Critical structure dose-volume constraint guidelines

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1 Definitions

1.1 Tolerance dose

$TD_{5/5}(\frac{1}{3})$ represents the dose at which there is a 5% probability of complication within 5 years after irradiation to $\frac{1}{3}$ of the defined critical structure.

1.2 Maximum dose

$D_{\max}$ represents the maximum dose recommended within a defined critical structure.

$D_{\max}^{1\%}$ and $D_{\max}^{5\%}$ indicate that 1% or 5% of the defined critical structure is permitted to exceed $D_{\max}$, respectively.

$D_{\max}^{\mathrm{point}}$ represents the maximum dose recommended to any point within a defined critical structure.

1.3 Mean dose

$\overline{D}$ represents the mean dose within a defined critical structure.

1.4 Relative volume dose constraint

$V_{20\mathrm{Gy}}^{\%}$ represents the relative volume (%) receiving more than 20 Gy.

$V_{20\%}^{\%}$ represents the relative volume (%) receiving more than 20% of the prescription dose.

1.5 Absolute volume dose constraint

$V_{20\mathrm{Gy}}^{\mathrm{cc}}$ represents the absolute volume (cc) receiving more than 20 Gy.

1.6 Sparing volume dose constraint

$S^{\text{cc}}_{20\text{Gy}}$ represents the absolute volume (cc) receiving less than 20 Gy.

1.7 Recommended guidelines

Recommended guidelines are shown in red. Unless otherwise specified, all guidelines assume conventional fractionation in 2 Gy fractions.

2 Brain

2.1 Whole brain

$$D^{\text{point}}_{\text{max}} = 5760 \text{ cGy}$$

2.1.1 Emami [1]

$$TD_{5/5}(\tfrac{1}{3}) = 6000 \text{ cGy}$$
$$TD_{5/5}(\tfrac{2}{3}) = 5000 \text{ cGy}$$
$$TD_{5/5}(\tfrac{3}{3}) = 4500 \text{ cGy}$$

2.1.2 Perez [2]

Doses of 5000 cGy to whole brain in 180 to 200 cGy fractions are well tolerated in adults. In children, the threshold dose is 3000 to 3500 cGy. The TD_5 in adults for necrosis is approximately 5000 cGy. [3] A threshold dose is 5760 cGy using 180 to 200 cGy fractions. [4] With focal areas, the TD_{50} is between 70 and 80 Gy. [5]

2.1.3 Other [6, 7]

$$D_{\text{max}} = 5500 \text{ cGy}$$

2.2 Eyes

$$D^{5\%}_{\text{max}} = 4500 \text{ cGy}$$

2.2.1 Emami [1]

$$TD_{5/5}(\tfrac{3}{3}) = 4500 \text{ cGy}$$
$$TD_{50/5}(\tfrac{3}{3}) = 6500 \text{ cGy}$$

2.2.2 RTOG 0525, 0513, BR-0021, BR-0013, 9710, 9402 [8]

$$D_{\text{max}} = 5000 \text{ cGy}$$

2.2.3 RTOG 9803 [8]

$$D_{\text{max}} = 5500 \text{ cGy}$$

2.2.4 RTOG 0225, 0022, 0421 [8]

$$\overline{D} < 3500 \text{ cGy}$$

2.3 Retina

$$D_{\text{max}}^{\text{point}} < \begin{cases} 5200 \text{ cGy} & \text{for benign tumors,} \\ 6000 \text{ cGy} & \text{for malignant tumors.} \end{cases}$$

2.3.1 Emami [1]

$$TD_{5/5}(\tfrac{3}{3}) = 4500 \text{ cGy}$$
$$TD_{50/5}(\tfrac{3}{3}) = 6500 \text{ cGy}$$

