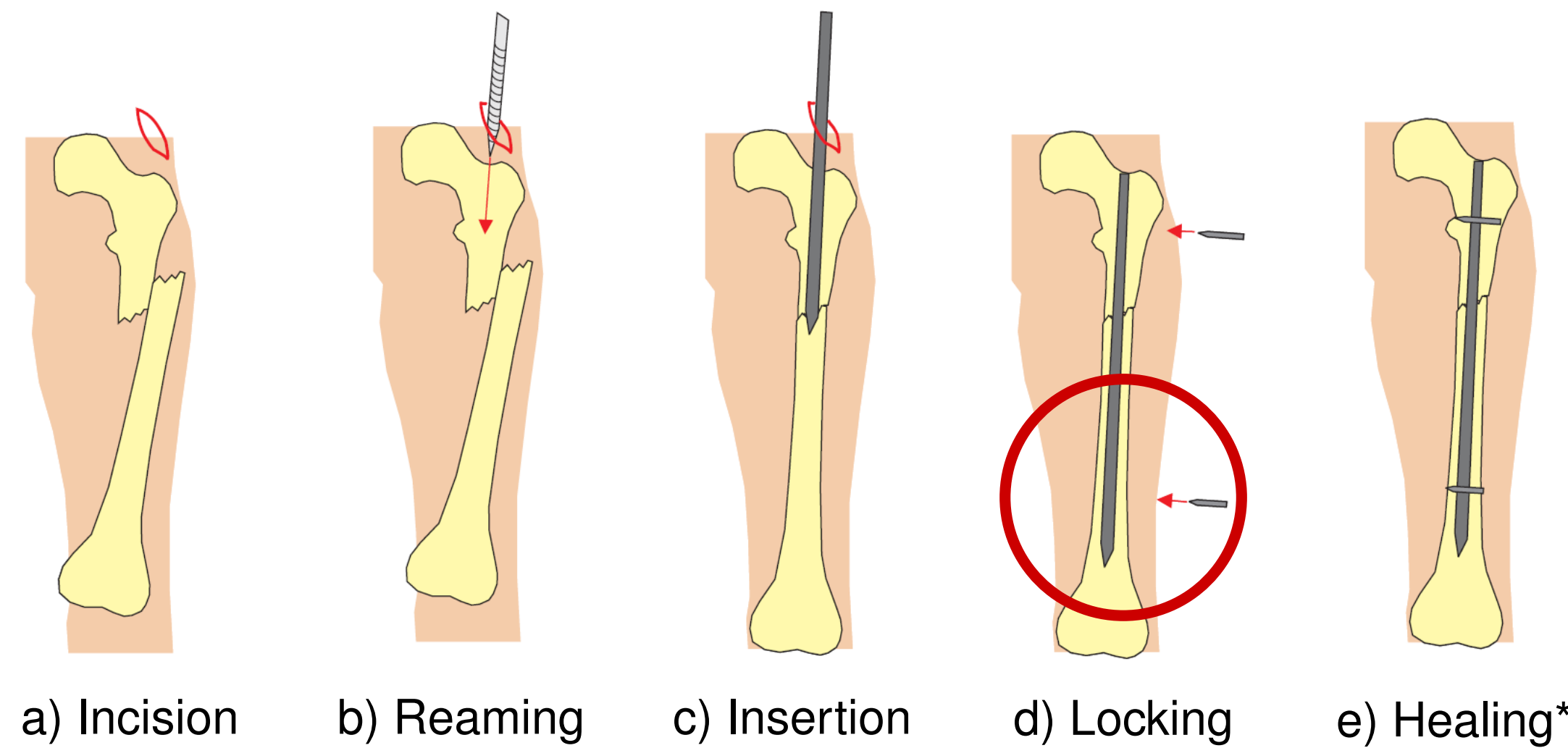


Radiation-Free Drill Guidance in Interlocking of Intramedullary Nails

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