

Contents

Introduction	23
History of brachytherapy	25
Radiobiology	31
3.1. References	34
Physical aspects – sources, dosimetry, dose specification	35
4.1. Sources	35
4.1.1. Radionuclides in brachytherapy	35
4.1.1.1. Gamma and characteristic X-ray radiation	35
4.1.1.2. Beta-emitters	36
4.1.2. Characterisation of source strength	36
4.2. Dosimetry	36
4.2.1. Control of reference air kerma rate	36
4.2.1.1. Measurement with well-type ionisation chambers	36
4.2.1.2. Measurement in compact chambers in solid body phantoms	36
4.2.2. Checking the source position	37
4.2.3. Calculation of dose distributions	37
4.2.3.1. Dose distributions of single sources	37
4.2.3.2. Reconstruction of source distribution	38
4.2.3.2.1. Individual reconstruction processes	39
4.2.3.3. Optimisation and visualisation of dose distributions	40
4.3. Dose specification	42
4.3.1. Dose specification in intraluminal and intracavitary therapy	44
4.3.1.1. Linear source (e.g. vaginal cylinder, oesophageal/bronchial applicators, vessels)	44
4.3.1.2. Non-surgically treated cervical carcinoma	45
4.3.1.3. Endometrial carcinoma not treated surgically	46
4.3.2. Dose specification in interstitial brachytherapy	47
4.3.2.1. Dose-volume histograms (DVH), relevant dose values and volumes, quality parameters (indices)	47
4.3.2.1.1. Relevant dose values and volumes	48
4.3.2.1.2. Quality parameters – QI indices	49
4.3.2.1.3. Examples for documentation	50
4.4. References	50
Quality assurance	52
5.1. Quality assurance for afterloading machines and procedures in case of emergency for a remote afterloader	52
5.2. Quality assurance in radiotherapy treatment planning systems	54
5.3. Special methods	55
5.4. References	57
Clinical treatment planning and imaging	58
6.1. Clinical treatment planning	58
6.1.1. Indication	58
6.1.1.1. Definitive treatment	58
6.1.1.2. Adjuvant therapy	58

6.1.2.	Gross Target Volume (GTV) and Clinical Target Volume (CTV)	58
6.1.3.	Selection of technique, preliminary and definitive treatment plan.....	59
6.1.3.1.	Interstitial brachytherapy	59
6.1.3.2.	Intracavitary brachytherapy.....	61
6.1.3.3.	Intraluminal brachytherapy	62
6.1.4.	Dose, dose fractionation, dose rate.....	62
6.1.5.	Infrastructure and personnel planning	63
6.1.6.	References	63
6.2.	Modern imaging techniques in brachytherapy	64
6.2.1.	Procedure for image-based localisation in brachytherapy.....	64
6.2.2.	Basics of image-guided brachytherapy.....	66
6.2.3.	Image-guided "preliminary treatment planning"	68
6.2.3.1.	Interstitial brachytherapy	69
6.2.3.2.	Intraluminal brachytherapy,	70
6.2.3.3.	Intracavitary brachytherapy.....	70
6.2.3.4.	Contact brachytherapy	71
6.2.4.	Image-guided application	71
6.2.5.	Image-guided "definitive treatment planning"	72
6.2.6.	References	74

Instruments and equipment 75

7.1.	Instruments for interstitial brachytherapy.....	75
7.1.1.	Temporary implants.....	75
7.1.1.1.	Needles, catheters (tubes)	75
7.1.1.2.	Templates.....	77
7.1.1.3.	Auxiliary instruments	79
7.1.2.	Permanent implants.....	80
7.2.	Instruments for intracavitary brachytherapy	82
7.2.1.	Uterovaginal applicators	82
7.2.2.	Vaginal applicators.....	84
7.2.3.	Endometrial applicators	84
7.2.4.	Intraluminal applicators for tumours in the oesophagus, bronchus, trachea, common bile duct and nasopharynx and for intravascular brachytherapy.....	84
7.2.5.	Moulds for cancers of the paranasal sinuses or orbit	85
7.3.	Surface applicators.....	85
7.3.1.	Skin applicators	85
7.3.2.	Eye applicators.....	86
7.4.	Afterloading devices	86
7.4.1.	The irradiation device	86
7.4.2.	The control unit	87
7.4.3.	Important requirements for radiation protection	88
7.5.	References.....	88

Intraoperative brachytherapy 89

8.1.	Indications and patient selection criteria.....	89
8.1.1.	Purpose and chances of the treatment.....	89
8.2.	Target volumes, dose specification and dose.....	90
8.3.	Technique, execution and practical tips.....	92
8.4.	Results	93
8.5.	Side effects	95