2.3.2 RTOG 0525, 0513, BR-0021, BR-0013, 9710, 9402 [8]

$$D_{\text{max}} = 5000 \text{ cGy}$$

2.3.3 RTOG 9803 [8]

$$D_{\text{max}} = 5500 \text{ cGy}$$

2.3.4 Perez [2]

Retinitis and optic neuropathy may occur following doses of 5000 to 6500 cGy, and even at lower doses if the individual fraction size is > 200 cGy. [9] The risk of retinopathy from hyperfractionated (110 to 120 cGy twice daily) regimens appears to be negligible in the 5000 to 6000 cGy range, and appreciably less than comparable doses in the 6000 to 7000 cGy range delivered by standard daily radiation. [10]

2.3.5 RTOG 0225, 0022, 0421 [8]

$$\overline{D} < 3500 \text{ cGy}$$

2.4 Lens

$$D_{\max}^{\text{point}} = 800 \text{ cGy}$$

2.4.1 Emami [1]

$$TD_{5/5}(\tfrac{3}{3}) = 1000 \text{ cGy}$$
$$TD_{50/5}(\tfrac{3}{3}) = 1800 \text{ cGy}$$

2.4.2 RTOG 9802 [8]

$$D_{\max} = 1000 \text{ cGy}$$

2.4.3 Other [11]

Fractionated doses under 400 to 500 cGy have not been reported to produce cataracts. [12] Cataracts always develop after radiation doses greater than 1000 cGy. [13]

2.4.4 Other

$$D_{\max}^{5\%} = 800 \text{ cGy}$$

2.5 Optic nerve

$$D_{\max}^{\text{point}} < \begin{cases} 5200 \text{ cGy} & \text{for benign tumors,} \\ 6000 \text{ cGy} & \text{for malignant tumors.} \end{cases}$$

2.5.1 Emami [1]

$$TD_{5/5}(\tfrac{3}{3}) = 5000 \text{ cGy}$$
$$TD_{50/5}(\tfrac{3}{3}) = 6500 \text{ cGy}$$

2.5.2 RTOG 9803 [8]

$$D_{\max} = 5500 \text{ cGy}$$

2.5.3 RTOG 0225 [8]

$$D_{\max} = 5400 \text{ cGy}$$
or
$$D_{\max}^{1\%} = 6000 \text{ cGy}$$

2.5.4 Other

$$D_{\text{max}}^{5\%} = 5000 \text{ cGy}$$
or
$$D_{\text{max}}^{1\%} = 6000 \text{ cGy}$$

2.6 Optic chiasm

$$D_{\text{max}}^{\text{point}} < \begin{cases} 5200 \text{ cGy} & \text{for benign tumors,} \\ 6000 \text{ cGy} & \text{for malignant tumors.} \end{cases}$$

2.6.1 Emami [1]

$$TD_{5/5}(\tfrac{3}{3}) = 5000 \text{ cGy}$$
$$TD_{50/5}(\tfrac{3}{3}) = 6500 \text{ cGy}$$

2.6.2 RTOG 0525, BR-0023, 9803 [8]

$$D_{\text{max}} = 5500 \text{ cGy}$$

2.6.3 RTOG 0513, BR-0021 [8]

$$D_{\text{max}} = 5400 \text{ cGy}$$

2.6.4 RTOG BR-0013, 9710, 9402 [8]

$$D_{\text{max}} = 6000 \text{ cGy}$$

2.6.5 RTOG 9802 [8]

$$D_{\text{max}} = 5670 \text{ cGy}$$

2.6.6 RTOG 0225 [8]

$$D_{\text{max}} = 5400 \text{ cGy}$$
or
$$D_{\text{max}}^{1\%} = 6000 \text{ cGy}$$

2.6.7 Other

$$D_{\text{max}}^{5\%} = 5000 \text{ cGy}$$
or
$$D_{\text{max}}^{1\%} = 6000 \text{ cGy}$$

2.7 Brainstem

$$D_{\max}^{\text{point}} < \begin{cases} 5200 \text{ cGy} & \text{for benign tumors,} \\ 6000 \text{ cGy} & \text{for malignant tumors.} \end{cases}$$