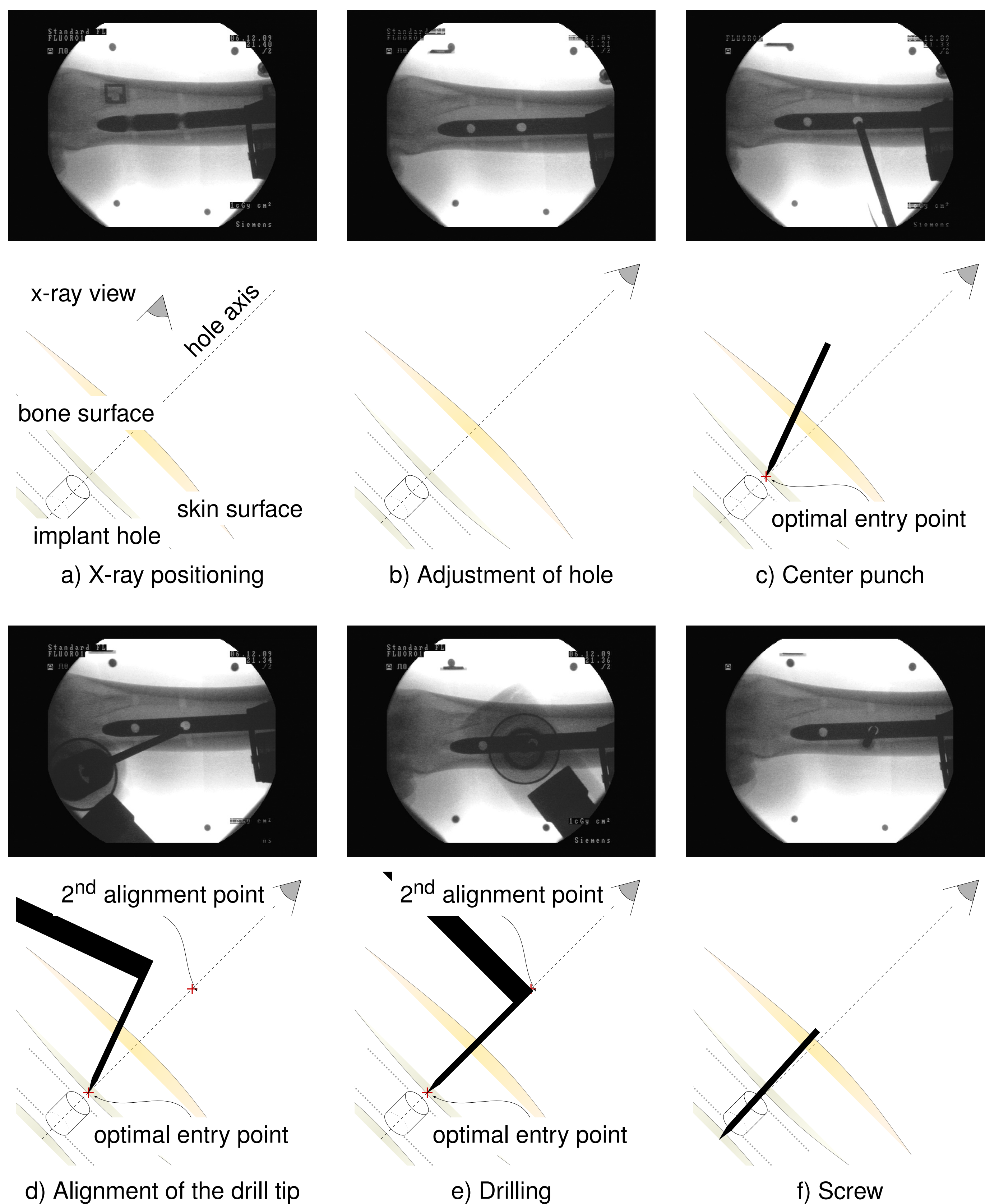
I. Intramedullary nailing



Challenge: Drill freehand through 4-6mm holes at 1-2cm depth under bone surface.