8.6.	Summary	95
8.7.	References	96
■	Interstitial hyperthermia	97
9.1.	Techniques of interstitial hyperthermia	97
9.2.	Planning, execution and documentation of interstitial hyperthermia	97
9.3.	Results of interstitial hyperthermia and brachytherapy	98
9.3.1.	Glioblastomas	98
9.3.2.	Local recurrences and regional recurrences of tumours of the head/neck	98
9.3.3.	Breast cancer	99
9.3.4.	Carcinoma of the prostate	100
9.3.5.	Tumours in the small pelvis	100
9.4.	New approaches for interstitial hyperthermia	100
9.5.	Summary	101
9.6.	References	101
■	Pre- and postoperative supportive care in brachytherapy	102
10.1.	Patient preparation	102
10.2.	Anaesthesia and patient positioning	102
10.3.	Pain management	103
10.3.1.	General principles	103
10.3.2.	Postoperative management	103
10.4.	Anti-infective therapy	104
10.4.1.	Pre- and postoperative antibiotic treatment	104
10.5.	Prophylaxis of thrombosis	104
10.6.	Pre- and postoperative supportive care by specific tumour sites	105
10.6.1.	Tumours of the head/neck	105
10.6.2.	Breast cancer	106
10.6.3.	Carcinoma of the prostate	107
10.6.4.	Gynaecological tumours	108
10.7.	Follow-up	109
10.8.	References	109
■	Cervical cancer	110
11.1.	Indications	110
11.2.	Treatment planning	110
11.2.1.	Target volume	110
11.2.2.	Dose calculation and treatment planning (dose specification)	111
11.2.3.	Dose, dose rate, fractionation	120
11.3.	Practical execution and technique	120
11.4.	Results	121
11.4.1.	Locally limited tumours	122
11.4.2.	Locally advanced tumours	122
11.4.3.	Concomitant chemoradiotherapy	122
11.5.	Side effects	122
11.6.	Summary	123
11.7.	References	123

Endometrial carcinoma	125
12.1. Indications, patient selection criteria	125
12.1.1. Intracavitary brachytherapy in primary endometrial carcinoma	125
12.1.2. Adjuvant intravaginal brachytherapy	125
12.1.3. Intracavitary and interstitial brachytherapy for recurrences	126
12.2. Treatment planning	126
12.2.1. Target volumes	126
12.2.1.1. Primary radiotherapy	126
12.2.1.2. Adjuvant brachytherapy	127
12.2.1.3. Interstitial brachytherapy	127
12.2.2. Dose specification	128
12.2.2.1. Primary radiotherapy	128
12.2.2.2. Adjuvant brachytherapy	128
12.2.2.3. Interstitial brachytherapy	128
12.2.3. Dose, dose rate, fractionation	128
12.3. Practical execution and technique	129
12.3.1. Primary radiotherapy	129
12.3.2. Adjuvant brachytherapy	129
12.3.3. Interstitial brachytherapy	129
12.4. Results	129
12.5. Side effects	130
12.6. Summary	130
12.7. References	130
Vaginal carcinoma	132
13.1. Indications	132
13.2. Treatment planning	132
13.2.1. Target volume	132
13.2.2. Dose calculation and treatment plan (dose specification)	133
13.2.3. Dose, dose rate and fractionation	136
13.3. Practical execution and technique	137
13.3.1. Vaginal brachytherapy	137
13.3.2. Vaginal and interstitial brachytherapy	137
13.4. Results	138
13.5. Side effects	138
13.6. Summary	138
13.7. References	139
Vulvar carcinoma	140
14.1. Indications, patient selection criteria	140
14.2. Treatment planning	140
14.2.1. Target volumes	140
14.2.2. Dose specification	140
14.2.3. Dose, dose rate, fractionation	141
14.3. Practical execution and technique	141
14.4. Results	143

14.5.	Side effects	144
14.6.	Summary	144
14.7.	References	144

Carcinoma of the female urethra 146

15.1.	Indications, patient selection criteria	146
15.2.	Treatment planning	146
15.2.1.	Target volumes	146
15.2.2.	Dose specification	146
15.2.3.	Dose, dose rate, fractionation	147
15.3.	Practical execution and technique	147
15.4.	Results	147
15.5.	Side effects	148
15.6.	Summary	148
15.7.	References	148

Carcinoma of the prostate 150

16.1.	Indications, patient selection criteria	150
16.1.1.	Permanent implantation	150
16.1.2.	Temporary implantation	150
16.1.3.	Contraindications to implantation	151
16.2.	Treatment planning	151
16.2.1.	Target volumes	151
16.2.2.	Dose specification, fractionation	152
16.2.2.1.	Permanent (LDR) brachytherapy	152
16.2.2.2.	Temporary (HDR) brachytherapy	152
16.3.	Practical execution and technique	153
16.3.1.	Permanent brachytherapy (seeds)	153
16.3.2.	Temporary brachytherapy (HDR afterloading)	156
16.4.	Results	158
16.4.1.	Permanent brachytherapy (seeds)	158
16.4.2.	Temporary brachytherapy (HDR)	158
16.5.	Side effects	159
16.5.1.	Permanent brachytherapy (seeds)	159
16.5.2.	Temporary brachytherapy (HDR)	159
16.6.	Summary	160
16.7.	References	160

