Integrating interventional CBCT imaging into the treatment workflow of traumatic musculoskeletal injuries

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2022 AAPM Annual Meeting – Washington, D.C.
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Disclosures and Disclaimer

- The concept and information presented in this paper are based on research and is not commercially available. Due to regulatory reasons its future available cannot be guaranteed.

- This research was funded in part by a Research Agreement and Funding from Siemens Healthcare GmbH, Erlangen Germany.
Introduction

Mounted

Floor

Detector

X-ray source

Siemens ARTIS pheno

Detector

Siemens cios spin

C-arm

X-ray source

Mobile

O-arm

Medtronic O-arm
Current Clinical Benefits

- Improved accuracy
- Reduced surgical revision probability
- Decrease operative times

Current Clinical Challenges

- **Current field of view**: ~17-20cm
- **Extended lateral field-of-view imaging**
- **Optimized metal artifact reduction imaging trajectories**
- **Metal Artifacts**
- **Laminectomy Pedicle screw fixation**
- **High-risk commonly performed procedures**
- **3D-printed surgical guides**
3D-Printed Surgical Guides

- Compliments surgical experience
- Individualised to each vertebra
- Reduce intraoperative imaging dose

Perforation rate

<1%
3D-Printed Surgical Guides

(1) Pre-operative Imaging
- Thoracic spine
- Cervical spine
- DICOM CBCT Images
- 3DSlicer

(2) Vertebral Segmentation
- T7

(3) Vertebral Models
- T2
- T12 T11 T10 T9 T8 T7
- T5 T4 T3
- C7
- C6 C5 C4 C3 C2
- Longitudinal osteotomy slots

(4) Drill Guide Development
- Template
- Pedicle screw trajectory plan (cylinders)
- Drill guides
- Drill guides
- Longitudinal osteotomy slots
3D-Printed Surgical Guides

(5) 3D-print
3D-Printed Surgical Guides

Pre-operative CBCT scan

Post-operative CBCT scan

32 screws

Mean axial angle difference (planned v measured)

$3.9^\circ \pm 1.9^\circ$

Mean sagittal angle difference (planned v measured)

$1.8^\circ \pm 0.8^\circ$

3D-Printed Surgical Guides

Post-operative CBCT scan

(A) C3   (B) C4   (C) C5   (D) C6   (E) C7

5 levels (10 cuts)

Average thickness of remaining laminar

1.6±0.2mm
Current Clinical Challenges

Current field of view: ~17-20 cm

Extended lateral field-of-view imaging

Optimized metal artifact reduction imaging trajectories

Metal Artifacts

Laminectomy

Pedicle screw fixation

High-risk commonly performed procedures

3D-printed surgical guides
Metal Artifact Reduction

Problem: Metal artifacts

Solution: Non-circular image acquisition
Metal Artifact Reduction

Y. Ma et al. Non-circular orbits on a clinical robotic C-arm for reducing metal artifacts in orthopedic interventions. American Association of Physicists in Medicine Annual Meeting 2021
Current Clinical Challenges

- **Current field of view**: ~17-20cm
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Extending the field of view

Extended field of view imaging

Problem:
Limited field of view

Solution:
Multi-turn reverse helical imaging
Extending the field of view

C-arm gantry rotation

Table start position

Table end position

T. Reynolds et al. Extended intraoperative longitudinal 3-Dimensional cone beam computed tomography imaging with a continuous multi-turn reverse helical scan. Investigative Radiology 2022
Extending the field of view

(A) Table

(B) C-arm

Positions, Velocities, Accelerations vs. Time for Table and C-arm
Extending the field of view

**Pre-operative imaging:**
CT

**Intraoperative imaging:**
CBCT: Multi-turn reverse helical

3D-3D registration immediately prior to procedure

T. Reynolds et al. *Extended intraoperative longitudinal 3-Dimensional cone beam computed tomography imaging with a continuous multi-turn reverse helical scan.* Investigative Radiology 2022
Extending the field of view

**Post-operative imaging:**
CT

**Intraoperative imaging:**
CBCT: Multi-turn reverse helical

Bring CT like coverage into the operating room for surgical verification

**Mean axial angle difference (CT v multi-turn reverse helical):**
3.3° ± 2.6°

**Mean sagittal angle difference (CT v multi-turn reverse helical):**
1.9° ± 1.5°

T. Reynolds et al. Extended intraoperative longitudinal 3-Dimensional cone beam computed tomography imaging with a continuous multi-turn reverse helical scan. Investigative Radiology 2022

American Association of Physicists in Medicine Annual Meeting 2022 – Thursday 7/14/22 @ 1:10pm

Future directions

- Extended FOV coverage (eliminate transfer CT)
- Weight bearing imaging

Emergency room

Operating room

Out patient

- Extended FOV coverage (eliminate transfer CT)
- Metal artifact reduction imaging
- Weight bearing imaging
Research Team and Collaborators

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3D-printed surgical guides
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