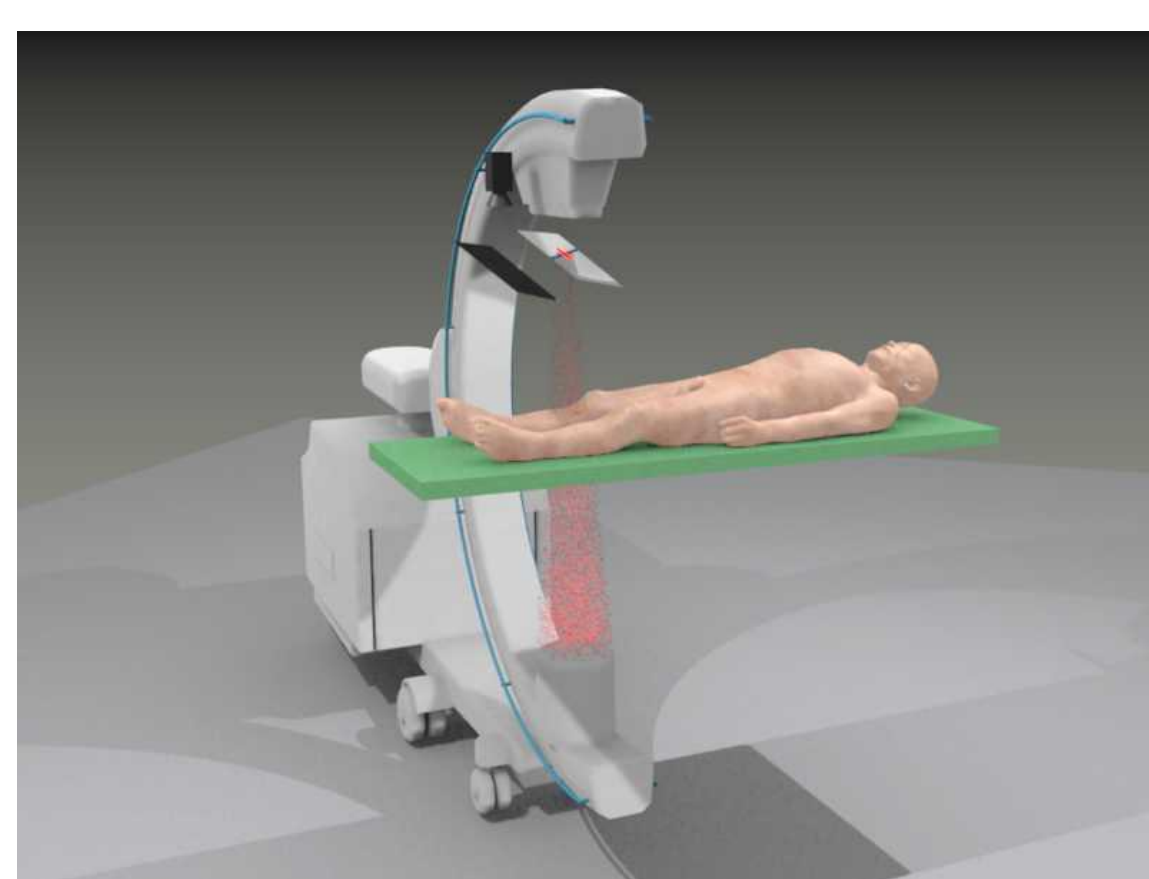
*Taken from Westphal, R., et al.: Robot assisted long bone fracture reduction. The International Journal of Robotics Research (2009)