Carcinoma of the penis 162

17.1.	Indications, patient selection criteria	162
17.2.	Treatment planning	162
17.3.	Practical execution and technique	162
17.3.1.	Contact brachytherapy	162
17.3.2.	Interstitial brachytherapy	163
17.4.	Results	164
17.5.	Side effects	164
17.5.1.	Acute side effects	164
17.5.2.	Late side effects	164

17.6.	Summary.....	165
17.7.	References	165
	ENT tumours	166
18.1.	Carcinoma of the lip	166
18.1.1.	Indications, patient selection criteria.....	166
18.1.2.	Treatment planning.....	166
18.1.2.1.	Target volumes	166
18.1.2.2.	Dose specification.....	166
18.1.2.3.	Dose, dose rate, fractionation.....	167
18.1.3.	Practical execution, technique.....	167
18.1.4.	Results.....	167
18.1.5.	Side effects	168
18.2.	Oral cavity: carcinoma of the floor of the mouth, carcinoma of the mobile tongue	168
18.2.1.	Indications, patient selection criteria.....	168
18.2.2.	Treatment planning	170
18.2.2.1.	Target volumes	170
18.2.2.2.	Dose specification.....	171
18.2.2.3.	Dose, dose rate, fractionation.....	171
18.2.3.	Practical execution, technique.....	172
18.2.4.	Results.....	174
18.2.5.	Side effects	174
18.3.	Oropharynx	174
18.3.1.	Indications, patient selection criteria.....	174
18.3.2.	Treatment planning	175
18.3.2.1.	Target volumes	175
18.3.2.2.	Dose specification.....	175
18.3.2.3.	Dose, dose rate, fractionation.....	175
18.3.3.	Practical execution, technique.....	175
18.3.4.	Results.....	177
18.3.5.	Complications	177
18.4.	Buccal mucosa	177
18.4.1.	Indications, patient selection criteria.....	177
18.4.2.	Treatment planning	177
18.4.2.1.	Target volumes	177
18.4.2.2.	Dose specification.....	178
18.4.2.3.	Dose, dose rate, fractionation.....	178
18.4.3.	Practical execution and technique.....	178
18.4.4.	Results.....	178
18.4.5.	Complications	178
18.5.	Nasopharynx	178
18.5.1.	Indications, patient selection criteria.....	178
18.5.2.	Treatment planning.....	178
18.5.2.1.	Target volumes	178
18.5.2.2.	Dose specification.....	179
18.5.2.3.	Dose, dose rate, fractionation.....	179
18.5.3.	Practical execution, technique.....	179
18.5.4.	Results.....	180
18.5.5.	Side effects	180
18.6.	Summary.....	181
18.7.	References	181

Breast cancer	184
19.1. Indications, patient selection criteria	184
19.1.1. Interstitial brachytherapy as boost	184
19.1.2. Postoperative interstitial brachytherapy alone	184
19.1.3. Postoperative surface/interstitial brachytherapy of the chest wall after chest wall recurrence in patients who have previously had radiotherapy	185
19.2. Treatment planning	185
19.2.1. Target volumes	185
19.2.1.1. Interstitial brachytherapy	185
19.2.1.2. Target volume for balloon brachytherapy	190
19.2.1.3. Target volume in surface brachytherapy	190
19.2.1.4. Target volume in interstitial brachytherapy for the chest wall	190
19.2.2. Dose specification	190
19.2.2.1. Interstitial brachytherapy	190
19.2.2.2. Balloon brachytherapy	191
19.2.2.3. Surface brachytherapy	192
19.2.2.4. Interstitial brachytherapy chest wall	192
19.2.3. Dose, dose rate, fractionation	192
19.3. Practical execution and technique	192
19.3.1. Interstitial brachytherapy	192
19.3.2. Balloon brachytherapy	195
19.3.3. Mould (surface brachytherapy)	195
19.3.4. Interstitial brachytherapy of the chest wall	196
19.4. Results	196
19.4.1. Boost	196
19.4.2. Interstitial brachytherapy alone	196
19.4.3. Surface radiotherapy of the chest wall as re-irradiation	196
19.5. Side effects	196
19.5.1. Boost	196
19.5.2. Interstitial brachytherapy alone	197
19.5.3. Surface salvage-brachytherapy as re-irradiation	197
19.6. Summary	198
19.7. References	198
Lung cancer	200
20.1. Indications, patient selection criteria	200
20.1.1. Curative endobronchial brachytherapy	200
20.1.2. Palliative endobronchial brachytherapy	201
20.1.3. Curative endobronchial brachytherapy combined with external beam radiotherapy	201
20.1.4. Palliative endobronchial brachytherapy in combination with external beam radiotherapy	201
20.2. Treatment planning	202
20.2.1. Target volumes	202
20.2.1.1. The target volume for a curative intention	202
20.2.1.2. The target volume for a palliative intention	202
20.2.2. Dose specification	202
20.2.2.1. The dose specification for a curative intention	202
20.2.2.2. The dose specification for a palliative intention	203
20.2.3. Dose, dose rate, fractionation	203