2.7.1 Emami [1]

$$TD_{5/5}(\tfrac{1}{3}) = 6000 \text{ cGy}$$
$$TD_{5/5}(\tfrac{2}{3}) = 5300 \text{ cGy}$$
$$TD_{5/5}(\tfrac{3}{3}) = 5000 \text{ cGy}$$

2.7.2 RTOG 0525 [8]

$$D_{\max} = 5500 \text{ cGy}$$

2.7.3 RTOG 0513, BR-0021, BR-0013, 9710, 9402 [8]

$$D_{\max} = 6000 \text{ cGy}$$

2.7.4 RTOG 9802 [8]

$$D_{\max} = 5670 \text{ cGy}$$

2.7.5 RTOG 0225 [8]

$$D_{\max} = 5400 \text{ cGy}$$
or
$$D_{\max}^{1\%} = 6000 \text{ cGy}$$

2.8 Internal auditory canal/cochlea

$$D_{\max}^{\text{point}} = 4500 \text{ cGy}$$

For contouring guidelines, please refer to [14].
The ototoxic effects of radiotherapy occur at the basal turn of the cochlea [15].

2.8.1 RTOG 0615 [8]

$$D_{\max}^{5\%} = 5500 \text{ cGy}$$

2.8.2 Bhandare [16]

$$\overline{D} \leq 6000 \text{ cGy}$$

2.8.3 Pan [17]

$$\overline{D} \leq 4500 \text{ cGy}$$

2.8.4 Perez [2]

Doses greater than 4500 cGy impair hearing, particularly in the higher frequencies. [17]

2.8.5 Other

$$\overline{D} \leq 5000 \text{ cGy}$$

3 Brain (one-fraction stereotactic radiosurgery)

3.1 Optic apparatus

$$D_{\text{max}}^{\text{point}} = 800 \text{ cGy}$$

3.1.1 Tishler [18]

$$D_{\text{max}} = 800 \text{ cGy}$$

3.1.2 Leber [19]

$$D_{\text{max}} = 1000 \text{ cGy}$$

3.2 Brain (normal parenchyma)

$$D_{\text{max}}^{\text{point}} = 1200 \text{ cGy}$$

3.3 Pituitary stalk

$$D_{\text{max}}^{\text{point}} = 800 \text{ cGy}$$

4 Head and neck

4.1 Parotid gland (one gland)

$$\overline{D} \leq 2600 \text{ cGy}$$
or
$$V^{\%}_{30\text{Gy}} < 50\%$$

4.1.1 RTOG 0522, 0435 [8]

$$\overline{D} \leq 2600 \text{ cGy}$$
or
$$V^{\%}_{30\text{Gy}} < 50\%$$

4.2 Parotid gland (both glands)

4.2.1 RTOG 0522, 0435 [8]

$$S^{\text{cc}}_{20\text{Gy}} \geq 20 \text{ cc}$$

4.3 Spinal cord

$$D^{\text{point}}_{\text{max}} = 4500 \text{ cGy}$$

4.3.1 RTOG 9803, 0412 [8]

$$D_{\text{max}} = 5000 \text{ cGy}$$

4.3.2 RTOG 0617 [8]

$$D_{\text{max}} = 5050 \text{ cGy}$$

4.3.3 RTOG 0225 [8]

$$D_{\text{max}} = 4500 \text{ cGy}$$
or
$$D^{1\%}_{\text{max}} = 5000 \text{ cGy}$$

4.3.4 RTOG 0522 [8]

$$V^{\text{cc}}_{48\text{Gy}} \leq 0.03 \text{ cc}$$

4.3.5 RTOG 0435 [8]

$$V^{\text{cc}}_{45\text{Gy}} \leq 1 \text{ cc}$$

4.3.6 RTOG 0623 [8]

$$D_{\text{max}} = 4500 \text{ cGy}$$

4.3.7 Other

$$D^{1\%}_{\text{max}} = 4500 \text{ cGy}$$
or
$$V^{\text{cc}}_{50\text{Gy}} \leq 1 \text{ cc}$$

