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Cervixkarzinom – Brachytherapie

ABBREVIATIONS	
HDR	High Dose Rate
D	Dose
BT	Brachytherapy
Dg	Diagnosis
SOP	Standard Operating Procedure
EBRT	External Beam RadioTherapy
ChT	Chemotherapy
IC	IntraCavitary
IS	InterStitial
US	Ultrasound
TRUS	TransRectal UltraSound
TAUS	TransAbdominal UltraSound
HR	High Risk
IR	Intermediate Risk
res	Residual
ICRU	International Comission on Radiology Units
PIBS	Posterior Inferior Bony Symphisis
EQD2	Equivalent D in 2 Gy per fraction
OAR	Organ at risk
TRAK	Total Reference Air Kerma
OTT	Overall Treatment Time
FU	Follow Up
TPS	Treatment Planning System
MTRA	Medizinisch-Technischer Radiologieassistent
MP	Medical Physicist
RV	Rectovaginal
RO	Radiation oncologist

PATIENT GROUP
<u>This document covers:</u> 1. Patients undergoing HDR BT for cervical cancer.
<u>This document doesn`t cover:</u> 1. Other BT indications. 2. EBRT.

PREPARATION FOR BRACHYTHERAPY	References

Refer to:	K:\RAO_QM\Handbuch\06. Patientenbezogener Behandlungsprozess\6.2. Therapieindikation-Durchführung-Nachsorge\06_02_04_Gynäkologie
1. Cervix cancer clinical SOP 2. Cervix cancer EBRT + ChT SOP	

BRACHYTHERAPY IMPLANT PLANNING: BT 0	References
1. Objective: insertion pre-plan for optimal implant. 2. Requirements: ○ *Minimal:* clinical examination & MRI at Dg + pre-BT examination. Images from each BT inform pre-planning of following BT fractions. ○ *Standard:* minimal + pre-BT MRI (5th week). ○ *Optimal:* minimal + pre-BT MRI with IC applicator in place.	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4110086/ https://www.sciencedirect.com/science/article/pii/S0167814013000261?via%3Dihub

BRACHYTHERAPY FRACTIONATION (BT 1-4)

- 4 applications, 4 BT fractions.
- Timing: weeks 6 & 7 from EBRT start.
- 2 applications/week, 1 fraction/application.

APPLICATOR INSERTION

1. Anesthesia: spinal / general. Paracervical block: exceptional & for IC BT-only.
2. Patient position: lithotomy.
3. Application area: disinfected & cover sterile.
4. Insert urinary catheter & fill balloon with normal saline. If IS needles needed close to bladder, use 3-luminal catheter for rinsing if bladder wall perforation. Pull balloon to bladder neck
5. Visualize portio with specula.
6. Grab ant. cervical lip with forceps & remove ventral speculum.
7. Fill bladder with normal saline & clamp catheter.
8. While exerting pull on forceps, insert uterine probe under US guidance.
9. Determined uterine length & flexion, choose applicator.
10. Dilate cervix under US guidance up to width for tandem insertion.
11. Insert tandem, remove forceps, re-insert specula.
12. Check flange position.
13. Verify tandem position with US.
14. Un-clamp catheter, remove specula.
15. Insert ring; use gel. Protect post. commissure & peri-urethral region.
16. Fix ring fixed to tandem.
    a. When only IC BT: vaginal packing, fix applicator, continue to 23.
    b. When IC/IS BT: use ring with holes under 15, continue to 17.
17. Insert needles. Blunt needles reduce organ perforation odds. Mucosa pre-puncturing with sharp needle facilitates blunt insertion.
18. Guide needles with TRUS +/- TAUS (especially retro-vesical needles).
19. Start with ventral followed by dorsal needles to avoid acoustic shadowing. If narrow vagina: may be better to start with dorsal needles.
20. Needle depths, angles guided by pre-plan, final placement by US.
21. Vaginal packing.
22. Fix applicator to patient.
23. Reposition to supine.
24. Post-anesthesia supervision.

