Radioiodine ($^{131}$I) therapy of thyroid disorders

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Effects of ionizing radiation on living cells

Healthy cell → Cell with damaged DNA → Cell death (necrosis)

Incorrect DNA repair → Unstable chromosomal aberration → Death (mitotic)

Correct DNA repair → Stable chromosomal aberration

large radiation dose → Cell death (necrosis)

No effect → Neoplasm

Programmed cell death (apoptosis)
$^{131}\text{I}$ – characteristics

- $\beta^-$ - 90% - 0.61 MeV (range in tissues < 2 mm)
- (0.8 mm)

Therapy

- $\beta^-$ - 90% - 0.61 MeV (range in tissues < 2 mm)

Diagnostics (scintigraphy)

- $\gamma$ - 85% - 0.364 MeV

$^{131}\text{I} \rightarrow ^{131}\text{Xe}$

$T_{1/2} = 8.04$ days
Radioiodine $^{131}$I therapy -
- absolute contraindications

- pregnancy and lactation,
- suspicion of thyroid cancer
Radioiodine ($^{131}$I) therapy of benign thyroid disorders - indications:

- Toxic multinodular goiter – Plummer’s disease,
- Solitary autonomous nodule - Goetsch’ disease,
- Graves’ disease,
- Nontoxic nodular goiter,
- Nontoxic diffuse goiter (size reduction).
Radioiodine $^{131}$I therapy of toxic nodular goiter - indications:

- method of choice in solitary autonomous nodule and multinodular goiter (if no significant obstruction of trachea)

Patient’s preparation to $^{131}$I
– nodular goiter
- radioiodine uptake in the thyroid gland before and after antithyroid compounds administration
(appearance of extra nodular thyroid tissue because of TSH increased concentration)
- before antithyroid compounds therapy - patient in a subclinical hyperthyroidism

$^{131}$I scintigraphy before antithyroid compounds administration

$^{131}$I scintigraphy after antithyroid compounds administration
Radioiodine ($^{131}$I) treatment in Graves’ disease,

- **indications:**

  all of the patients – especially these:

  - in whom antithyroid compounds therapy is not effective or contraindicated,
  - patients after previous thyroid gland surgery or other surgery in the neck region,
  - patients with contraindications to the surgery (heart, lung or kidney diseases)
Patient’s preparation to $^{131}$I
– Graves’ disease
- radioiodine uptake in the thyroid gland before and after antithyroid compounds administration is similar
- patient before $^{131}$I therapy should be in euthyroid condition or in slight hypothyroidism

$^{131}$I scintigraphy before antithyroid compounds administration
$^{131}$I scintigraphy after antithyroid compounds administration
Radioiodine $^{131}$I therapy of nontoxic nodular goiter and nontoxic diffuse goiter

-indications:

- patients with contraindications to the surgery (heart, lung or kidney diseases), the aim of the treatment is reduction of goiter volume.

- patients without these contraindications (especially with very large goiter volume) should be treated with surgery.
Patient’s preparation to $^{131}\text{I}$

Before radioiodine ($^{131}\text{I}$) therapy the following drugs must be withdrawn:
- Antithyroid compounds (methimazole, carbimazole, propylthiouracyl) 2-3 days before treatment in Graves’ disease,
  ? days (a few days) in Toxic multinodular goiter,
- $\text{LT}_3$ (Levotriiodothyronine) drugs - 2 weeks,
- $\text{LT}_4$ (Levothyroxine) - 4 weeks,
- Lugol’s solution, other drugs with kalium iodatum – 3 weeks,
- Amiodarone - 3 – 6 months,

Any examination containing iodine contrast agents should be avoided for at least 3 - 4 weeks before $^{131}\text{I}$ therapy.

Sabri,1999; Tuttle et al.,1995; Andrade et al., 2001
Patient’s preparation to $^{131}$I

- physical examination,
- estimation of the serum TSH, fT$_4$ (free thyroxine) and fT$_3$ (free triiodothyronine) concentrations,
- antithyroid peroxidase antibodies (TPOAb), anti-TSH receptor antibodies (TRAb), antithyroglobulin antibodies (TgAb),
- ultrasound examination of thyroid gland,
- scintigraphy of thyroid gland,
- 24 hour iodine thyroid uptake ($T_{up}$),
- ultrasound guided fine-needle biopsy in evaluation of thyroid nodules.
Solid isoechogenic nodule (functional nodule, with regular hypoechoic margins, without microcalcifications)

Solid hypoechoic nodule (suspicious nodule, with irregular margins and microcalcifications)

Solid nodule with different echogenisity (suspicious nodule, with irregular margins and microcalcifications)

Solid hypoechoic nodule (suspicious nodule, with irregular increased blood flow)
Radioiodine ($^{131}$I) therapy

Relative contraindications:

- unmanageable urinary incontinence
- low 24 hour iodine thyroid uptake,
- hyperthyroidism (thyrotoxicosis) with high $fT_3$ and $fT_4$ concentration (the risk of development of thyrotoxic crisis),
- large volume of the goiter,
- active phase of Grave’s ophtalmopathy,
- young age.
Radioiodine ($^{131}$I) therapy

Interventions:
- low 24 hour iodine thyroid uptake,

- Lithium carbonate increases retention of $^{131}$I in thyroid gland,
- human recombinant TSH (rhTSH) increases thyroid iodide uptake ($T_{up}$).