4.4 Mandible

$$D^{\text{point}}_{\text{max}} = 7000 \text{ cGy}$$

4.4.1 RTOG 0225, 0615 [8]

$$D_{\text{max}} = 7000 \text{ cGy}$$
or
$$D^{1\%}_{\text{max}} = 7500 \text{ cGy}$$

4.5 Temporomandibular joint

$$D^{\text{point}}_{\text{max}} = 7000 \text{ cGy}$$

4.5.1 RTOG 0225, 0615 [8]

$$D_{\text{max}} = 7000 \text{ cGy}$$
or
$$D^{1\%}_{\text{max}} = 7500 \text{ cGy}$$

4.6 Lips

4.7 Oral cavity

$$V^{\%}_{60\text{Gy}} \leq 10\%$$

4.7.1 Other

$$V^{\%}_{60\text{Gy}} \leq 10\%$$

4.8 Glottic larynx

$$V^{\%}_{50\text{Gy}} \leq 33\%$$
or
$$D_{\text{max}} = 4500 \text{ cGy}$$

The glottic larynx volume includes the voice box area, arytenoids, false cords, and one subglottic slice (3-mm).

4.8.1 RTOG 0022 [8]

$$V^{\%}_{50\text{Gy}} \leq 33\%$$

4.8.2 RTOG 0522, 0435 [8]

$$D_{\text{max}} = 4500 \text{ cGy}$$

4.9 Internal auditory canal/cochlea

Please refer to Section 2.8.

4.10 Pituitary fossa

$$D^{\text{point}}_{\text{max}} = 4000 \text{ cGy}$$

The pituitary fossa volume includes the pituitary stalk.

4.10.1 RTOG 9802 [8]

$$D_{\text{max}} = 5670 \text{ cGy}$$

4.10.2 Other

$$D^{5\%}_{\text{max}} = 5000 \text{ cGy}$$

4.11 Eyes

Please refer to Section 2.2.

4.12 Retina

Please refer to Section 2.3.

4.13 Optic nerve

Please refer to Section 2.5.

4.14 Brainstem

See Section 2.7

4.15 Temporal lobes

$$D_{\text{max}}^{\text{point}} = 6000 \text{ cGy}$$

Note: Limit dose to the temporal lobes as reasonably possible.

4.15.1 RTOG 0225 [8]

$$D_{\text{max}} = 6000 \text{ cGy}$$
or
$$D_{\text{max}}^{1\%} = 6500 \text{ cGy}$$

4.16 Optic chiasm

Please refer to Section 2.6.

4.17 Brachial plexus

$$D_{\text{max}} = 6600 \text{ cGy}$$

4.17.1 RTOG 0615, 0617 [8]

$$D_{\text{max}} = 6600 \text{ cGy}$$

4.17.2 RTOG 0522, 0435, 0412 [8]

$$D_{\text{max}} = 6000 \text{ cGy}$$

5 Breast

5.1 Ipsilateral lung

$$V_{30\%}^{\%} < 15\%$$
or
$$V_{20\text{Gy}}^{\%} \leq 20\%$$

5.1.1 RTOG 0413 [8]

$$V^{\%}_{30\%} < 15\%$$

5.1.2 Other

$$V^{\%}_{20\text{Gy}} \leq 20\%$$

5.2 Contralateral lung

$$V^{\%}_{5\%} < 15\%$$

5.2.1 RTOG 0413 [8]

$$V^{\%}_{5\%} < 15\%$$

5.3 Heart

$$V^{\%}_{5\%} < \begin{cases} 5\% & \text{for right-sided lesions,} \\ 40\% & \text{for left-sided lesions.} \end{cases}$$

5.3.1 RTOG 0413 [8]

$$V^{\%}_{5\%} < \begin{cases} 5\% & \text{for right-sided lesions,} \\ 40\% & \text{for left-sided lesions.} \end{cases}$$

5.3.2 Other

$$V^{\%}_{15\text{Gy}} < 10\%$$

5.4 Contralateral breast

$$D_{\max} = 3\% \text{ of the prescribed dose}$$
or
$$D_{\max} < 500 \text{ cGy}$$

