



# First Animal Cadaver Study for Interlocking of Intramedullary Nails under Camera Augmented Mobile C-arm

## A Surgical Workflow Based Preclinical Evaluation

*Lejing Wang<sup>1</sup>. Juergen Landes (M.D.)<sup>2</sup>. Simon Weidert (M.D.)<sup>2</sup>. Tobias Blum<sup>1</sup>. Anna von der Heide<sup>2</sup>. Ekkehard Euler (M.D.)<sup>2</sup>. and Nassir Navab<sup>1</sup>*

<sup>1</sup> Chair for Computer Aided Medical Procedures (CAMP). TU Munich. Germany

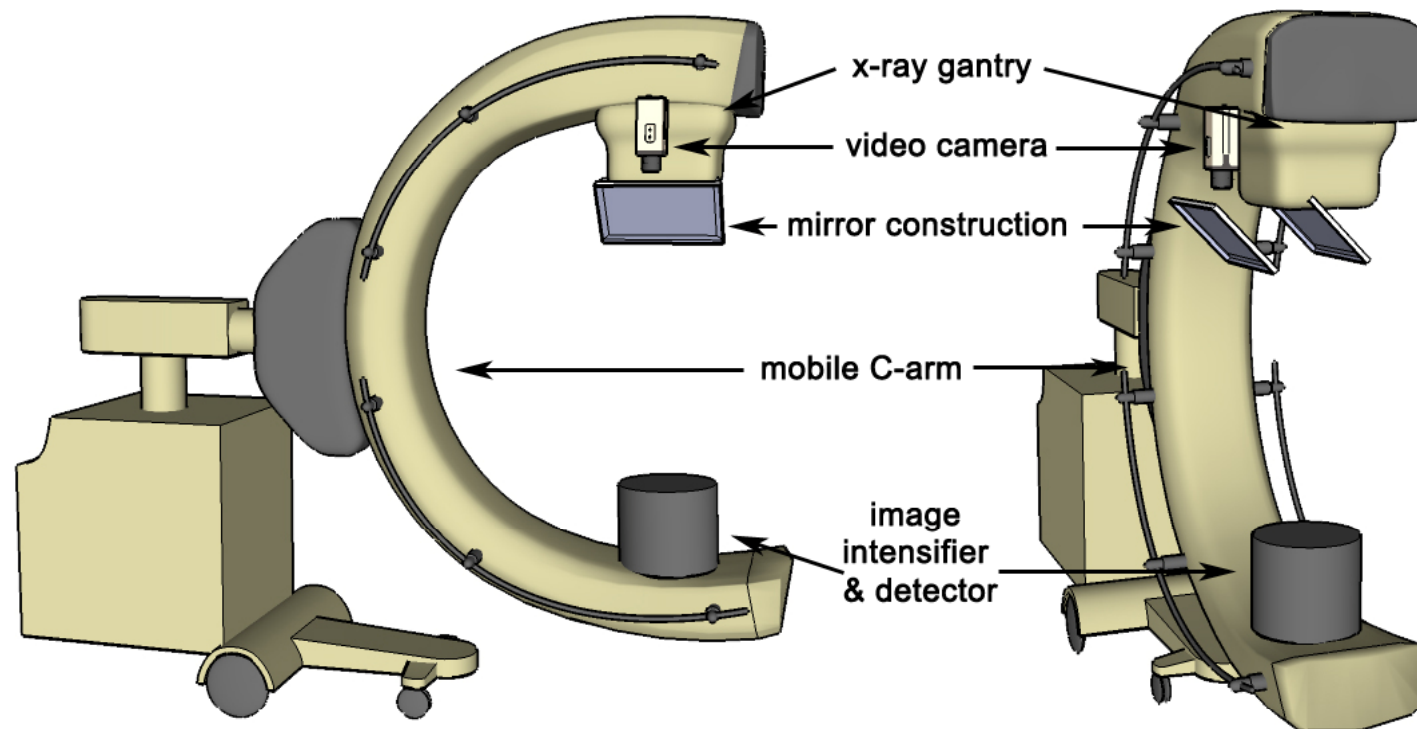
<sup>2</sup> Trauma Surgery Department. Klinikum Innenstadt. LMU Munich. Germany

Presented by *Lejing Wang*

---

## Camera Augmented Mobile C-arm (CamC)

- The Camera Augmented Mobile C-arm (CamC)<sup>1,2</sup> system augments a regular mobile C-arm by a video camera and mirror construction