25. Transport to MRI / CT.

IMAGING FOR TREATMENT PLANNING	
CT	References
1. Position: supine, arms on chest, support under knees. 2. I.v. contrast. 3. Bladder filling: ○ Standard: empty & fill with 50 ml normal saline. ○ Individualized: ROs instruction. 4. Scanning: BT Protocol, 1 mm slices. 5. Region: 3 cm above tandem to vaginal introitus. 6. Import to TPS, inform physics.	https://www.sciencedirect.com/science/article/pii/S0167814021062484?via%3Dihub
MRI	References
1. Rule out contraindications & ferromagnetic parts. 2. Position: supine, arms on chest, support under knees. 3. I.v. contrast: none. 4. Bladder filling: ○ Standard: empty & fill with 50 ml normal saline. ○ Individualized: ROs instruction. 5. Sequences - all T2w FSE: ○ axial (perpendicular to couch) ○ para-axial (perpendicular to cervical canal) ○ para-coronal (parallel to cervical canal) ○ para-sagittal (parallel to cervical canal) ○ Space 6. Regions: ○ Axial, paraxial: i. Upper border L3 to lower border ischial tuberosities. ii. Always entire uterus. iii. Entire vagina when invaded. ○ Para-sagittal: i. Between lateral borders of obturator muscles. ii. Include uterine corpus, cervix, vagina, tumor. ○ Para-coronal: i. Ant. surface of sacrum to post. border of symphysis. ii. Include uterine corpus, cervix, vagina, tumor. 7. Register MRI with CT when both done.	Recommendations from Gynaecological (GYN) GEC-ESTRO Working Group (IV): Basic principles and parameters for MR imaging within the frame of image based adaptive cervix cancer brachytherapy - PubMed (nih.gov)

CONTOURING			
Target volumes			
ICRU GEC ESTRO Nomenclature	*USZ Nomenclature*	*Conversion ICRU to USZ*	https://www.sciencedirect.com/science/article/pii/S0167814004005791?via%3Dihub ICRU Report 89, Book Gyn: K:\RAO_Aerzte\Anforderung_Planungsauftrag\HDR_Planungsauftrag\2. Literature, Test cases 2021 Workshop
GTV-T_{res} BT 1-n	GTV1_V1_2aA-X	0 mm from GTV-T_{res} BT	
CTV-T_{HR} BT 1-n	CTV1_V1_2aA-X	0 mm from CTV-T_{HR} BT	
CTV-T_{IR} BT 1-n	CTV2_V1_2aA-X	0 mm from CTV-T_{IR} BT	

No PTV	PTV1_V1_2aA-X	0 mm from CTV-T_{HR} BT	lectures, Video\03_2021 Literatur WS German Book (in progress)
	PTV2_V1_2aA-X	0 mm from CTV-T_{IR} BT	
Organs at risk			
Bladder, urethra, rectum, sigmoid colon, & bowel. If distal vagina involved: + anus, clitoris, vulva.			

APPLICATOR RECONSTRUCTION & POINTS PLACEMENT	References
1. Tandem & ring: from library (MP) 2. Needles: manually digitize (MP) 3. Point A, ICRU RV, ICRU-bladder, Vag. surface, PIBS, PIBS-2 & +2 (MP) 4. Reconstruction & points check (2nd MP).	https://www.sciencedirect.com/science/article/pii/S0167814010003683?via%3Dihub ICRU Report 89: K:\RAO_Aerzte\Anforderung_Planungsauftrag\HDR_Planungsauftrag\2. Literature, Test cases 2021 Workshop lectures, Video\03_2021 Literatur WS

DOSE OPTIMISATION	
General	References
1. Clinical input from RO: ○ Planning aims & D constraints. ○ "Centroid" needles (eventual loading >accepted limits) ○ "OAR" needles (eventual loading < accepted limits). ○ Sub-volumes that need prioritization. ○ Intentional dosimetric "non-conformity margins". ○ If nothing specified, general instructions apply. 2. Manual optimization preferred over automated tools.	GEC ESTRO Recommendations (upcoming) German Book (upcoming) EMBRACE 2 Protocol

