Comparison of Transmissions from Erbium, Molybdenum, and Thulium vs Lead for Use in Reduction of Downscatter-Crossstalk Photons in Nuclear Cardiology Imaging

Kingsley Anosike¹, Nathan Gaffney¹, Richard Stahman¹, and Dr. Gregory Passmore² (Mentor)
¹College of Mathematics and Sciences, ²College of Allied Health Sciences
CURS Summer Scholars Program, Georgia Regents University, Augusta, Georgia

INTRODUCTION

Technetium-99m (99mTc - 140 keV peak) and Thallium-201 (201Tl - 70-80 keV peaks) are radionuclides that are used to analyze the health of myocardial tissue. The amount of each radionuclide present in the myocardium is imaged using a gamma camera which allows medical professionals to determine the health of a patient's heart (Figure 1). Collimators are large metal gratings that are constructed to allow only geometrically orthogonal photons to be captured by the gamma camera in order to obtain the highest resolution possible to aid in accurate diagnosis. Lead (Pb) is commonly used as a collimator material, but it has an 88 keV K-shell photon, which interferes with the lower energy photons from the 70-80 keV energy 201Tl peaks. This phenomenon is known as “down-scatter” or “cross-talk”.

This project is designed to test the feasibility of using dense metal attenuators (Erbium, Er; Molybdenum, Mo; and Thulium, Tm) rather than lead (Pb) to reduce the significant 99mTc cross-talk photons in the 201Tl photopeak range. Use of other dense metals with low K-shell absorption peaks should reduce the down-scatter component and eliminate the Pb x-ray cross-talk interference in the 99mTc energy window. Acquisitions of energy spectra for the dual isotopes will be obtained for the non-Pb metals Er, Mo, and Tm. Outcomes are based on transmission spectra and attenuation acquisitions using comparative statistics to ascertain the extent of scatter component and interference reduction gained through the use of a non-Pb collimator.

Figure 1.

METHODS

- To determine which metals were suitable for testing, we evaluated metals with densities near that of lead (Pb) and K-shell X-ray energies below 80 keV.
- Linear attenuation coefficients were derived from the NIST physical reference database for photons in the 80 and 150 keV energy range. Calculations were conducted for the metal 1/2 penetration ratios. This was done using the standard attenuation equation: \( P(x) = \frac{1}{2} P(0) \cdot e^{-\mu x} \).
- \( 99mTc \) source was collimated and placed in a plastic isotope stand over the lead the multi-channel analyzer to ensure consistent geometry.
- Counts were acquired in the energy window and the 201Tl energy window.
- Sliced metal disks were placed atop the hole of the NaI well counter during trials testing metal attenuation.
- The plastic isotope stand with the source secured was placed atop the slice.
- Counts with no metal attenuator (null) a Pb control metal attenuator, and the three selected metal attenuators were recorded.
- The percent transmission of each metal was collected by taking the respective \( \frac{1}{2} \text{penetration} \) ratios from the recorded radiation counts.
- \% Transmission = Counts with attenuator (I) / Counts null (I0)
- $T = \frac{\mu_1}{\mu_2}$ test was conducted to determine the significance of the difference in the mean of the percent transmission for all three metals in comparison to lead (Pb).

RESULTS

Table 1. Metal characteristics.

<table>
<thead>
<tr>
<th>Metals</th>
<th>Z</th>
<th>$\mu$ (g/cm²)</th>
<th>$\mu$ (80 keV)</th>
<th>$\mu$ (150 keV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb</td>
<td>82</td>
<td>11.34</td>
<td>88</td>
<td>27.4</td>
</tr>
<tr>
<td>Er</td>
<td>57</td>
<td>9.07</td>
<td>57</td>
<td>58.8</td>
</tr>
<tr>
<td>Mo</td>
<td>42</td>
<td>10.28</td>
<td>19</td>
<td>20.2</td>
</tr>
<tr>
<td>Tm</td>
<td>69</td>
<td>9.32</td>
<td>59</td>
<td>59.7</td>
</tr>
</tbody>
</table>

Table 2. Transmission/attenuation comparisons.

<table>
<thead>
<tr>
<th>Metals</th>
<th>% Trans</th>
<th>% Metal vs. Pb</th>
<th>% Trans</th>
<th>% Metal vs. Pb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb</td>
<td>96</td>
<td>control</td>
<td>91</td>
<td>control</td>
</tr>
<tr>
<td>Er</td>
<td>94</td>
<td>T = 4.766</td>
<td>93</td>
<td>T = 4.615</td>
</tr>
<tr>
<td>Mo</td>
<td>92</td>
<td>p = 0.0001*</td>
<td>97</td>
<td>T = 10.307</td>
</tr>
<tr>
<td>Tm</td>
<td>94</td>
<td>T = 4.191</td>
<td>93</td>
<td>T = 3.686</td>
</tr>
</tbody>
</table>

CONCLUSIONS

T-tests showed that all differences in transmission between Er, Mo, and Tm were significant when compared to Pb in both the 99mTc energy range and the 201Tl energy range. Er, Mo, and Tm performed better as attenuators (lower percent transmission) than lead in the 201Tl energy range. All three, however, did not perform as well as Pb in the 99mTc energy range. Cross-talk was not observed using the Er, Mo, and Tm attenuators and is possibly the reason all three performed better than Pb in the 201Tl energy range. The 88 keV K-shell photon from the Pb added counts in the 201Tl range thus appearing to lower the attenuation.

Er was found to transmit less photons in the 201Tl range than Pb. However, Pb transmitted less photons than Er in the 99mTc range. Tb had similar transmission data in both 201Tl and 99mTc ranges which yielded identical transmissions to two significant figures. Both have K-shell x-rays below the 201Tl window (Table 1) which meant that there was no cross-talk for both Er and Tb in the 99mTc energy window or the 201Tl energy range. Mo had the lowest transmission for the 201Tl peak of the metals examined and the lowest K-shell x-ray (20 keV) demonstrating that Mo was the best attenuator for the 201Tl energy range. However, Mo had the highest transmission for the 99mTc energy range. T-tests confirmed that the aforementioned differences in transmission were statistically significant. The 88 keV K-shell x-ray from Pb likely added cross-talk in the 99mTc energy range which made the transmission appear higher in that range for Pb. It is possible that the Pb attenuated more photons from the source compared to Er, Mo and Tb, but cross-talk from the K-shell x-rays in the Pb added to the final counts.

REFERENCES