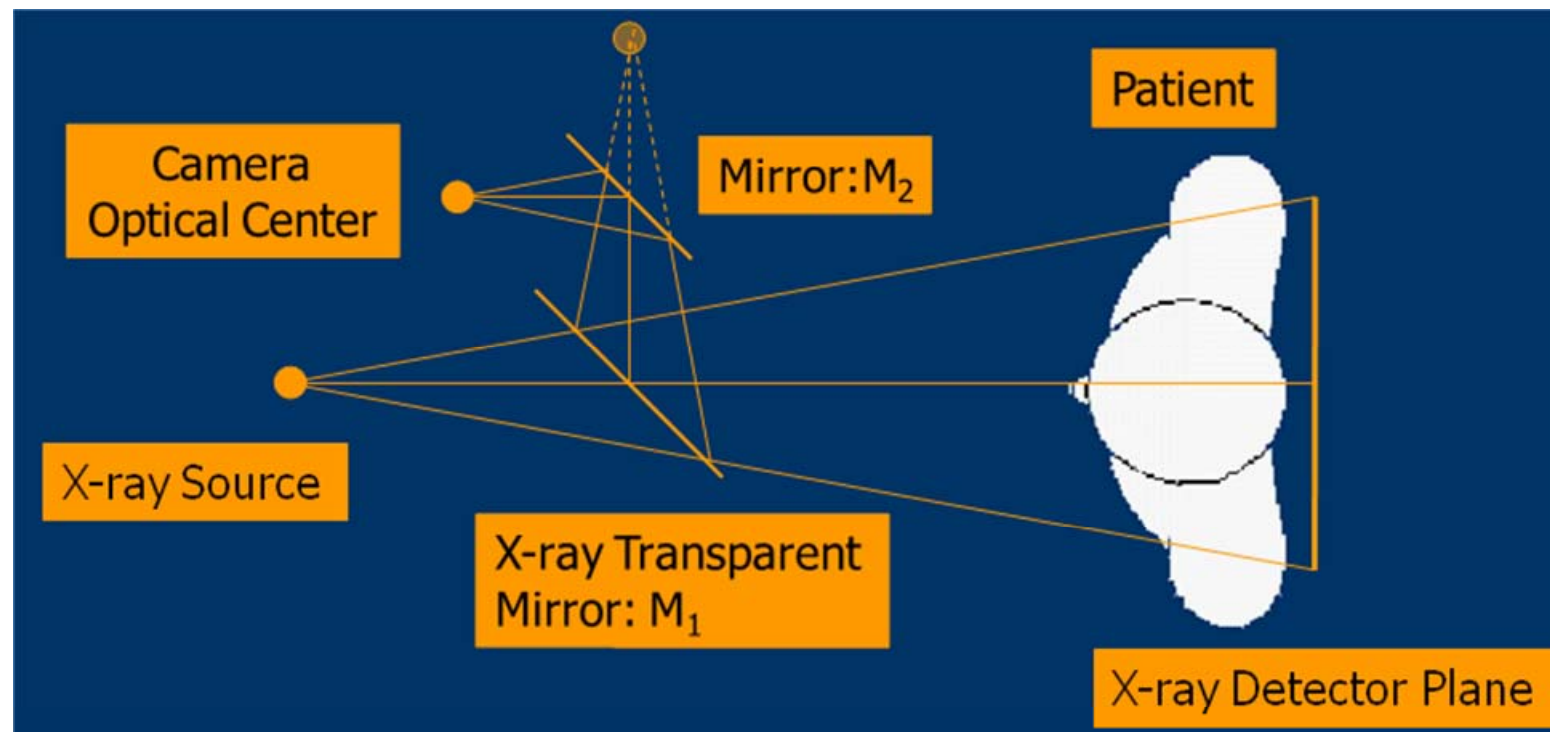


1. Navab et al. IWAR 1999.

2. Navab et al. IEEE TMI 2010

## Camera Augmented Mobile C-arm (CamC)

- Construction concept <sup>1,2</sup>

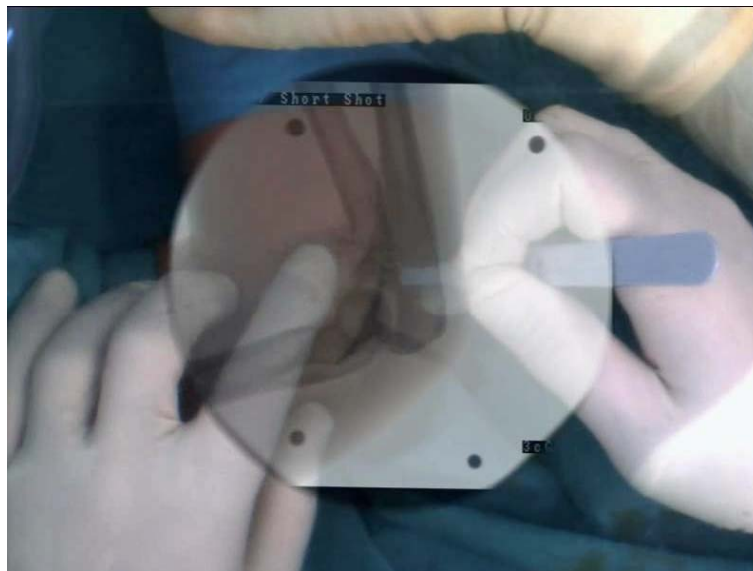


1. Navab et al. IWAR 1999.

2. Navab et al. IEEE TMI 2010

## X-ray and Video Image Overlay

- X-ray images are co-registered with video images without any further calibration or registration during the intervention.



### First Applications:

- needle guidance<sup>1</sup>
- Trauma: interlocking of intramedullary nails<sup>2</sup>
- Spine: pedicle screw placement<sup>3</sup>
- Implant/Foreign-body removal
- Joint fractures
- X-ray positioning

CamC is expected to reduce radiation <sup>4</sup>

1. Mitschke et al. MICCAI 00.
2. Heining et al. CAOS 2006
3. Heining et al. IGCARS. 2006
4. Navab et al. IEEE TMI 2010



## Previous Work of CamC Evaluation

- Technical system properties
  - Accuracy of the overlay <sup>1</sup>
  - Absorbed and scattered radiation of the mirror <sup>2</sup>
- Pre-clinical study, CamC vs. CT for vertebroplasty using spine phantoms<sup>3</sup>
  - one surgeon and five samples
  - no significant result
- **In this work,**
  - **workflow based comparison method is presented**
  - **evaluate the clinical impacts of the CamC system**

1. Navab et al. IEEE TMI 2010

2. Wang et al. BVM 2009

3. Traub et al. AMIARCS 2008



## Evaluation of Image Guided Surgery (IGS) Systems

- Clinical evaluation is an important phase in the development of IGS systems
  - Practicability, efficiency and clinical suitability need to be confirmed
- An assessment framework with six levels from technical system properties to social and legal impacts <sup>1</sup>
