3°	5%	15%	Not listed	Matched groups
Sparmann et al[28]	120/120	Stryker	0–2°	2.5%	22.5%	0%	Prospective randomized
Victor and Hoste (current study)	50/50	iON	0–2°	0%	26.5%	0%	Prospective randomized

Victor-Hoste. Image-based computer-assisted TKA leads to lower variability in coronal plane. CORR, 2004, 428:131-139

CAS systems are operator dependent

Garbage in

Garbage out

CAOS or CHAOS?

Surgical Navigation will allow us to get closer to a perfect TKA

There are a few Level I RCT’s

- s.s improvement in alignment and angular deviation between NAV and free-hand TKA
- There are no long term studies
- The long-term effects are unknown

Mechanical instrumentation vs Navigation

- Accurate and reproducible placement (<3^{o} varus-valgus) in all 20 cases
- In only 4 cases perfect alignment

Stulberg, CORR, 2003

Jig vs Navigation TKA

RCT

- Less blood loss (less canal instrumentation)
- Better alignment of femoral and tibial components
- 13 minutes added time

Chauhan et al. Computer-Assisted Knee Arthroplasty Versus a Conventional Jig-Based Technique. A Randomised, Prospective Trial. JBJS Br. 2004;86:372-7.

- 50 robotic implantations (CASPAR)
- Historical controls
- 0.8 degrees vs. 2.6 degrees (man.)
- No difference in knee functional scores at the 3 and 6 months follow up

Siebert et al. Technique and first clinical results of robot-assisted total knee replacement. Knee. 2002;9(3):173-80.

Navigated vs Manual TKA

- PRCT, 50 vs 50
- Increased operative time
- No difference in blood loss, patellar alignment, tibial slope, postoperative scores
- Improvement in coronal alignment
- All CAS patients between 0-2°
- Similar clinical outcome and complication rates

Victor, Hoste. Image-based computer-assisted TKA leads to lower variability in coronal plane. CORR, 2004, 428:131-139

Navigated vs Manual TKA

- 50 vs 50
- good alignment in 92 vs 72%
- no ligament balancing software

Perlick et al. Navigation in total-knee arthroplasty: CT-based implantation compared with the conventional technique. Acta Orthop Scand. 2004 ;75:464-70.

- Retrospective study, II-1
- Orthopilot
- 100 vs 100 TKA
- Better positioning
- 79% excellent axes vs 28%
- 10 min added time

Haaker et al. Computer-assisted navigation increases precision of component placement in total knee arthroplasty. CORR. 2005;433:152-9.

Extramedullary vs Intramedullary vs CAOS TKA

- RCT
- Greater consistency and accuracy in implant placement
- Coronal 93% vs 73% vs 60%
- Sagittal 90% vs 63% vs 76% (IM)
- Longer OP duration 30 min
- Less drainage in the drain
- Similar incision lengths

Chin, J. Arthroplasty, 2005

Navigation in UKR

- Prospectively
- 15 vs 15 UKR
- More accurate alignment with navigation

Cossey, Spriggins. The use of computer-assisted surgical navigation to prevent malalignment in unicompartmental knee arthroplasty.
J Arthroplasty. 2005 ;20(1):29-34.

Problems that can be improved or eliminated by surgical navigation

- Improper alignment
- Improper sizing of the femur
- Malrotation
- Elevation of the joint line
- Improper ligament balancing
- Fat embolism

- CAS arthroplasty using navigation and robotic systems is still in the investigational stage.

- Studies have only addressed short-term outcomes.

- Long term effectiveness (revision rate, implant longevity, pain, functional performance) has not been demonstrated.