IC Optimization

1. Initial step: activate dwell positions along tandem & ring in "standard pattern".
2. Specify 7 Gy at point A. Outcome scenarios:
   - *Adequate target and OAR dose(s)*: All objectives met. Standard loading optimal.
   - *Adequate target and excessive OAR dose(s):* Global/local IC downscaling may achieve aims. If this is impossible w/o target coverage compromise, IC & IS technique needed.
   - *Excessive target +/- excessive OAR dose(s):* Global/local IC downscaling may achieve aims. Attention: point A D, TRAK, iso-D surface V & breaking down of high D within CTV-T_{HR} and GTV-T_{res}. If IC de-escalation fails to achieve aims, IC & IS technique needed.
   - *Inadequate target +/- excessive OAR dose(s):* IC escalation for inadequate target coverage +/- reduction of OAR exposure may achieve aims. Commonly possible if CTV-T_{HR} ≤5 mm beyond planning-aim iso-D of standard plan at point A level. If not, IC & IS technique needed.

IS Optimization

Parallel IS needles can expand planning-aim iso-D for ca. 10-15 mm at point A level. Oblique needles: for deeper targets. IC component should be predominant contributor to overall TRAK.

1. Start by standard IC loading & specification of 7 Gy at point A.
2. Assuming (near)-ideal IS geometry, reduce IC loading locally/globally below OAR limits.
3. Adapt cranial tandem positions according to cranial CTV-T_{HR} border; D non-conformity of up to 10 mm above CTV-T_{HR} advised, if no excessive OAR D.

4. Load parallel needles before oblique.
5. Select needle with optimal ratio between distance from OAR & ability to cover target.
    a. Rotate sagittal / coronal images parallel to selected needle & place them along its plane.
    b. In "needle-eye-view" activate dwell positions along the length traversing CTV-T_{HR}.
    c. Adjust needle dwell-times according to CTV-T_{HR} and OAR.
    d. Max. needle dwell time of up to 10-20% of the original tandem dwell time preferred.
    e. Dwell time may be >20% if needle far from OAR & deep in CTV-T_{HR}.
    f. Dwell time may be <10% in needles close to OAR / at CTV-T_{HR} edge.
6. Do step 5 for each needle, last for channels near OAR and/or with small impact on target coverage.
7. Check D distribution and DVH continuously to iteratively inform optimization.
8. Assess V receiving 150% and 200% D: avoid extension in OAR and/or outside target.
9. After manual optimization, graphical fine-tuning can be done. Avoid excessive loading and/or formation of confluent high-D volumes.

PLANNING AIMS & CONSTRAINTS: General rules

1. Planning aim priority decreases L to R in Tables below.
2. Aim: achieve soft constraints in ≥ ~70-80% of patients.
3. Aim: achieve hard constraints in ≥ ~90-95% of patients.
4. Bladder/rectum invasion at BT: hard constraints may be exceeded.
5. Advanced PM inv. at BT: target hard constraints may not be reached.
6. CTV-T_{HR} soft constr. <95Gy not of highest priority: often exceeded in small tumors at BT.
7. EMBRACE II: bladder D_{2cm3} hard constraint was 90 Gy. 85 Gy now proposed, but may be difficult to achieve in large CTV-T_{HR} at BT.
8. Sigmoid/bowel: D constraints particularly relevant with non-mobile loops.

TARGET AIMS: **total** $EQD2_{10}$ for EBRT + BT

	D90 CTV-T_{HR}	*D98 CTV-T_{HR}*	*D98 GTV_{res}*	*D98 CTV-T_{IR}*	*Point A*	*OTT*
Soft	> 90 Gy < 95 Gy	> 80 Gy	> 95 Gy	> 60 Gy	> 65 Gy	50 days
Hard	> 85 Gy	> 75 Gy	> 90 Gy	-	-	55 days