- We present a workflow based comparison of a novel IGS solution with a conventional solution, which
  - identifies the advantages and disadvantages on single step
  - easily generalizes results for single workflow steps
  - improves communication between technical researchers and surgeons



# Surgical Workflow Based Evaluation

- The workflow based comparison method consists of the following steps
  1. Initializing the assessment objective  
motivation, surgical context, hypothesis, assessment level<sup>1</sup> **surgical strategy and performance<sup>1</sup>**
  2. Modeling the workflow  
choosing surgical procedures, analyzing the workflow
  3. Defining evaluation criteria  
measurement parameters,
  4. Performing experiments and acquiring measurement parameters  
video or live observations, same setup for novel and conventional solution
  5. Comparing results  
statistical analysis

1. Jannin. P. & Korb. W.: Image-Guided Interventions - Technology and Applications. Volume chapter 18. Springer (2008)

## Interlocking of Intramedullary Nails

- Several computer assisted solutions were developed
  - miniature robot <sup>1</sup>
  - optical tracking <sup>2</sup>
- A clinical study of interlocking: navigation vs. C-arm <sup>3</sup>
- We focus on evaluating the clinical impact of CamC by performing interlocking (**not** for interlocking)

### Because interlocking

- is commonly used in fracture reduction surgery
- uses mobile C-arms
- requires skill and a large number of X-ray shots
- involves various common surgical tasks. e.g. X-ray positioning, targeting, and drilling