- hyperthyroidism (thyrotoxicosis) with high $fT_3$ and $fT_4$ concentration (the risk of development of thyrotoxic crisis),
- large volume of the goiter,
- active phase of Grave’s ophtalmopathy,
- young age.
Radioiodine ($^{131}I$) therapy 

Interventions: 
- low 24 hour iodine thyroid uptake, 
- Lithium carbonate increases retention of $^{131}I$ in thyroid gland, 
- human recombinant TSH (rhTSH) increases thyroid iodide uptake ($T_{up}$).

- hyperthyroidism (thyrotoxicosis) with high fT$_3$ and fT$_4$ concentration (the risk of development of thyrotoxic crisis), 
- Lithium carbonate, 
- Antithyroid compounds (methimazole, carbimazole, propylthiouracil) used after $^{131}I$ treatment, 
- Lugol’s solution,

- large volume of the goiter, 
- active phase of Grave’s ophtalmopathy, 
- young age.
Radioiodine ($^{131}$I) therapy
Interventions:

- low 24 hour iodine thyroid uptake,
  - Lithium carbonate increases retention of $^{131}$I in thyroid gland,
- human recombinant TSH (rhTSH) increases thyroid iodide uptake ($T_{up}$).
- hyperthyroidism (thyrotoxicosis) with high $fT_3$ and $fT_4$ concentration (the risk of development of thyrotoxic crisis),
- Lithium carbonate,
- Antithyroid compounds (methimazole, carbimazole, propylthiouracil) used after $^{131}$I treatment,
- Lugol’s solution,

- large volume of the goiter (patients who do not agree to surgery can get $^{131}$I treatment)

- active phase of Grave’s ophtalmopathy,
- young age.
nodular goiter
*nodular goiter

veins dilation due to goiter compression
*nodular goiter
*nodular goiter

antero-posterior and lateral thorax X-ray
*nodular goiter

MRI
Radioiodine ($^{131}$I) therapy

**Interventions:**

- Low 24 hour iodine thyroid uptake
  - Lithium carbonate increases retention of $^{131}$I in thyroid gland,
- Human recombinant TSH (rhTSH) increases thyroid iodide uptake ($T_{up}$).
- Hyperthyroidism (thyrotoxicosis) with high $fT_3$ and $fT_4$ concentration (the risk of development of thyrotoxic crisis),
- Lithium carbonate,
- Antithyroid compounds (methimazole, carbimazole, propylthiouracil) used after $^{131}$I treatment,
- Lugol’s solution,
- Large volume of the goiter (patients who do not agree to surgery can be treated with $^{131}$I)
- Active phase of Grave’s ophtalmopathy,
- Glucocorticosteroids administration
- Young age.
Grave’s ophtalmopathy
Radioiodine ($^{131}\text{I}$) therapy

Interventions:

- Low 24 hour iodine thyroid uptake
  - Lithium carbonate increases retention of $^{131}\text{I}$ in thyroid gland,
  - Human recombinant TSH (rhTSH) increases thyroid iodide uptake ($T_{up}$).

- Hyperthyroidism (thyrotoxicosis) with high $fT_3$ and $fT_4$ concentration (the risk of development of thyrotoxic crisis),
  - Lithium carbonate,
  - Antithyroid compounds (methimazole, carbimazole, propylthiouracyl) used after $^{131}\text{I}$ treatment,
  - Lugol’s solution,

- Large volume of the goiter (patients who do not agree to surgery can be treated with $^{131}\text{I}$)

- Active phase of Grave’s ophthalmopathy,
  - Glucocorticosteroids administration

- Young age

- Thyroid ablative therapy
Strategy of $^{131}$I administration in the treatment of benign thyroid diseases

- constant activities applied

5 - 10 - 15 mCi $^{131}$I

Strategy of $^{131}$I administration in the treatment of benign thyroid diseases

calculation of activity using simplified formula

$$A \ [\text{MBq}] = \frac{m \ [\text{g}] \times D \ [\text{Gy}] \times 22.5}{T_{\text{up}} \ [%] \times T_{1/2} \ [\text{d}]}$$

Where:
- $A$ - activity $[\text{MBq}/37 = \text{mCi}]$
- $m$ – mass (volume) of the goiter or nodule $[\text{g}]$
- $D$ – effective dose $[\text{Gy}]$
- $T_{\text{up}}$ – radiiodine uptake $[\%]$
- $T_{1/2}$ – effective half life time $[\text{days}]$

Riccabona G. EANM-continuing education, Duesseldorf, 1994
Effective dose in different thyroid diseases

**Toxic nodular goiter** 150 – 200 Gy

*Riccabona, 1994; Guhlmanni et al., 1995; Dietlein et al., 1999.*

**Solitary autonomous nodule** 300 – 400 Gy

*Kinser et al., 1989; Seeger et al., 1995; Dietlein et al., 1999.*
Effective dose in different thyroid diseases

