Internal dose estimation for iodine thyroid blocking (ITB)

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Introduction

1. Background
2. Internal dose estimation for thyroid blocking
Introduction

◆ Iodine thyroid blocking (ITB)
  - By stable iodine (potassium iodide, KI) administration
  - Significantly reduced effectiveness by delay of administration

◆ Internal dose assessment for thyroid blocking

\[
Internal\ dose = \frac{M}{m(t)} \times e(50) \quad \rightarrow \text{Dose coefficient}
\]

  ▪ Absence of dosimetric data for thyroid blocking
    - ICRP reference data does not consider the thyroid blocking
    ⇒ **Dosimetric data considering iodine thyroid blocking** is required
Thyroid blocking in biokinetic model

1. Thyroid blocking mechanism
2. Implementation of thyroid blocking in iodine biokinetic model
3. Calculation of dosimetric data
Implementation of thyroid blocking in biokinetic model

- Thyroid blocking in biokinetic model

Three-compartment model (ICRP 56)  
- blocking of thyroid uptake

New model (ICRP 137)  
- inhibition of thyroidal hormone synthesis
01 Implementation of thyroid blocking in biokinetic model

- Time-dependent transfer rate, $r_{Th}$
  - Serum (Blood) concentration of inorganic iodide $\leftrightarrow$ Thyroid uptake suppression
  - $r_{Th} \leftrightarrow$ Thyroid uptake (suppression)

$$r_{Th} = R \cdot 0.377 \cdot I_{serum}^{-0.9}$$

$R$ = notational rate constant (77.52)
$I_{serum}$ = inorganic iodide concentration in serum ($\mu g/dL$)

Human experiment (Blum & Eisenbud, 1967)

Biokinetic model calculation (KIRAMS)
Calculation of dosimetric data

- Calculation of compartment model
  - by KIRAMS computer module (MATLAB)
  - The calculation time step: 1 h (0.04 d)
  - $r_{Th}$ was repeatedly calculated and substituted at each calculation step

- Calculation of dose coefficients

  ICRP publication 103
  SAF based on Voxel phantom (ICRP 133)
  Nuclide decay data (ICRP 107)
Verification and validation

1. Verification of calculation algorithm and modules
2. Validation of biokinetic model regarding thyroid blocking
01 Verification of calculation algorithm and modules

◆ Comparison of dose coefficients for normal thyroid with ICRP reference
  ▪ For I-131 (ICRP 137), deviation ~ 2.2 %

< I-131, inhalation, Type F, AM >
02 Validation of biokinetic model regarding thyroid blocking

- Comparison with experimental data

Thyroid uptake after exposure (administration at 2 h after exposure)

Protective effect (administration of 100 mg KI)
Dosimetric data for thyroid blocking

1. Thyroid retention functions
2. Dose coefficients
3. Dose per content function (DPCF)
Thyroid retention functions according to the administration time
(I-131 inhalation, type F, 1μm)

Administration 'before' exposure

Administration 'after' exposure
Thyroid equivalent dose coefficients

Thyroid equivalent dose coefficients according to the administration time
(I-131 inhalation, type F, 1μm)

<table>
<thead>
<tr>
<th>Administration time (h)</th>
<th>Thyroid Dose Coefficients (Sv/Bq)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adult males</td>
</tr>
<tr>
<td>-96</td>
<td>3.40E-07</td>
</tr>
<tr>
<td>-72</td>
<td>2.98E-07</td>
</tr>
<tr>
<td>-48</td>
<td>1.55E-07</td>
</tr>
<tr>
<td>-24</td>
<td>4.66E-08</td>
</tr>
<tr>
<td>-12</td>
<td>2.32E-08</td>
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<tr>
<td>0</td>
<td>1.17E-08</td>
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<tr>
<td>2</td>
<td>8.15E-08</td>
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<tr>
<td>4</td>
<td>1.42E-07</td>
</tr>
<tr>
<td>6</td>
<td>1.88E-07</td>
</tr>
<tr>
<td>8</td>
<td>2.24E-07</td>
</tr>
<tr>
<td>10</td>
<td>2.52E-07</td>
</tr>
<tr>
<td>12</td>
<td>2.73E-07</td>
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<tr>
<td>16</td>
<td>3.02E-07</td>
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<tr>
<td>20</td>
<td>3.19E-07</td>
</tr>
<tr>
<td>24</td>
<td>3.29E-07</td>
</tr>
</tbody>
</table>
Insensitive measurement time point (dev.=25%)

1 d after the exposure, any data can be used without considering the administration time with an expected uncertainty of 25%.
05

Retrospective estimation of individual-specific ITB effectiveness

1. Determination of thyroid blocking level
2. Dosimetric data according to thyroid blocking level
Determination of thyroid blocking level

◆ ITB Levels

<table>
<thead>
<tr>
<th>Level</th>
<th>Protective effect (%)</th>
<th>note</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>unblocked</td>
</tr>
<tr>
<td>1</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>100</td>
<td>completely blocked</td>
</tr>
</tbody>
</table>

◆ Ratio of urinary excretion to thyroid retention activity, \( R_{UT}(t, Tc) \)

\[
R_{UT}(t, Tc) = \frac{M_U(t, Tc)}{M_T(t)}
\]

- \( M_U(t, Tc) \): activity excreted via urine
- \( M_T(t) \): activity retained in the thyroid
- \( t \): the time after exposure
- \( T_c \): the urine collection time
Example

- Collected urine activity (t=36 h)
  \[ 30,000 \text{ Bq} \]
- Thyroid activity (t=36 h)
  \[ 600 \text{ Bq} \]

\[ R_{U/t} = \frac{M_U}{M_T} \]
\[ = \frac{30,000}{600} = 50 \]
Dose calculation

Dosimetric data according to ITB level

Thyroid retention functions

<table>
<thead>
<tr>
<th>ITB level</th>
<th>Thyroid equivalent dose coefficient, ((\text{Sv}/\text{Bq}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>3.68E-07</td>
</tr>
<tr>
<td>Level 1</td>
<td>1.88E-07</td>
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<tr>
<td>Level 2</td>
<td>7.33E-08</td>
</tr>
<tr>
<td>Level 3</td>
<td>3.48E-08</td>
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<tr>
<td>Level 4</td>
<td>1.53E-08</td>
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<tr>
<td>Level 5</td>
<td>3.45E-09</td>
</tr>
<tr>
<td>Level 6</td>
<td>1.88E-09</td>
</tr>
</tbody>
</table>
Conclusion

1. Summary and further research
Summary

- For dose assessment when stable iodine is administered, thyroid retention functions and dose coefficients according to administration time were calculated.
- The new iodine biokinetic model should be considered for thyroid dose estimation in case of thyroid blocking.
- After the insensitive time point, any data can be used regardless of administration time.
- Individual-based estimation of ITB effectiveness can be achieved by estimating the ratio of urinary excretion to thyroid retention activity.

Further research

- Age-dependent data for thyroid blocking
- Korean-specific iodine biokinetic model
THANK YOU
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