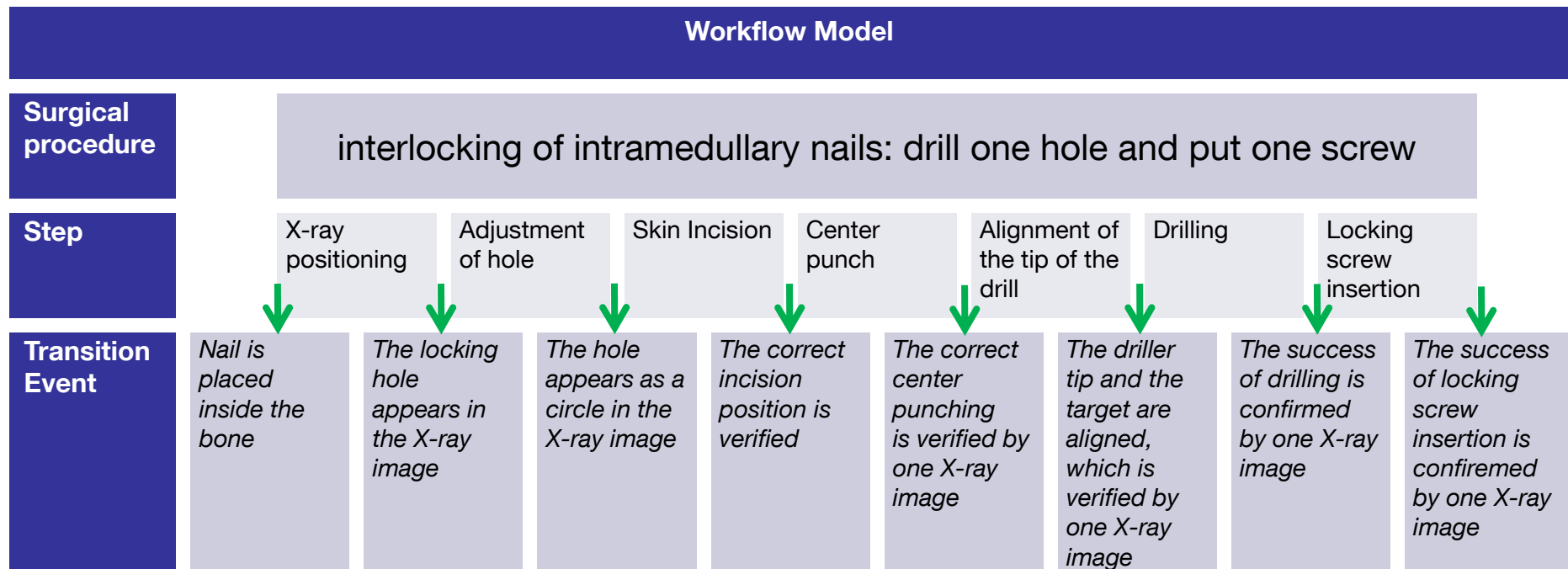
*Courtesy of AO Foundation*

1. Yaniv & Joskowicz IEEE TMI 2005
2. Leloup et al. IEEE TMI 2008
3. Suhm et al. Injury 2004





# Workflow Model of Interlocking





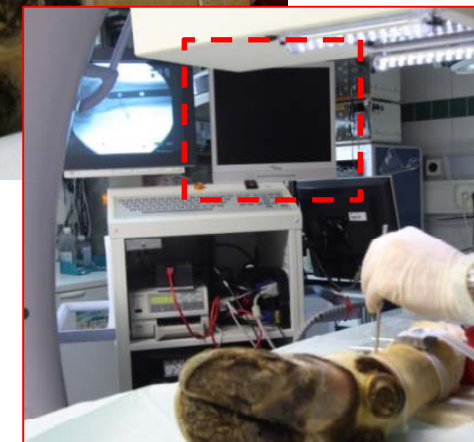
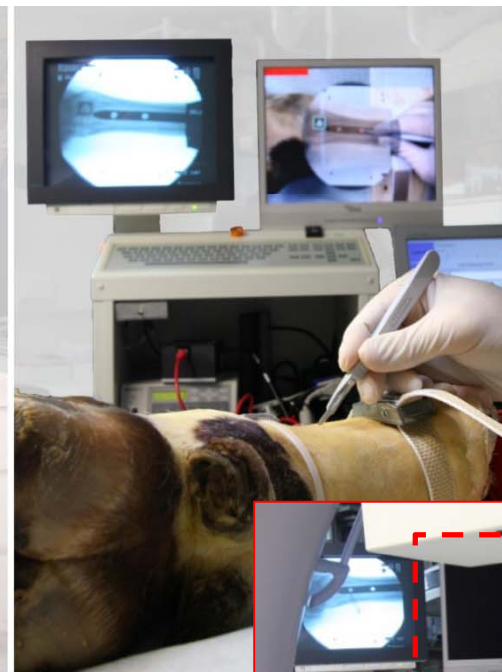
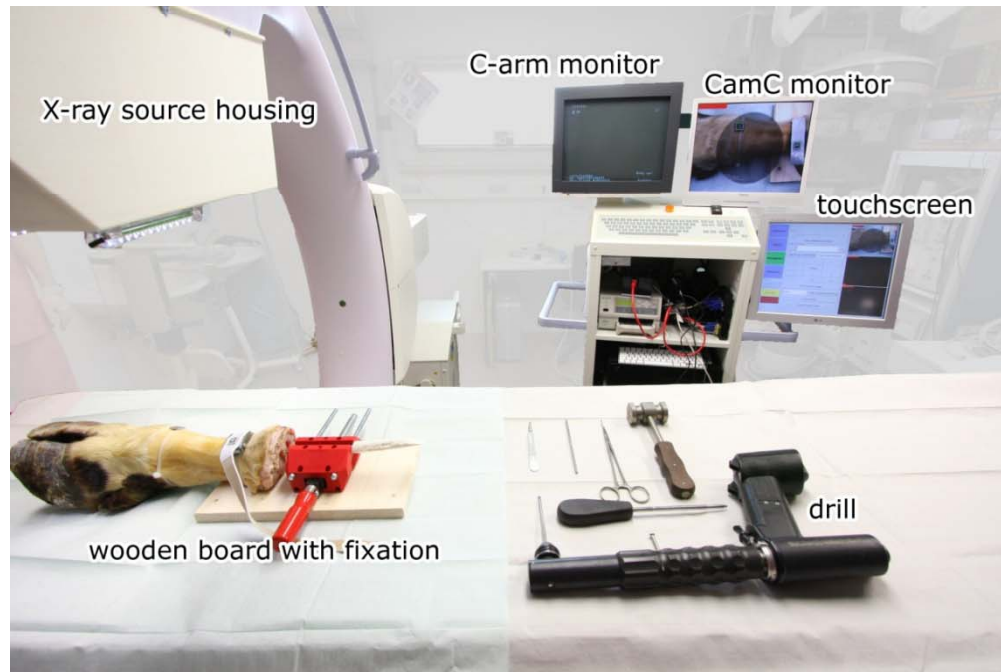
## Defining Evaluation Criteria

- Evaluation criteria
  - The amount of applied radiation exposure
  - The performance of the surgical procedure
- Measurement parameters
  - the number of X-ray shots
  - operation time
  - quality of drilling (assessed by surgeons giving scores 1, 2, 3, or 5)<sup>1</sup>
- Measures of statistics
  - Mean
  - STD
  - P-value (paired t-test)

1. Suhm et al. Injury 2004

# Materials and Experiments

## CamC setup



- Foreleg of cow cadaver
- 27 pair cases. i.e. 54 procedures
- Five surgeons
- Parameters are recorded manually

## C-arm setup



# Comparing Results

Drilling quality		
CamC group	1.78 ± 0.64	0.17