Conventional Surgical Workflow via X-Rays for Freehand Distal Locking

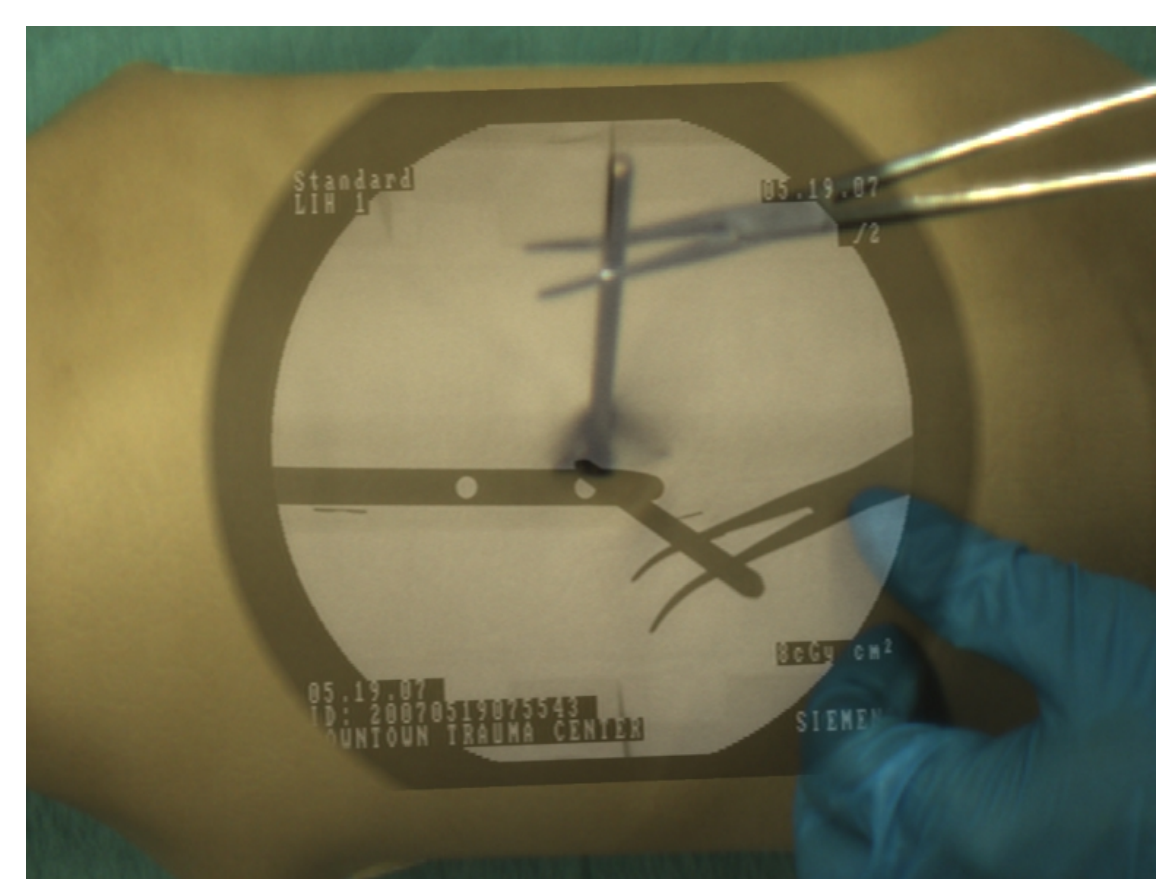


Standard Clinical Practice: 13.1 ± 2.5 X-ray shots and 13.9 ± 3.2 minutes per hole

II. Intra-Operative Augmented Reality: AR-Fluoroscope ²