In the Future

- Implants and tools will merge
- CAOS will be at the core of the O.R.
- Reduce OR time
- Improve patient outcomes

Navigation will become

- Simpler
- Cheaper
- Radiation free
- Time efficient

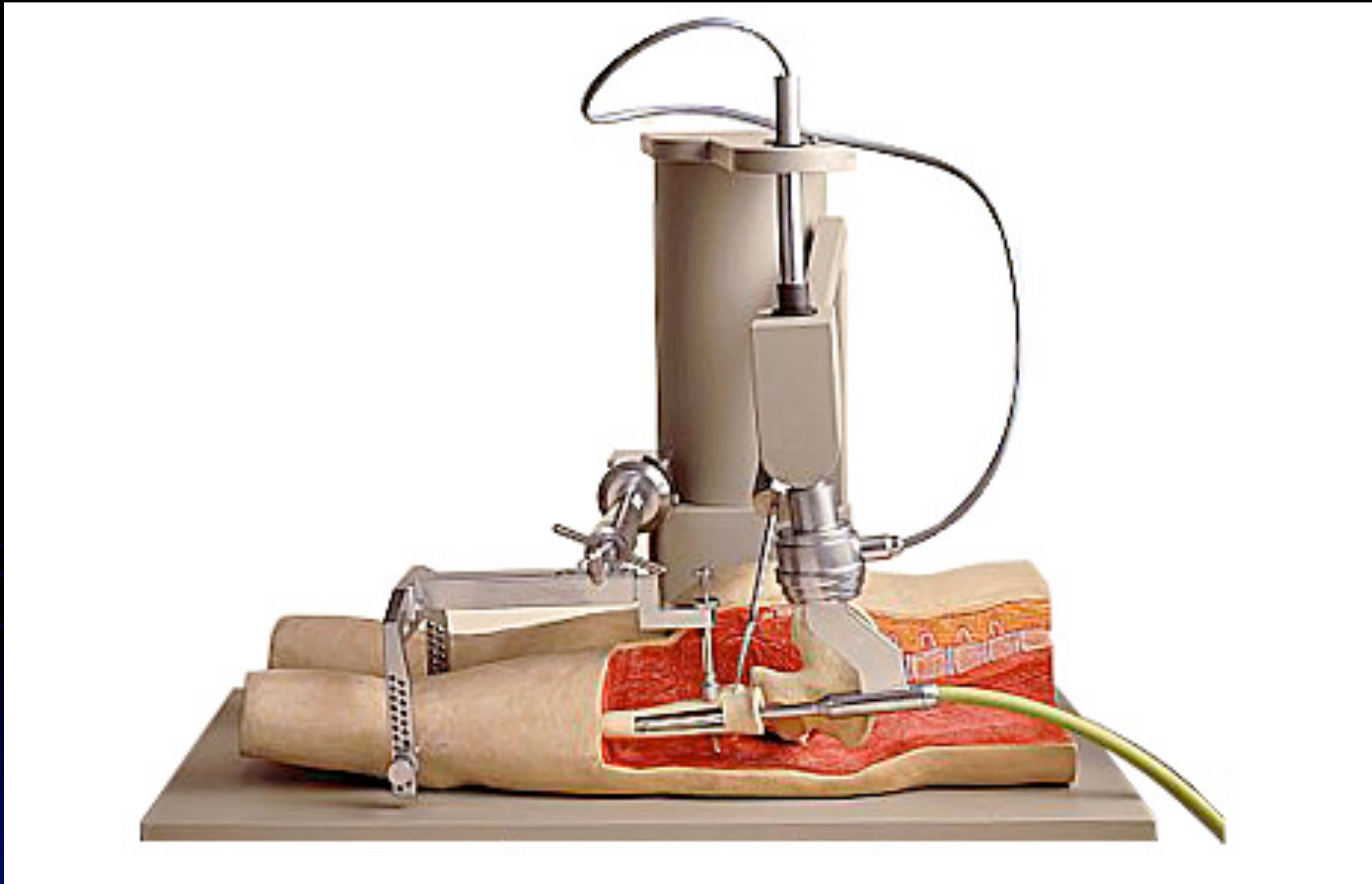
The Future

- Portable systems
- Low cost
- Part of every OR suite
- Heads up display
- Aid the surgeon
    - Residents
    - Low volume surgeon

The Future of Robotic Surgery

1. Intelligence
2. Addition of degrees of freedom = dexterity
3. Embedding sensors into the end effectors (force, displacement)

Future: Robodoc performing surgery



To intrude an unskilled hand into such a piece of divine mechanism as the human body is indeed a fearful responsibility.

Joseph Lister


Thank You