C-arm group	2.07 ± 0.78	

	X-ray Positioning	Adjustment of hole	Skin incision	Center punch	Alignment of the tip of the drill	Drilling	Locking screw insertion	Overall
<i>The number of X-ray shots (mean ± STD)</i>								
CamC group	1.04 ± 0.19	2.96 ± 1.56	0.04 ± 0.19	2.56 ± 2.38	1.59 ± 1.34	1.22 ± 0.64	1.00 ± 0.00	10.41 ± 3.59
C-arm group	1.44 ± 0.70	2.85 ± 1.51	2.67 ± 1.21	4.63 ± 2.62	2.51 ± 1.56	2.89 ± 0.64	1.00 ± 0.00	17.63 ± 4.65
P-value	0.0052	0.71	< 0.0001	0.00057	0.10	0.0033	1.00	< 0.0001
<i>Operation time (mean ± STD) in second</i>								
CamC group	21.96 ± 7.16	24.63 ± 18.85	20.22 ± 7.13	62.41 ± 50.04	26.70 ± 18.52	148.52 ± 105.55	53.22 ± 48.72	357.67 ± 157.64
C-arm group	24.85 ± 9.93	21.22 ± 12.94	28.56 ± 9.89	58.74 ± 33.70	25.89 ± 23.82	151.59 ± 90.21	39.56 ± 20.24	350.41 ± 108.73
P-value	0.16	0.40	0.00099	0.67	0.88	0.88	0.079	0.77



assessment objective -> modeling the workflow -> defining evaluation criteria -> performing experiments -> **comparing results**