5.4.1 RTOG 0413 [8]

$$D_{\max} = 3\% \text{ of the prescribed dose}$$

5.4.2 Other

$$D_{\text{max}} < 500 \text{ cGy}$$

5.5 Treated breast (dose homogeneity)

$$\begin{Bmatrix} V^{\%}_{110\%} & < 5\% \\ V^{\%}_{115\%} & < 1\% \end{Bmatrix}$$

5.5.1 William Beaumont Hospital

$$\begin{Bmatrix} V^{\%}_{110\%} & < 5\% \\ V^{\%}_{115\%} & < 1\% \end{Bmatrix}$$

5.6 Thyroid

$$D_{\text{max}} = 3\% \text{ of the prescribed dose}$$

5.6.1 RTOG 0413 [8]

$$D_{\text{max}} = 3\% \text{ of the prescribed dose}$$

6 Lung and esophagus

6.1 Bilateral lungs

Both left and right normal lung volumes should be contoured for calculation of dosimetric parameters.

$$V^{\%}_{20\text{Gy}} < 22\%$$

6.1.1 RTOG 0412 [8]

$$V^{\%}_{20\text{Gy}} \leq 30\%, \text{ preferably} \leq 25\%$$

6.1.2 RTOG 0617, 0623 [8]

$$\begin{Bmatrix} \overline{D} & \leq 2000 \text{ cGy} \\ V^{\%}_{20\text{Gy}} & \leq 37\% \end{Bmatrix}$$

6.1.3 Graham [20]

$$V_{20\text{Gy}}^{\%} < 22\%$$

6.1.4 Seppenwoolde [21]

$$\overline{D} < 1500 \text{ cGy}$$

6.1.5 Kong [22]

$$\left\{ \begin{array}{ll} \overline{D} & < 20 \text{ Gy} \\ V_{20\text{Gy}}^{\%} & < 30\% \\ V_{13\text{Gy}}^{\%} & < 27\% \end{array} \right\}$$

6.2 Heart

$$V_{45\text{Gy}}^{\%} \leq 67\%$$

6.2.1 RTOG 0412 [8]

$$\left\{ \begin{array}{l} V_{60\text{Gy}}^{\%} \leq 33\% \\ V_{45\text{Gy}}^{\%} \leq 67\% \\ V_{30\text{Gy}}^{\%} \leq 100\% \end{array} \right\}$$

6.2.2 RTOG 0436, 0113 [8]

$$\left\{ \begin{array}{l} V_{50\text{Gy}}^{\%} \leq 33\% \\ V_{45\text{Gy}}^{\%} \leq 67\% \\ V_{40\text{Gy}}^{\%} \leq 100\% \end{array} \right\}$$

6.2.3 RTOG 0617, 0623 [8]

$$\left\{ \begin{array}{l} V_{60\text{Gy}}^{\%} \leq 33\% \\ V_{45\text{Gy}}^{\%} \leq 67\% \\ V_{40\text{Gy}}^{\%} \leq 100\% \end{array} \right\}$$

6.2.4 Other

$$V_{40\text{Gy}}^{\%} \leq 30\% \text{ to } 40\%$$

6.3 Spinal cord

Please refer to Section 4.3.

6.4 Brachial plexus

Please refer to Section 4.17.

6.5 Esophagus

$$V^{\%}_{55\text{Gy}} \leq 67\%$$

6.5.1 RTOG 0412 [8]

$$\left\{ \begin{array}{l} V^{\%}_{65\text{Gy}} \leq 33\% \\ V^{\%}_{55\text{Gy}} \leq 67\% \\ V^{\%}_{45\text{Gy}} \leq 100\% \end{array} \right\}$$

6.5.2 RTOG 0617, 0623 [8]

$$\overline{D} < 3400 \text{ cGy}$$

6.6 Liver

$$V^{\%}_{25\text{Gy}} < 50\%$$

6.6.1 RTOG 0412 [8]

$$\left\{ \begin{array}{l} V^{\%}_{35\text{Gy}} \leq 50\% \\ V^{\%}_{25\text{Gy}} \leq 100\% \end{array} \right\}$$

