A Phantom for CT Gout Identification: Fabrication and Longevity

Joseph S. Ausmus, MS; Robert G. Paden, MS; Samuel J. Fahrenholtz, PhD; and William F. Sensakovic, PhD
Mayo Clinic, Phoenix, AZ

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Purpose

To develop a phantom for evaluating CT gout identification and to determine gout phantom longevity

Innovation/Impact

This study describes the fabrication of a phantom suitable for evaluating, optimizing, and harmonizing CT gout identification. We tested multiple materials and confirmed that the phantom is stable over roughly 2.5 months, which should be sufficient for clinical and research uses.

Gout Optimization

Phantom-Based Optimization of CT Gout Identification: Impact of Acquisition, Reconstruction, and Processing Settings by Ausmus, Fahrenholtz, Paden, & Sensakovic

CONTACT

William F. Sensakovic
Mayo Clinic
Phoenix, AZ
Sensakovic.William@mayo.edu

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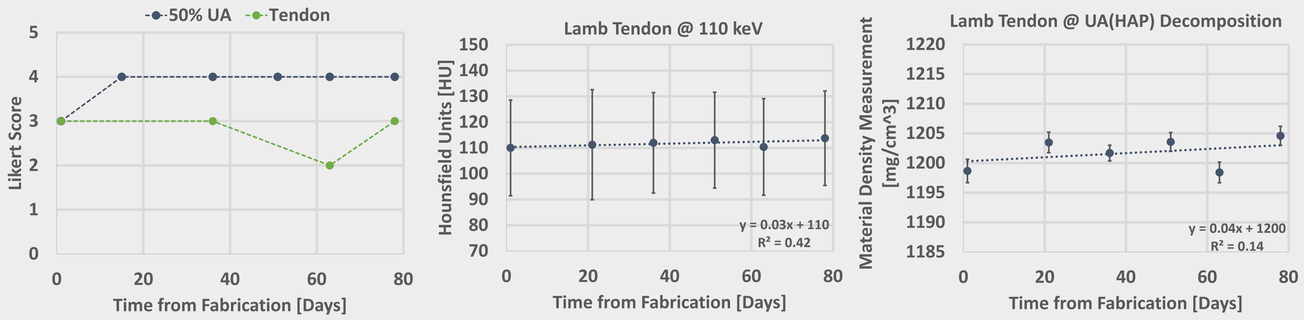
INTRODUCTION

- Evaluating, optimizing, and harmonizing CT gout identification protocols requires a consistent standard for comparisons
- A phantom for such tasks must:
  - Accurately mimic tissue attenuation & size
  - Accurately mimic pathology
  - Be inexpensive & have a reasonable difficulty to assemble
  - Have longevity appropriate for repeated scanning for the task
- This study investigated the construction of a phantom suitable for CT gout identification

RESULTS

- HU for soft tissues:
  - Agar 17±13 HU, gelatin 43±14 HU, & polyacrylic 4±27 HU
- HU for tendon (Chart 1):
  - Lamb tendon 107±14 HU, beef tendon 144±13 HU, rawhide 119±31 HU, & polyurethane 66±2 HU
- Likert, HU, & concentration longevity trends were small and not clinically significant (Chart 1)
- Longevity was:
  - Last imaging taken at 78 days
  - Fungal growth substantial at 93 days
- Desiccation change:
  - Phantom contracted < 1 mm



Likert Scale:
0: not detected
1: < 20% insert volume identified
2: 21% - 50% insert volume identified
3: 51% - 80% insert volume identified
4: > 80% insert volume identified

Chart 1. Left: Likert score from one physicist for tendon and uric acid (UA). Images were scored using the default setting and gout overlay (Figure 1). Middle: Hounsfield units were stable over weeks. No trends were appreciated across all inserts, though small trends were noted within individual inserts. Right: Concentration (i.e., material density) for UA(HAP) were also stable with small trends that were not clinically significant. All error bars are measurements of sample standard deviation and not standard error.

METHODS AND MATERIALS

- Different human tissue mimics were tested
  - Soft tissue: agar, gelatin, & polyacrylic
  - Tendon: lamb tendon, beef tendon, rawhide, & polyurethane
  - Gout: uric acid (UA) & UA sodium salt (UASS)
  - Pseudo-gout: calcium pyrophosphate
- Materials were evaluated based on:
  - Difficulty to work with
  - HU on 110 keV monoenergetic reconstructions
  - Material decomposition concentrations
- A final phantom was fabricated based on the best materials for each tissue
  - Dimensions were similar to a human lower leg: 5” x 7.5” x 5”
  - Inserts: Gout and pseudo-gout mimics with concentration of 10%-50%, tendon, bone, & 50% gout cubes with side length of 2-10 mm
- Phantom measurements were made between Day 1 and Day 78
  - HU at 110 keV
  - Concentrations in gout decomposition
  - Gout overlay images were evaluated on a 5-point Likert scale (Chart 1)
  - Agar dimensions
- Construction time & cost were estimated