Graves’ disease

- 120 – 150 Gy patients with small thyroid gland,
- 150 – 180 Gy patients with large thyroid gland,


- 300 Gy and more - ablative therapy

Schicha, 1997; Willemsen et al., 1993; Peters et al., 1997,
Dietlein et al., 1999.
Effective dose in different thyroid diseases

Nontoxic nodular goiter
Nontoxic diffuse goiter
(the aim of the treatment is volume reduction)
50 – 100 Gy

Bonneme et al., 1999; Wesche et al., 2001
Patient’s preparation to $^{131}$I

treatment is provided by the accredited Nuclear Medicine Departments in Poland

- out-patients, therapy $< 800$ MBq $^{131}$I,
- in-patients, therapy $> 800$ MBq $^{131}$I.
Complication of radioiodine ($^{\text{131}}\text{I}$) therapy in patients with hyperthyroidism (thyrotoxicosis) and non-toxic nodular goiter

- transient aggravation of hyperthyroidism,
- development of thyrotoxic crisis (exceptionally)
- rarely thyroid pain or dysphagia
- increase of thyroid antibodies concentration
- trigger of autoimmune thyroid disease
- aggravation of Grave’s ophtalmopathy?

- not proved:
carcinogenesis other than in thyroid gland
leukemia
genetic malformations in the offspring
Results of the $^{131}I$ treatment hyperthyroidism (after 6 months)

- Nodular goiter: 25% Euthyroid condition, 19% Hypothyroidism, 56% Hyperthyroidism
- Solitary nodular goiter: 18% Euthyroid condition, 10% Hypothyroidism, 72% Hyperthyroidism
- Graves' disease: 33% Euthyroid condition, 40% Hypothyroidism, 27% Hyperthyroidism
Results of the $^{131}$I treatment non-toxic goiter

Follow-up post $^{131}$I treatment

euthyroid condition – observation,

hypothyroidism – LT4 (Levothyroxine) substitution therapy,
hyperthyroidism – re-treatment with $^{131}$I,
other therapy (surgery, antithyroid compounds).
Radioiodine \(^{131}I\) therapy of malignant thyroid diseases - indications:

- Papillary thyroid carcinoma (PTC)
- Follicular thyroid carcinoma (FTC)
Radioiodine ($^{131}$I) therapy of malignant thyroid diseases - indications:

- ABLATION of post-surgical thyroid remnants

For patients undergoing $^{131}$I ablation of thyroid remnants, administered activities in the range of 1.11 GBq to 5.55 GBq (60-150 mCi) are given.

According to EANM 2003 guidelines, administered activities in the range of 3.7-5.55 GBq (100-150 mCi) are applied.
Radioiodine ($^{131}$I) therapy of malignant thyroid diseases - indications:

- **TREATMENT – (RE-TREATMENT)**

For patients undergoing re-treatment for residual disease, local or regional recurrence, activities in the range of 3.7-5.55 GBq (100-150 mCi) are used.

For patients with distant (bone) metastases 7.4 GBq (200 mCi) or more may be used.

Caution is recommended in patients with diffuse lung metastases in a view of the potential risk of radiation fibrosis.

For young children treatment activity is approximately 37 MBq/kg (1 mCi/kg) of body weight.
The isotopes treatment in medicine (without thyroid diseases)

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Treatment of bone metastases in patients with breast and prostate cancer

isotopes: 
\[^{89}\text{Sr}\] \text{Strontium chloride,}
\[^{153}\text{Sm}\] \text{Samarium}

Aim
palliation of pain from bone metastases
Radiation synovectomy
(Radiosynovectomy)

isotopes used:

\[ ^{90} \text{Y} - \text{Yttrium}, \]

\[ ^{186} \text{Re} - \text{Rhenium sulfide} \]

\[ ^{169} \text{Er} - \text{Erbium citrate} \]
Radiation synovectomy (Radiosynovectomy)

isotopes used:

$^{90}\text{Y}$ - big joint - only for knee joint,
$^{186}\text{Re}$ - middle joints - shoulder, wrist, elbow, hip, ankle,
$^{169}\text{Er}$ - small joints - carpometacarpal, metacarpophalangeal, proximal interphalangeal.
Radiation synovectomy (Radiosynovectomy)

Indications:

- rheumatoid arthritis,
- other inflammatory joint diseases,
- persistent synovial effusion,
- pigmented villonodular synovitis,
- hemophilic joint disease.
Radiation synovectomy (Radiosynovectomy)

Aim of the treatment:

- pain relief in joints,
- swelling reduction,
- reduction of stiffness,
- effusion reduction,
- improvement of function.
Radiation synovectomy (Radiosynovectomy)

Absolute contraindications:
- pregnancy,
- breast-feeding.

Relative contraindications:
- children and young adults
Radioimmunotherapy – new approach in treatment of hematological malignancies

Isotopes:

\[ {^{90}}Y \text{- Yttrium conjugated monoclonal antibody to CD 20} \]

B-cell non-Hodgkin's lymphoma
Thank You for Your attention