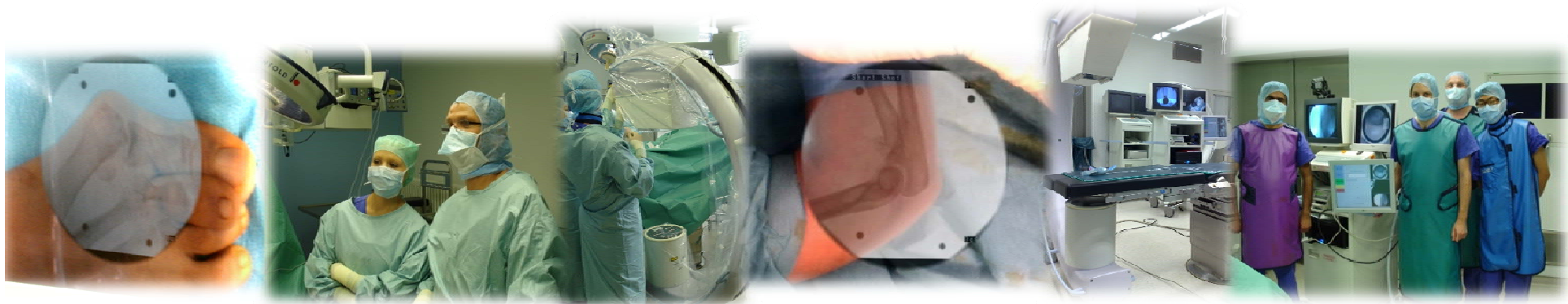
## Discussion & Conclusion

- Evaluate the clinical impact of the CamC system
    - surgical workflow based evaluation
    - Interlocking on cow cadaver forelegs
  - Surgeons performed surgical tasks more confidently when using CamC
  - Overall results
    - significantly less radiation exposure
    - similar operation time and similar drilling quality
  - CamC has its main positive impact in the following surgical tasks
    - **X-ray positioning, skin incision**, center punch, and **drilling**
    - they are also common in different surgical procedures
-

## Acknowledgement

- Thanks to Trauma Surgery Department, Klinikum Innenstadt, LMU Munich
- Our colleagues at NARVIS lab

# Thank you for your attention



- CAMC system has been developed with partial support from Siemens Healthcare



## Ongoing...

- Continue pre-clinical study
  - foreign body removal
  - learning curve analysis
- Workflow based comparison for clinical study
  - first 43 surgeries were carried out using CamC
  - complete 43 surgeries using C-arm for matching pairs