20.3.	Practical execution and technique.	204
20.4.	Results	205
20.4.1.	Results of endobronchial HDR or LDR brachytherapy alone in curative intention	205
20.4.2.	Results of combined external beam and endobronchial radiotherapy in curative intention	205
20.4.3.	Results of endobronchial HDR or LDR brachytherapy alone in palliative intention	206
20.4.4.	Results of combined external beam and endobronchial radiotherapy in palliative intention	206
20.5.	Side effects	206
20.6.	Interstitial and intraoperative brachytherapy – indication, technique, results	207
20.7.	Summary	208
20.8.	References	208

Oesophageal carcinoma 211

21.1.	Indications, patient selection.	211
21.2.	Treatment planning	211
21.2.1.	Target volumes	211
21.2.2.	Dose specification.	213
21.2.3.	Dose, dose rate, fractionation.	214
21.3.	Practical execution and technique.	214
21.4.	Results	215
21.5.	Side effects	216
21.6.	Summary	216
21.7.	References	217

Carcinoma of the anal canal 218

22.1.	Indications, patient selection criteria	218
22.2.	Treatment planning	218
22.2.1.	Target volumes	218
22.2.2.	Dose specification.	219
22.2.3.	Dose, dose rate, fractionation.	219
22.3.	Practical execution and technique.	219
22.4.	Results and side effects	221
22.5.	Side effects	222
22.6.	Summary	222
22.7.	References	222

Skin tumours 224

23.1.	Indications, patient selection criteria	224
23.2.	Treatment planning	224
23.2.1.	Target volumes	225
23.2.2.	Dose specification.	225
23.2.3.	Dose, dose rate, fractionation.	225
23.3.	Practical execution and technique.	225
23.4.	Results	227
23.5.	Side effects	229
23.6.	Summary	229
23.7.	References	229

Choroidal melanomas	231
24.1. Indications, patient selection criteria	231
24.2. Treatment planning	231
24.2.1. Target volumes	231
24.2.2. Eye plaques	232
24.2.2.1. Ruthenium-106 eye plaques	232
24.2.2.2. Iodine-125 eye plaques	232
24.2.3. Dose specification and dosimetry	233
24.2.3.1. Ruthenium-106 eye plaques	233
24.2.3.2. Iodine-125 eye plaques	234
24.3. Practical execution and technique	234
24.4. Results	236
24.4.1. Ruthenium-106 brachytherapy	236
24.4.2. Iodine-125 brachytherapy	237
24.5. Side effects	237
24.6. Summary	238
24.7. References	238
Paediatric malignancies	239
25.1. Indications	239
25.2. Treatment planning	239
25.2.1. Target volumes	239
25.2.2. Dose specification	239
25.2.3. Dose, dose rate, fractionation	239
25.3. Practical execution and technique	239
25.4. Results	240
25.5. Side effects	240
25.6. Summary	240
25.7. References	240
Intracranial brachytherapy	241
26.1. Indications, patient selection criteria	241
26.1.1. Intradural malignancies	241
26.1.2. Intracranial extradural malignancies	241
26.2. Treatment planning	241
26.3. Results	241
26.4. Side effects	241
26.5. Summary	242
26.6. References	242
Soft tissue sarcomas	243
27.1. Indications, patient selection criteria	243
27.2. Treatment planning	243
27.2.1. Target volumes	243
27.2.2. Dose specification	243
27.2.3. Dose, dose rate, fractionation	243
27.3. Practical execution and technique	243

27.4.	Results	244
27.5.	Side effects	244
27.6.	Summary	246
27.7.	References	246
	Pterygium and keloids	248
28.1.	Indications, patient selection criteria	248
28.2.	Treatment planning	248
28.2.1.	Target volumes	248
28.2.2.	Dose specification	248
28.2.3.	Dose, dose rate, fractionation	248
28.3.	Practical execution and technique	249
28.4.	Results	251
28.5.	Side effects	251
28.6.	Summary	252
28.7.	References	252
	Perspectives in brachytherapy	254
29.1.	References	259
	Index	261