Mirror construction



X-Ray/Video Overlay

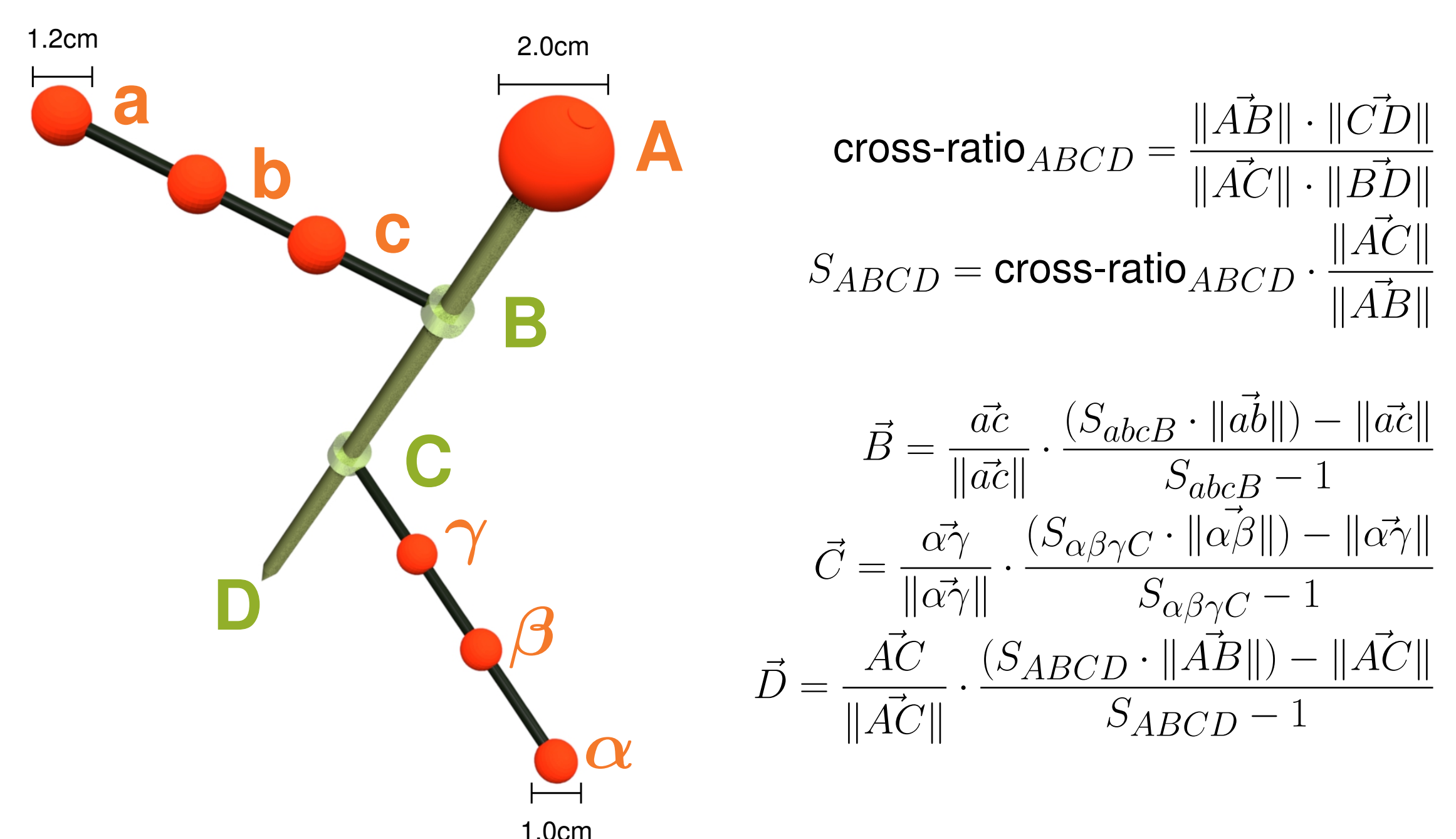
- Instrument tip is not visible in video or reference X-Ray image.
- Surgeons had to revert back to X-Ray guidance.