## Two Clinical Distal Interlocking

- Humerus
- Femur





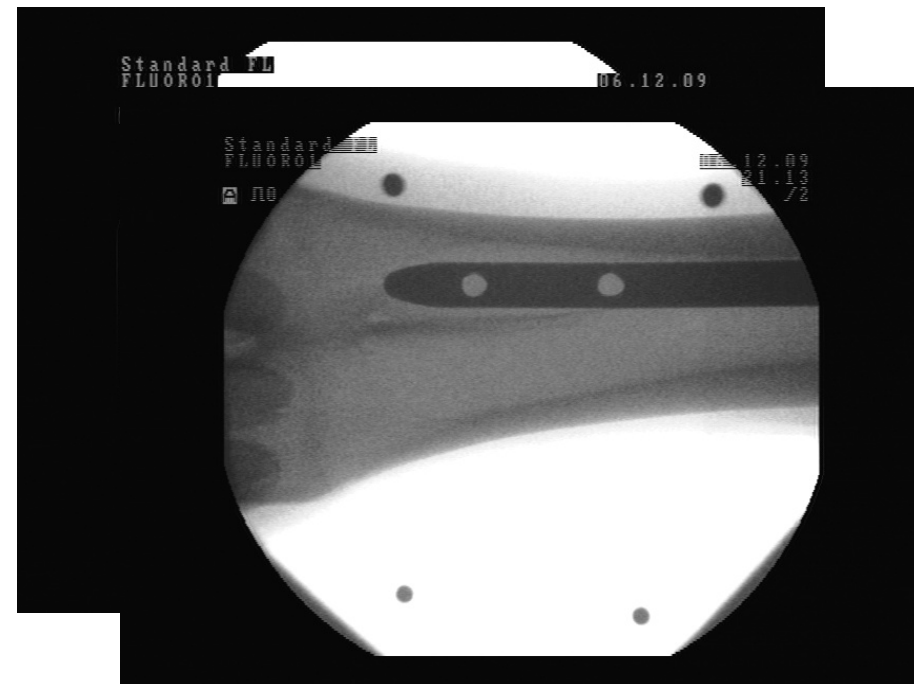
# X-ray Positioning



- Intuitive video-based guidance for moving C-arm



CamC



C-arm

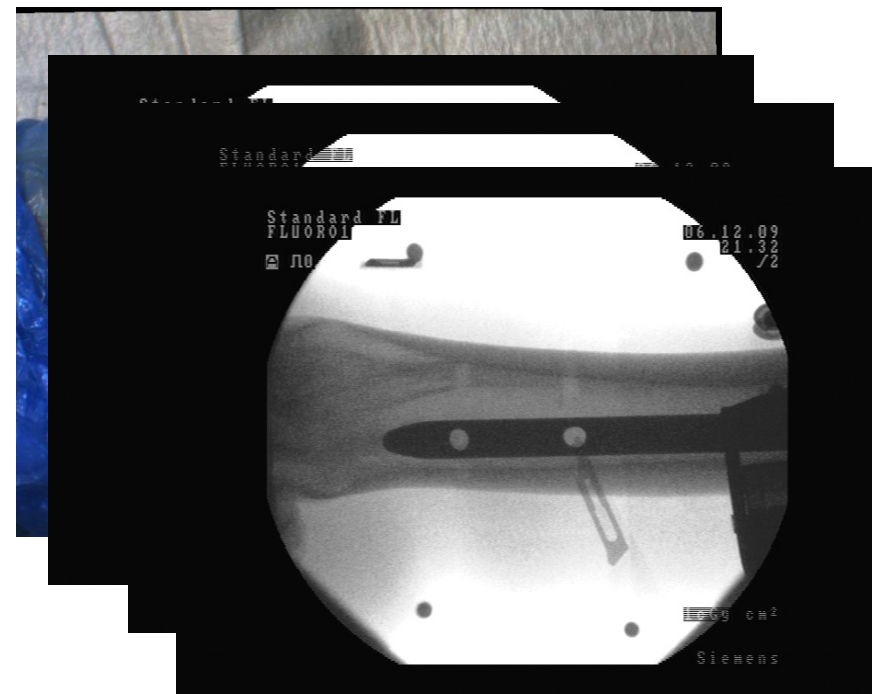
## Skin Incision



- Find the target place for skin incision using the guidance of the video with an aligned X-ray image