6.6.2 RTOG 0436, 0113 [8]

$$\left\{ \begin{array}{l} V^{\%}_{35\text{Gy}} \leq 50\% \\ V^{\%}_{30\text{Gy}} \leq 100\% \end{array} \right\}$$

6.6.3 DeVita [23]

Tolerable courses (5% chance of radiation-induced liver disease) for whole liver radiation in patients who have not received alkylator therapy appear to be 21 Gy in 3 Gy fractions, 25 Gy in 2.5 Gy fractions, and 30 Gy in 2 Gy fractions.

6.6.4 RTOG 0116, 0411, PA-0020 [8]

$$\left\{\begin{array}{l} V^{\%}_{30\text{Gy}} \leq 50\% \\ V^{\%}_{20\text{Gy}} \leq 67\% \end{array}\right\}$$

6.6.5 Other

$$V^{\%}_{25\text{Gy}} < 50\%$$

7 Lung (three-fraction stereotactic body radiation therapy)

7.1 Bilateral lungs

$$V^{\%}_{20\text{Gy}} \leq 10\%$$

7.1.1 RTOG 0618 [8]

$$V^{\%}_{20\text{Gy}} \leq 10\%$$

7.2 Spinal cord

$$D^{\text{point}}_{\text{max}} = 1800 \text{ cGy } (600 \text{ cGy per fraction})$$

7.2.1 RTOG 0618 [8]

$$D^{\text{point}}_{\text{max}} = 1800 \text{ cGy } (600 \text{ cGy per fraction})$$

7.3 Esophagus

$$D^{\text{point}}_{\text{max}} = 2100 \text{ cGy } (700 \text{ cGy per fraction})$$

7.3.1 RTOG 0618 [8]

$$D^{\text{point}}_{\text{max}} = 2700 \text{ cGy } (900 \text{ cGy per fraction})$$

7.4 Brachial plexus

$$D_{\text{max}}^{\text{point}} = 2400 \text{ cGy (800 cGy per fraction)}$$

7.4.1 RTOG 0618 [8]

$$D_{\text{max}}^{\text{point}} = 2400 \text{ cGy (800 cGy per fraction)}$$

7.5 Heart/pericardium

$$D_{\text{max}}^{\text{point}} = 3000 \text{ cGy (1000 cGy per fraction)}$$

7.5.1 RTOG 0618 [8]

$$D_{\text{max}}^{\text{point}} = 3000 \text{ cGy (1000 cGy per fraction)}$$

7.6 Trachea/bronchus

$$D_{\text{max}}^{\text{point}} = 3000 \text{ cGy (1000 cGy per fraction)}$$

7.6.1 RTOG 0618 [8]

$$D_{\text{max}}^{\text{point}} = 3000 \text{ cGy (1000 cGy per fraction)}$$

7.7 Skin

$$D_{\text{max}}^{\text{point}} = 2400 \text{ cGy (800 cGy per fraction)}$$

7.7.1 RTOG 0618 [8]

$$D_{\text{max}}^{\text{point}} = 2400 \text{ cGy (800 cGy per fraction)}$$

8 Pancreas and biliary system

8.1 Spinal cord

Please refer to Section 4.3.

8.2 Liver

8.2.1 Emami [1]

$$TD_{5/5}(\tfrac{1}{3}) = 5000 \text{ cGy}$$
$$TD_{5/5}(\tfrac{2}{3}) = 3500 \text{ cGy}$$
$$TD_{5/5}(\tfrac{3}{3}) = 3000 \text{ cGy}$$

8.2.2 RTOG 0438 [8]

$$\left\{ \begin{matrix} V^{\%}_{27\text{Gy}} \leq 30\% \\ V^{\%}_{24\text{Gy}} \leq 50\% \end{matrix} \right\}$$

