TOWARDS QUANTIFICATION OF KIDNEY STONE USING X-RAY DARK-FIELD TOMOGRAPHY

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Introduction

- Kidney stones is:
  - a renal disease with high prevalence and lifetime recurrence rate
  - one of the major reasons for emergency room visits
- Treatment of kidney stones is an increasing important topic
- Different types of kidney stones require specific treatments, accurate diagnosis is the key [1]
- Common imaging techniques are insufficient to differentiate kidney stone types [2]
- We present a **proof-of-concept study for differentiating kidney stones using X-ray dark-field tomography**
- The voxel-wise ratio dark-field/absorption is evaluated for kidney stones quantification

Methods and Experiments

- Reconstruction as optimization problem:

$$\underset{\mathbf{u}^{\cdot}\in R^n}{\operatorname{argmin}} \|\mathbf{u}^{\cdot}\|_{\mathrm{wTV}} \quad \text{s.t.} \quad \mathbf{A}\mathbf{u}^{\cdot} = \mathbf{p}^{\cdot} \ .$$

$\mathbf{A}$: system matrix $\|\cdot\|_{\mathrm{wTV}}$: weighted TV norm
$\mathbf{u}^{\cdot}$: absorption/dark-field signals
$\mathbf{p}^{\cdot}$: absorption/dark-field projections

- A weighted total-variation-regularized reconstruction algorithm [3] is applied in CONRAD framework[4]

- Evaluation is performed on:
  - **Pure materials kidney stones**: one calcium oxalate stone and one struvite stone:
    - X-ray tube voltage of 80keV
    - Two frames are averaged per image
    - 400 projections on a half circle
    - Stones with diameters between 3mm to 5mm
  - **Phantom of a mixture of kidney stones** (Fig. 1):
    - Voxel in equal parts randomly labeled as calcium oxalate and struvite
    - Averaged absorption/dark-field signals from real stones are used as voxel coefficients
    - Sinogram is generated from 400 projections with Gaussian noise

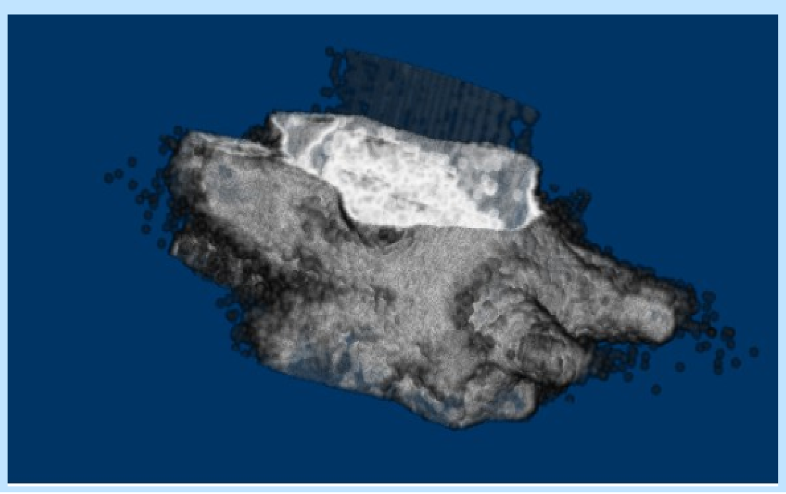

Fig. 1 : a 3-D volume rendering of the full phantom.