Navigation solutions other than AR:

- 3D IR-Navigation: Leloup et al., TMI2008 [≥ 2 X-Rays]¹
- Guided X-Rays: Windolf et al., BMC2012 [7.4 ± 3.4 X-Rays]³

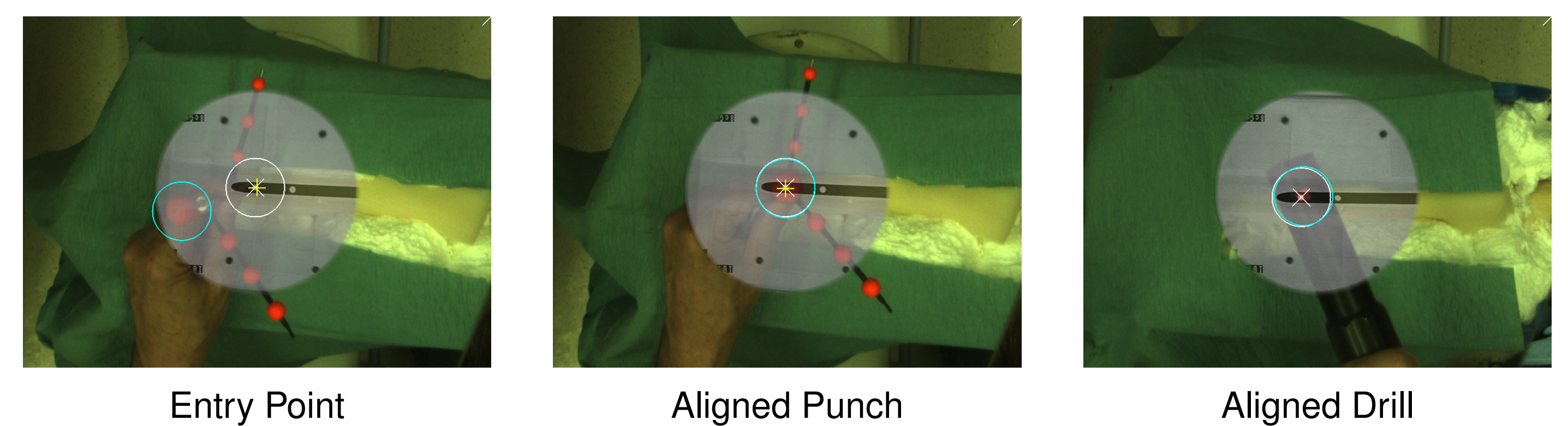
III. Radiation-Free Drill Guidance

Novel Single-View AR Video Guidance based on Chained Cross-Ratios



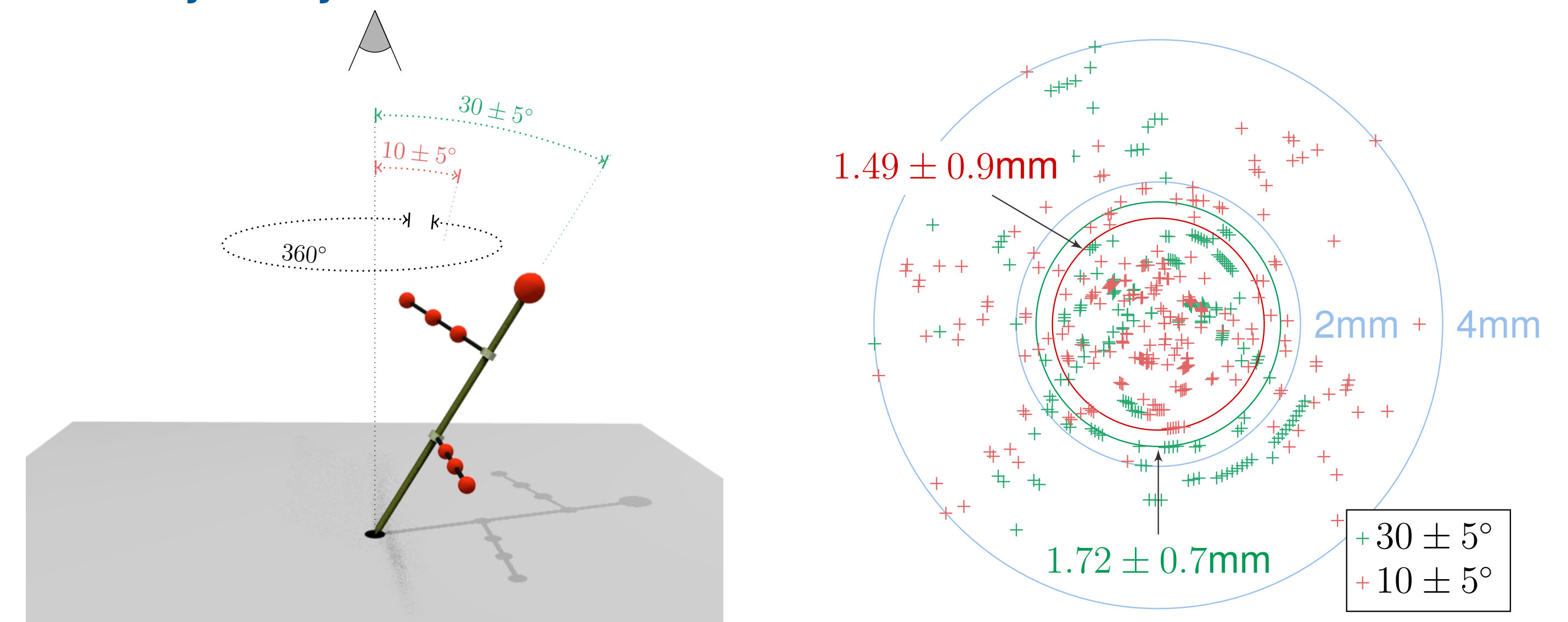
- B and C are first estimated from the side branches.
- The center punch tip (D) is estimated through A, B and C.