8.3 Kidney

$$V^{\%}_{18\text{Gy}} \leq 67\%$$

8.3.1 RTOG 0436 [8]

$$\left\{ \begin{matrix} V^{\%}_{50\text{Gy}} \leq 33\% \\ V^{\%}_{30\text{Gy}} \leq 67\% \\ V^{\%}_{23\text{Gy}} \leq 100\% \end{matrix} \right\}$$

8.3.2 RTOG 0116, 0411, PA-0020 [8]

$$V^{\%}_{18\text{Gy}} \leq 67\%$$

8.4 Small bowel

$$V^{\%}_{50\text{Gy}} \leq 5\%$$

8.4.1 RTOG 0822 [8]

$$\left\{ \begin{matrix} V^{\text{cc}}_{35\text{Gy}} \leq 180 \text{ cc} \\ V^{\text{cc}}_{40\text{Gy}} \leq 100 \text{ cc} \\ V^{\text{cc}}_{45\text{Gy}} \leq 65 \text{ cc} \end{matrix} \right\}$$

8.4.2 RTOG 0529 [8]

$$\begin{Bmatrix} V^{cc}_{30Gy} \leq 200 \text{ cc} \\ V^{cc}_{35Gy} \leq 150 \text{ cc} \\ V^{cc}_{45Gy} \leq 20 \text{ cc} \\ D^{point}_{max} = 50 \text{ Gy} \end{Bmatrix}$$

8.4.3 RTOG 0534 [8]

$$V^{cc}_{45Gy} \leq 150 \text{ cc}$$

8.4.4 RTOG 0418 [8]

$$V^{\%}_{40Gy} \leq 30\%$$

8.4.5 Other

$$V^{\%}_{50Gy} \leq 5\%$$

9 Pelvis (rectum, anus, female pelvis)

9.1 Small bowel

Please refer to Section 8.4.

9.2 Rectum

9.2.1 RTOG 0418 [8]

$$V^{\%}_{30Gy} \leq 60\%$$

9.3 Bladder

$$D^{point}_{max} = 50 \text{ Gy (in the context of rectal cancer)}$$

9.3.1 RTOG 0822 [8]

$$\begin{Bmatrix} V^{\%}_{40Gy} \leq 40\% \\ V^{\%}_{45Gy} \leq 15\% \\ D^{point}_{max} = 50 \text{ Gy} \end{Bmatrix}$$

9.3.2 RTOG 0529 [8]

$$\left\{\begin{array}{l} V^{\%}_{35\text{Gy}} \leq 50\% \\ V^{\%}_{40\text{Gy}} \leq 35\% \\ D^{5\%}_{\max} = 50 \text{ Gy} \end{array}\right\}$$

9.3.3 RTOG 0418 [8]

$$V^{\%}_{45\text{Gy}} \leq 35\%$$

9.3.4 Other

$$V^{\%}_{40\text{Gy}} \leq 30\%$$

9.4 Femoral heads

Please refer to Section 10.4.

10 Prostate

10.1 Rectum

$$V^{\text{cc}}_{72\text{Gy}} < 15 \text{ cc}$$

10.1.1 RTOG 0126, 0415 [8]

$$\left\{\begin{array}{l} V^{\%}_{75\text{Gy}} \leq 15\% \\ V^{\%}_{70\text{Gy}} \leq 25\% \\ V^{\%}_{65\text{Gy}} \leq 35\% \\ V^{\%}_{60\text{Gy}} \leq 50\% \end{array}\right\}$$

10.1.2 RTOG 0621 [8]

$$\left\{\begin{array}{r} V^{\%}_{66.6\text{Gy}} \leq 25\% \\ V^{\%}_{50\text{Gy}} \leq 50\% \end{array}\right\}$$

10.1.3 RTOG 0534 [8]

$$\left\{\begin{array}{l} V^{\%}_{65\text{Gy}} \leq 25\% \\ V^{\%}_{40\text{Gy}} \leq 45\% \end{array}\right\}$$