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Results and Discussion

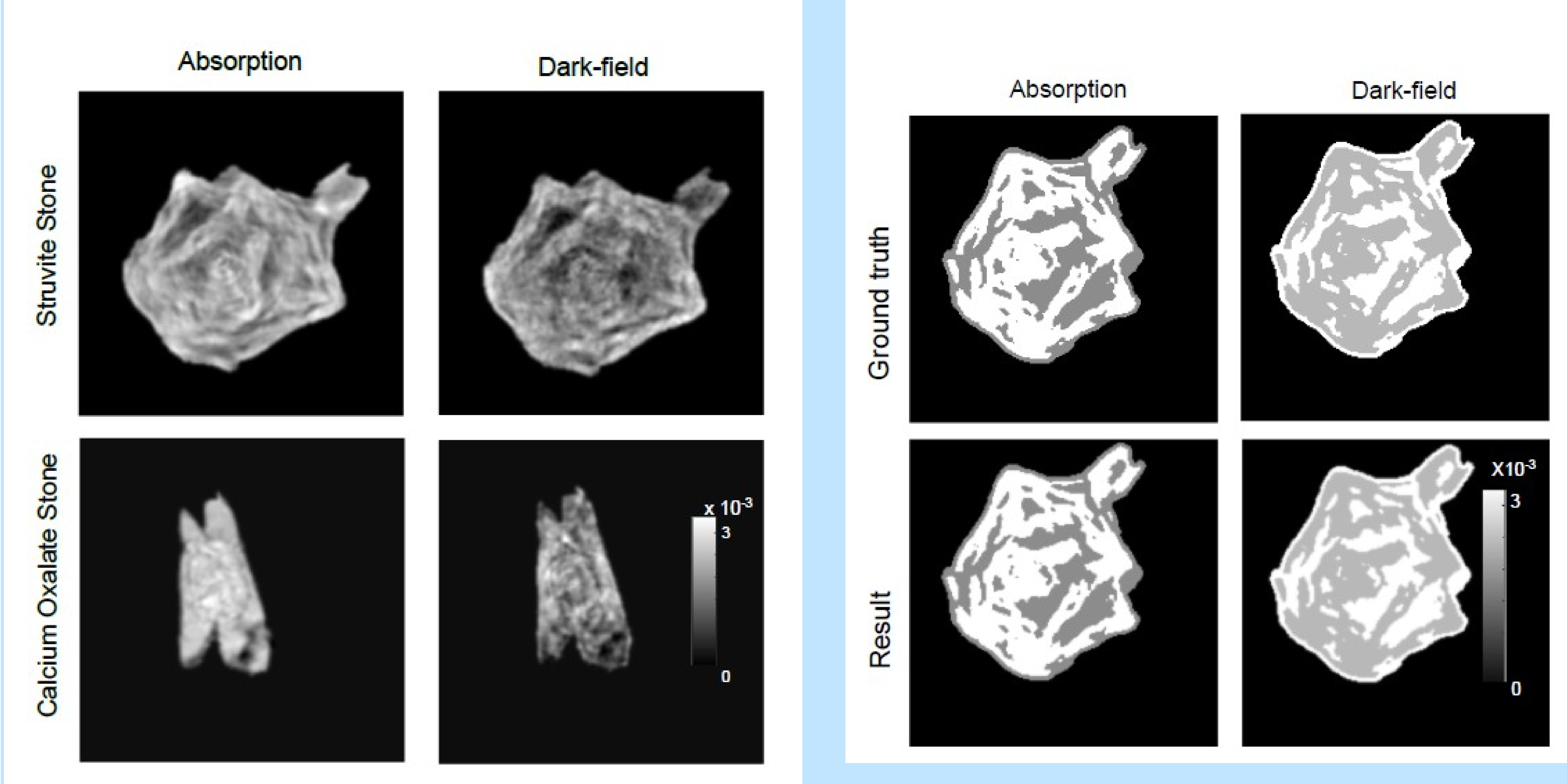

Fig. 2: Reconstruction of real stone (left) and phantom (right)

- Figure 2: Reconstructions of the scanned stones and the phantom.
  The struvite stone shows **higher mean absorption and lower mean dark-field** than calcium oxalate stone.

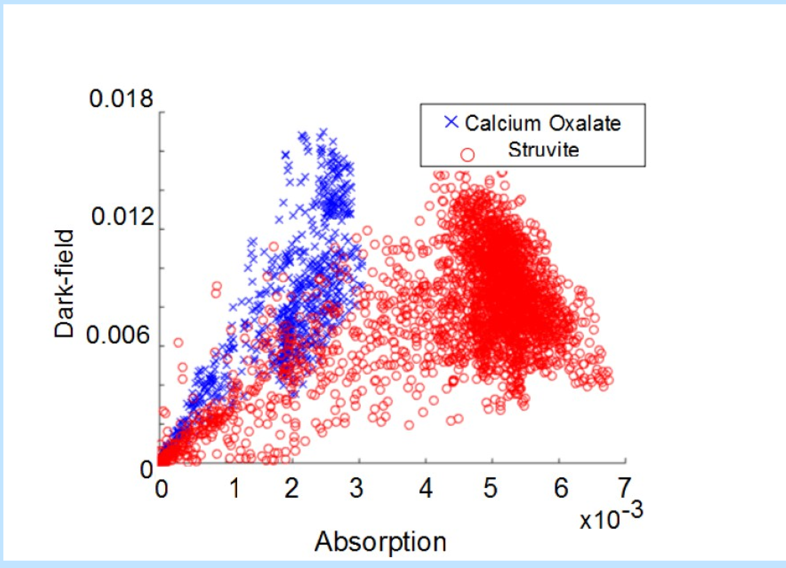

Fig. 3: dark-field /absorption of one representative slice from struvite (red) and calcium oxalate (blue).

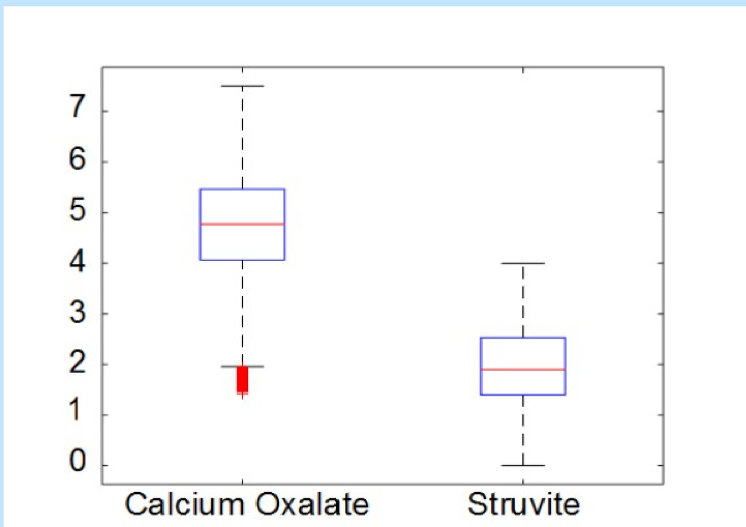

Fig. 4: Box-whisker diagram of dark-field/absorption from both stones.

- Stone types differ in dark-field/absorption ratio (Fig. 3)
- Both stone types are clearly separable (Fig. 4)

Conclusions

- X-ray dark-field tomography has the potential to characterize kidney stones
- Struvite and calcium oxalate stones can be distinguished in experiments on real data
- Phantom study of mixture stone types indicates the ability for mixed-type stone differentiation.
- Future work of investigation the effectiveness is required

Reference

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