CamC



C-arm

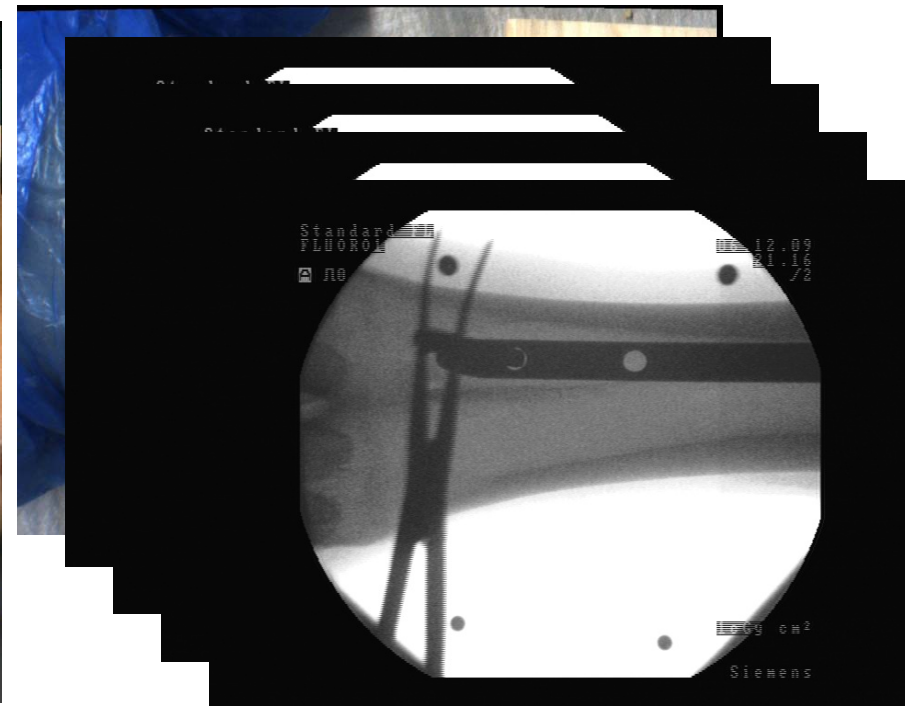
## Center Punch



- Easily identify the location for center punch



CamC

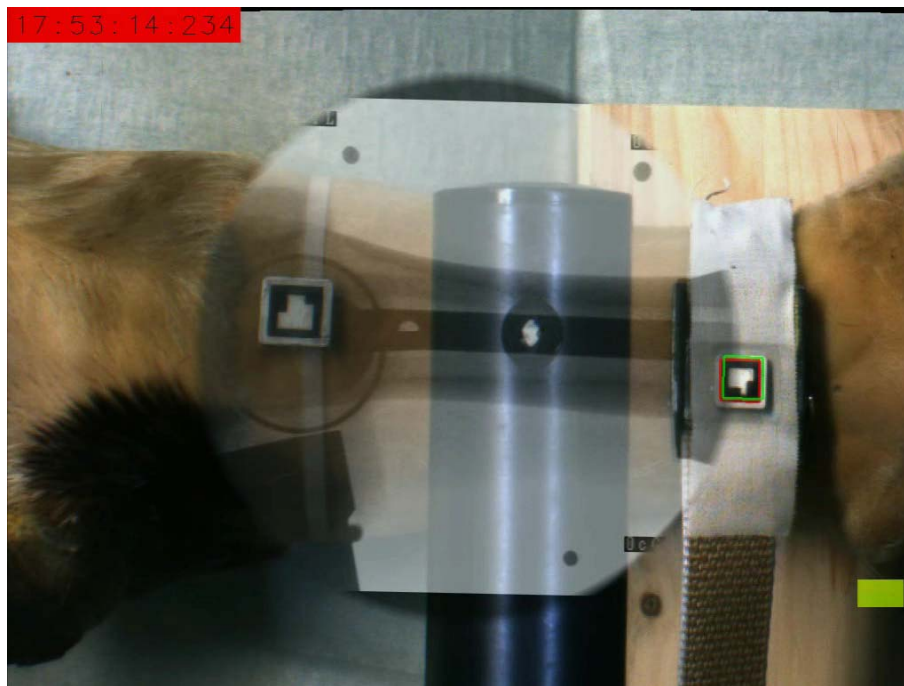


C-arm

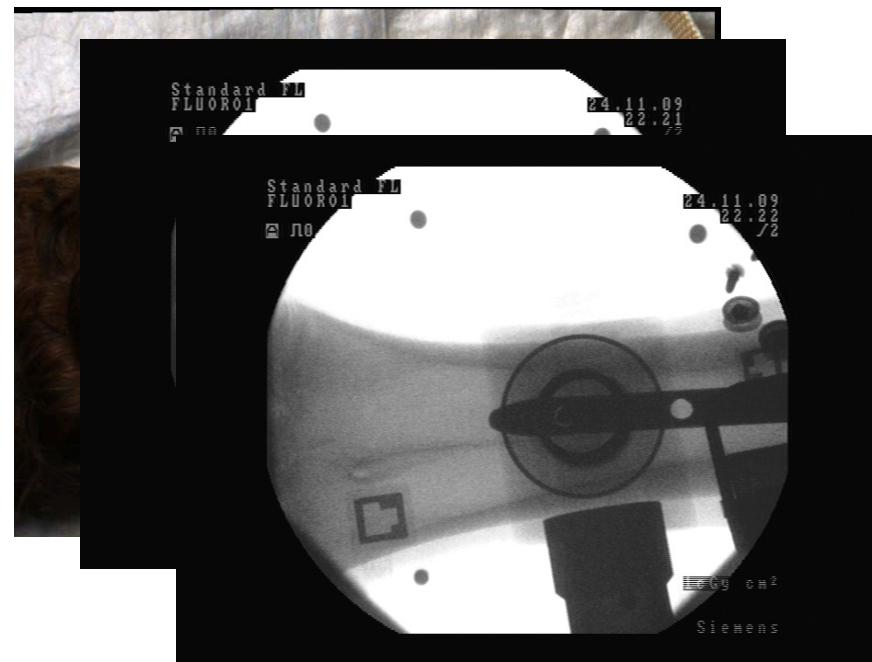
# Drilling



- The overlay of X-ray and video image can support the control of drilling axis



CamC



C-arm



**END OF PRESENTATION**

---