OAR CONSTRAINTS: **total** $EQD2_3$ for EBRT + BT

	D2cm3 Rectum	*D2cm3 Bladder*	*point D ICRU RV*	*point D ICRU Bladder*	*D2cm3 Bowel*	*D2cm3 Sigmoid*
Soft	< 65 Gy	< 80 Gy	< 65 Gy	< 75 Gy	< 65 Gy	< 70 Gy
Hard	< 75 Gy	< 85 Gy	< 75 Gy	< 85Gy	< 75 Gy	< 75 Gy

TARGET AIMS: average nominal D for BT **per fraction**

	D90 CTV-T_{HR}	*D98 CTV-T_{HR}*	*D98 GTV_{res}*	*D98 CTV-T_{IR}*	*Point A*	*OTT*
Soft	> 7.8 Gy < 8.4 Gy	> 6.5 Gy	> 8.3 Gy	> 3.5 Gy	> 4.4 Gy	NA
Hard	> 7 Gy	> 5.8 Gy	> 7.8 Gy	-	-	NA

OAR CONSTRAINTS: average nominal D for BT **per fraction**

	D2cm3 Rectum	*D2cm3 Bladder*	*point D ICRU RV*	*point D ICRU bladder*	*D2cm3 Bowel*	*D2cm3 Sigmoid*
Soft	< 4 Gy	< 5.4 Gy	< 4 Gy	< 5 Gy	< 4 Gy	4.4
Hard	< 5 Gy	< 5.8 Gy	< 5 Gy	< 5.8 Gy	< 5 Gy	< 5 Gy

PLAN REVIEW & APPROVAL

1. Plan review & approval (RO).

2. Plan review & approval (MP & 2nd MP).

PRE-TREATMENT CHECKS & TREATMENT
1. Afterloader morning QA check (MTRA). 2. Emergency equipment check (MTRA). 3. Import approved plan to afterloader console (MTRA). 4. Check channel treatment times (MTRA & MP). 5. Approve plan (MTRA). 6. Time-out: patient, procedure, applicator, positions, times, plan name, source strength (MTRA). 7. Remove afterloader from safe (MTRA). 8. Connect transfer tubes to applicator (RO) & afterloader (MTRA). Check visually & verbally. 9. Empty, then fill bladder with 50 ml normal saline. 10. "Push Test" & "Length Test" are performed (MTRA). 11. Last Man Out sequence (MTRA). 12. Adjust treatment room cameras (MTRA). 13. Specify team member for the case of emergency entry in BT room (MTRA). 14. Inform RO that pre-treatment checks are completed (MTRA). 15. Signal treatment start (RO). 16. Start treatment (MTRA). 17. Import & approve Treatment Report in ARIA (MTRA).

APPLICATOR REMOVAL (RO & Nurse)
1. BT room, supine in bed or lithotomy on operating table. 2. Sedation & analgesia. 3. Remove vaginal packing. 4. Remove needles. 5. Remove tandem. 6. Inject Xylocain gel intravaginaly. 7. Remove ring. Protect vaginal walls. 8. Clinical examination and rinsing. 9. If bleeding: pressure with tampon, hemostatic mesh (i.e. Surgicel) & packing. 10. If persistent bleeding: continue 9, call gynecologist, monitor, standby for transfusion. 11. If no bleeding: remove urinary catheter. 12. Observe (K:\RAO_QM\Handbuch\06. Patientenbezogener Behandlungsprozess\6.2. Therapieindikation-Durchführung-Nachsorge\06_02_04_Gynäkologie)

TREATMENT RECORDING & REPORTING (RO & MP)	
• According to ICRU Report 89. • Departmental EQD2 spreadsheets.	Prescribing, Recording, and Reporting Brachytherapy for Cancer of the Cervix - PubMed (nih.gov) K:\RAO_Aerzte\Anforderung_Planungsauftrag\HDR_Planungsauftrag\1. TOOLS\Cervix Tools

POST-TREATMENT INSTRUCTIONS (RO)	
• Bleeding, fever, chills, pain: visit doctor. • Delay vaginal dilatation for 3-6 weeks after last BT. • Plan next BT or post-treatment FU.	K:\RAO_Aerzte\Anforderung_Planungsauftrag\HDR_Planungsauftrag\1. TOOLS\Cervix Tools