linear attenuation coefficient at any energy can be obtained
optimization for the given DE spectra. BMD assumes that
projection-based basis material decomposition (BMD) method
photoelectric/Compton basis (Ph/Co) with exponent
water/compact bone basis (W/CB) and
of [2] were investigated. 2 variants for BMD were considered:

Material and Methods:

Comparison of stopping power estimators from dual-energy

Purpose or Objective: Proton range in patients is
determined from the stopping power ratio (SPR) of tissues
relative to water along the beam path. SPR map can be
derived from dual-energy computed tomography (DECT) and
the Bethe-Bloch equation. In this study, we propose and
compare the accuracy and the precision of several
procedures to estimate the SPR from DECT.

Material and Methods: Image-based method of [1] and
projection-based basis material decomposition (BMD) method
of [2] were investigated. 2 variants for BMD were considered:
water/compact bone basis (W/CB) and
photoelectric/Compton basis (Ph/Co) with exponent
optimization for the given DE spectra. BMD assumes that
linear attenuation coefficient at any energy can be obtained
by a linear and energy-independent combination of these
basis functions. Electron density ρe and effective atomic
number Zeff are common DECT outputs. For each
decomposition method, 4 empirical relationships to convert
DE outputs to SPR were evaluated which were all calibrated
with materials used by [3] for the stoichiometric calibration.
The first approach [4] was a calibrated relation between the
logarithm of the mean excitation energy of tissues Im and
Zeff (Zeff, In Im). The second approach consisted in
reconstructing the electronic cross section at 100 keV oe,100
from the BMD results. To avoid intermediate variable Zeff, a
novel calibrated relation between oe,100 and Im values
(oe,100, Im) was proposed. The third method involved a
calibration curve between (oe,100, SPR/ρe). The last
approach consisted in the direct conversion of pe into SPR
through the (pe,SPR/ρe) relation proposed by [5]. Only
the last method can be considered independent of the energy
spectra.

Virtual DECT acquisitions of the imagingRing (medPhoton,
Salzburg) of the phantom Gammex 467 were carried out by
means of deterministic Monte Carlo simulations in Gate
with realistic detector response model. Scatter-free fan-beam
acquisitions with 720 projections were considered. Realistic
Poisson noise corresponding to a 20mGy central dose was
added to the projections.

Results: Relative errors of SPRs of phantom inserts estimated
using 4 empirical relationships for each decomposition
method are shown in Table1 as μ ± σ. A penalty was imposed
to pixel values with Im, Zeff and oe values outside human
range. Lung tissue inserts show maximum error. (oe,100,
SPR/ρe) approach is the least appropriate in terms of
precision. (oe,100, Im) and (Zeff, ln Im) behave in the same
manner. Results show that the method proposed by [5]
provides better accuracy and precision.

Conclusion: Comparison of different calibration methods to
convert DE data into SPR was carried out. A novel
relationship between oe and Im was proposed and behaves
similarly to (Zeff, ln Im) curve. Energy independent poly-line
(pe,SPR/ρe) curves present better accuracy and precision.
DECT is a promising technique to determine the SPR of
human tissues. Optimization of the acquisition parameters
and the algorithm to extract the required patient information
is mandatory.

References:


EP-1847 Dual-energy CT for range prediction in proton and
ion therapy

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Conclusions: Novel calibrated relations between σe,100 and Im
values outside human range. Lung tissue inserts show
maximum error. (σe,100, SPR/ρe) approach is the least
appropriate in terms of precision. (σe,100, Im) and (Zeff, ln Im)
behave in the same manner. Results show that the method
proposed by [5] provides better accuracy and precision.

Table 1: Relative errors in the SPRs of phantom inserts for different
DECT methods and empirical relationships considered in this study to
calculate dual-energy data to SPR.

<table>
<thead>
<tr>
<th>Method</th>
<th>(m, ln Im)</th>
<th>(σe,100, SPR/ρe)</th>
<th>Image-based</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMD (W/CB)</td>
<td>0.2 ± 0.0</td>
<td>0.3 ± 0.4</td>
<td>-</td>
</tr>
<tr>
<td>BMD (Ph/Co)</td>
<td>-1.9 ± 7.4</td>
<td>-0.3 ± 13</td>
<td>0.2 ± 0.3</td>
</tr>
<tr>
<td>(Zeff, ln Im)</td>
<td>-1.9 ± 7.4</td>
<td>-0.3 ± 13</td>
<td>0.2 ± 0.3</td>
</tr>
</tbody>
</table>