10.1.4 Rule of 100

$$\left\{\begin{array}{r} V^{\%}_{50\%} \leq 50\% \\ V^{\%}_{60\%} \leq 40\% \\ V^{\%}_{70\%} \leq 30\% \\ V^{\%}_{80\%} \leq 20\% \\ V^{\%}_{90\%} \leq 10\% \\ V^{\%}_{100\%} \leq 5\% \end{array}\right\}$$

10.1.5 Pollack

$$\left\{\begin{array}{r} V^{\%}_{65\mathrm{Gy}} \leq 17\% \\ V^{\%}_{40\mathrm{Gy}} \leq 35\% \end{array}\right\}$$

10.1.6 Kupelian [24]

$$V^{\mathrm{cc}}_{78\mathrm{Gy}} < 15\ \mathrm{cc}$$

10.1.7 Other

$$V^{\mathrm{cc}}_{72\mathrm{Gy}} < 15\ \mathrm{cc}$$

10.2 Bladder

$$V^{\%}_{50\mathrm{Gy}} < 50\%$$

10.2.1 RTOG 0126, 0415 [8]

$$\left\{\begin{array}{r} V^{\%}_{80\mathrm{Gy}} \leq 15\% \\ V^{\%}_{75\mathrm{Gy}} \leq 25\% \\ V^{\%}_{70\mathrm{Gy}} \leq 35\% \\ V^{\%}_{65\mathrm{Gy}} \leq 50\% \end{array}\right\}$$

10.2.2 RTOG 0621 [8]

$$\left\{\begin{array}{r} V^{\%}_{66.6\mathrm{Gy}} \leq 40\% \\ V^{\%}_{50\mathrm{Gy}} \leq 60\% \end{array}\right\}$$

10.2.3 RTOG 0534 [8]

$$\begin{Bmatrix} V^{\%}_{65\text{Gy}} \leq 40\% \\ V^{\%}_{40\text{Gy}} \leq 60\% \end{Bmatrix}$$

10.2.4 Pollack

$$\begin{Bmatrix} V^{\%}_{65\text{Gy}} \leq 25\% \\ V^{\%}_{40\text{Gy}} \leq 50\% \end{Bmatrix}$$

10.2.5 Other

$$V^{\%}_{50\text{Gy}} < 50\%$$

10.3 Penile bulb

$$\begin{Bmatrix} V^{\%}_{30\text{Gy}} \leq 15\% \\ D^{\text{point}}_{\text{max}} = 35\text{Gy} \end{Bmatrix}$$

10.3.1 RTOG 0126, 0415 [8]

$$\overline{D} \leq 5250 \text{ cGy}$$

10.3.2 Mohideen [25]

$$\begin{Bmatrix} V^{\%}_{30\text{Gy}} \leq 15\% \\ D^{\text{point}}_{\text{max}} = 35\text{Gy} \end{Bmatrix}$$

10.4 Femoral heads

$$V^{\%}_{50\text{Gy}} \leq 10\%$$

10.4.1 RTOG 0822 [8]

$$\begin{Bmatrix} V^{\%}_{40\text{Gy}} \leq 40\% \\ V^{\%}_{45\text{Gy}} \leq 15\% \\ D^{\text{point}}_{\text{max}} = 50 \text{ Gy} \end{Bmatrix}$$

10.4.2 RTOG 0529 [8]

$$\left\{\begin{array}{l} V^{\%}_{30\mathrm{Gy}} \leq 50\% \\ V^{\%}_{40\mathrm{Gy}} \leq 35\% \\ D^{5\%}_{\max} = 44 \text{ Gy} \end{array}\right\}$$

10.4.3 RTOG 0534 [8]

$$V^{\%}_{50\mathrm{Gy}} \leq 10\%$$

10.4.4 RTOG 0418 [8]

$$V^{\%}_{30\mathrm{Gy}} \leq 15\%$$

10.4.5 Other

$$D^{5\%}_{\max} = 50 \text{ Gy}$$

10.4.6 Other

$$D_{\max} = 25 \text{ Gy}$$

10.5 Small bowel

Please refer to Section 8.4.

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