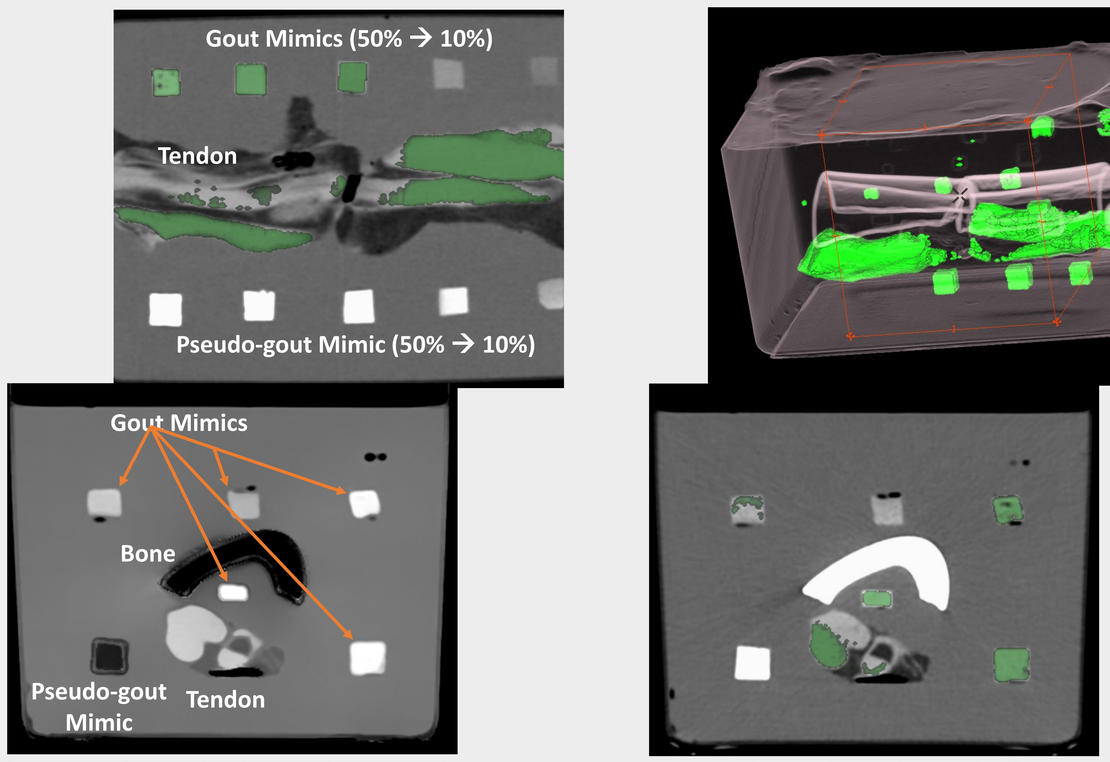


Figure 1. Top Left: Coronal CT slice through phantom 70 keV mono-energetic reconstruction with uric acid overlay (green). Identification used the vendor’s default identification settings. Note the identification of 30%-50% gout inserts and large parts of the tendon (Likert rating 3), but not the pseudo-gout mimic at any tested concentration (Likert rating 0). Top Right: Volumetric reconstruction with uric acid overlay (green). Bottom Left: Uric acid (hydroxyapatite) decomposition. Note the bright gout mimics and dark bone and pseudo-gout inserts. Bottom Right: 110 keV image through the same slice with identification overlay (green).

DISCUSSION

- Agar was the preferred tissue material due to its more solid structure and melting point allowing the phantom to be poured in layers without melting the previous layer or inserts
- UA was preferred due to lower cost and inability to dissolve UASS in high concentrations
- Lamb tendon was preferred due to its HU similarity to human tendon
- No consistent and clinically meaningful HU, concentration, or Likert rating changes over time were noted among inserts
- Materials were generally stable for 2.5 months
  - Keeping plastic wrap on the exposed side, refrigeration, and keeping the container lid on extended longevity
  - Fungal growth was at the top surface only and could be removed if necessary to improve longevity
  - Contraction from desiccation was very small and only affected the phantom side exposed directly to air
- Constant mixing of inserts during solidification is necessary to ensure homogeneity
- Pouring the phantom requires about 12 hrs including waiting for layers to cool and we believe that time could be reduced by optimizing the process
- Cost per phantom was ~$250 in materials

CONCLUSIONS

A cheap phantom suitable for evaluating CT gout identification was developed. Phantom longevity makes it useful for evaluation and quality tasks. Future work will focus on reducing fabrication time and identifying elements that could be made permanent.