Video Augmentations Proposed by Surgeons



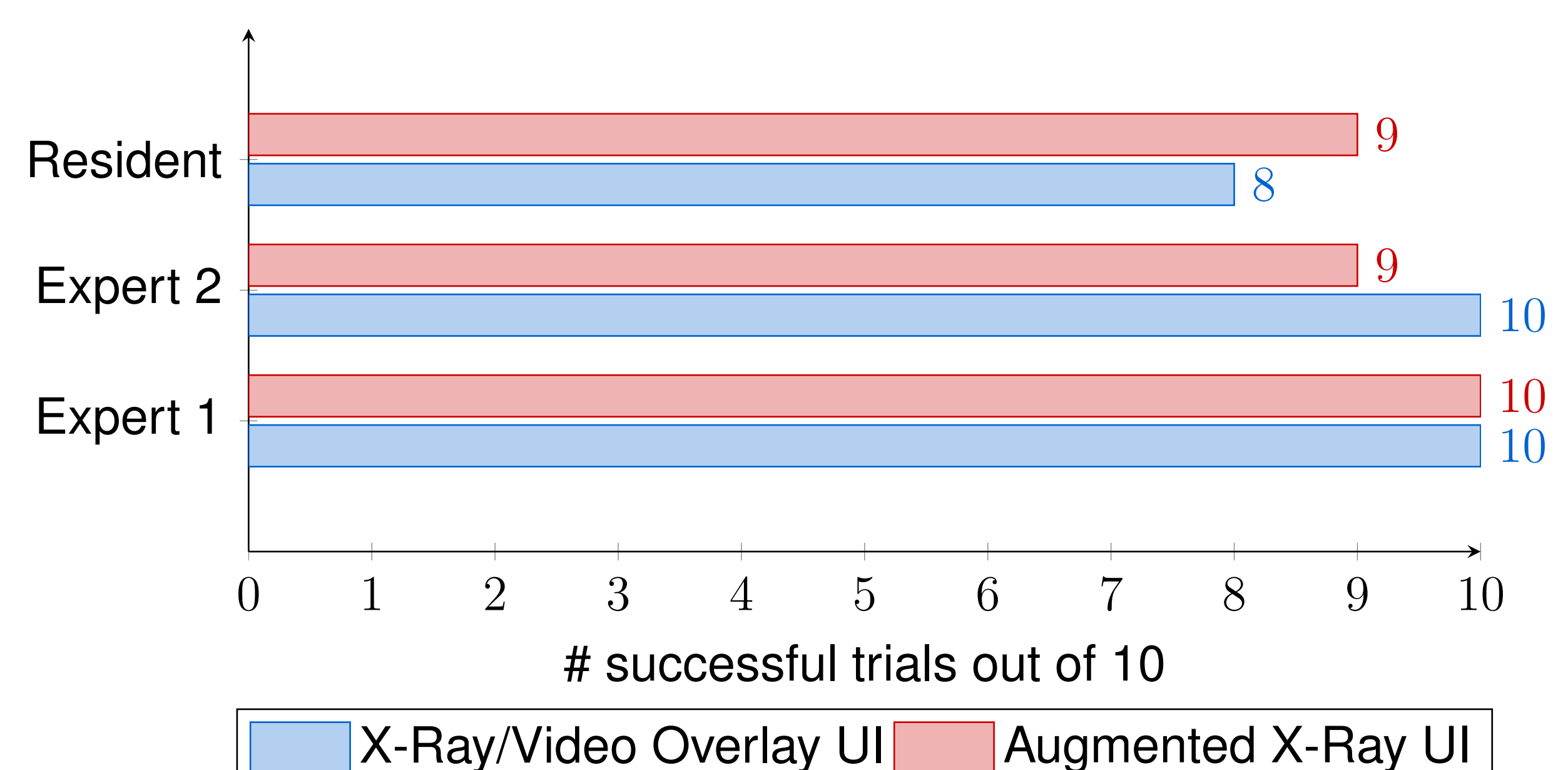
IV. Evaluation

Accuracy Study



- Two sample series; at $10 \pm 5^\circ$ and at $30 \pm 5^\circ$ cone angle towards camera.
- Average error $1.72 \pm 0.7\text{mm}$; 57% of the samples were below the mean error, 98% below 4mm.

Preclinical Experiments on Phantom Bones



- Failures due incorrect hammering on center punch.
- Average of about 2 mins for workflow steps c) to e).

References

- [1] Leloup, T., et al.: A novel technique for distal locking of intramedullary nail based on two non-constrained fluoroscopic images and navigation. IEEE TMI 27(9), 1202–1212 (2008)
- [2] Wang, L., et al.: First animal cadaver study for interlocking of intramedullary nails under camera augmented mobile c-arm: a surgical workflow based preclinical evaluation. In: IPCAI'10, pp. 56–66
- [3] Windolf, M., et al.: Reinforcing the role of the conventional c-arm - a novel method for simplified distal interlocking. BMC Musculoskeletal Disorders 13(1), 8 (2012)