From the IVAR pilot to recommendations for end-to-end auditing of Norwegian radiation therapy centers in the NO-SHANE project

Teknisk dokument
29.04.2025, nummer 34

Dosimetry auditing in Norway

DSA
Direktoratet for strålevern og atomsikkerhet

Referanse

Danielsen T, Djupvik LH, Eklund K, Frengen J, Hansen EL. Dosimetry auditing in Norway. From the IVAR pilot to recommendations for end-to-end auditing of Norwegian radiation therapy centers in the NO-SHANE project.
Teknisk dokument nr. 34. Østerås: Direktoratet for strålevern og atomsikkerhet, 2024.

Emneord

Dosimetri. Stråleterapi. Revisjoner.

Resymé

Denne rapporten omhandler et pilotprosjekt (IVAR, 2018-2022) og et planlagt kommende prosjekt (NO-SHANE, 2025-2027) om revisjoner av dosimetri i ekstern strålebehandling ved norske offentlige sykehus.

Reference

Danielsen T, Djupvik LH, Eklund K, Frengen J, Hansen EL. Dosimetry auditing in Norway. From the IVAR pilot to recommendations for end-to-end auditing of Norwegian radiation therapy centers in the NO-SHANE project.
Technical Document no. 34. Østerås: Radiation and Nuclear Safety Authority, 2024.
Language: English.

Key words

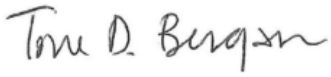
Dosimetry. Radiation therapy. Audits.

Abstract

This report concerns a pilot project (IVAR, 2018-2022) and a planned upcoming project (NO-SHANE, 2025-2027) of dosimetry auditing of external beam radiation therapy at Norwegian public hospitals.

Prosjektleder: Elisabeth Lindbo Hansen

Godkjent:



avdelingsdirektør, avdeling strålesikkerhet

Publisert 29.04.2025
Sider 15

DSA,
Postboks 329,
0213 Oslo,
Norge.

Telefon 67 16 25 00
Faks 67 14 74 07
Email dsa@dsa.no
dsa.no

ISSN 2387-5240

Dosimetry auditing in Norway

From the IVAR pilot to recommendations for end-to-end auditing of Norwegian radiation therapy centers in the NO-SHANE project

Turi Danielsen [Forfattere]
Linda Holth Djupvik
Karin Eklund
Jomar Frengen
Elisabeth Lindbo Hansen

fra Direktoratet for strålevern [xxxxx]
og atomsikkerhet (DSA)

Østerås, 2024 [xxxxx]
Norway

Contents

1 From the IVAR pilot to the NO-SHANE project

This report concerns a pilot project (IVAR, 2018-2022) and a planned upcoming project (NO-SHANE, 2025-2027) of dosimetry auditing of external beam radiation therapy at Norwegian public hospitals. The projects are coordinated by the Norwegian Radiation and Nuclear Safety Authority (DSA). Between 2018 and 2022, five radiation therapy centers were audited for reference dosimetry and for dose delivery planned with a treatment planning system (TPS) in the IVAR pilot. Starting from 2025, DSA plans to offer end-to-end auditing to all Norwegian radiation therapy centers for a period of roughly two years, with the possibility of establishing such auditing as a permanent program after 2027. This end-to-end auditing is designed to follow a protocol developed under the coordination of the IAEA [1,2]. A recent IAEA Human Health Series publication [3] on accuracy requirements and uncertainties in radiation therapy lists auditing as its fourth recommendation to radiation therapy centers:

> *"An independent dosimetry audit should be performed for every new installation that is about to embark on radiation treatments. In addition, regular (e.g., annual) audits should be performed using remote services or on-site visits (or equivalent)."*

According to this publication, auditing minimizes the risk of major errors and aids in improving accuracy. The Norwegian auditing process aims to also encourage knowledge exchange between radiation therapy centers by including in every auditing team a medical physicist from a center other than that which is being audited.

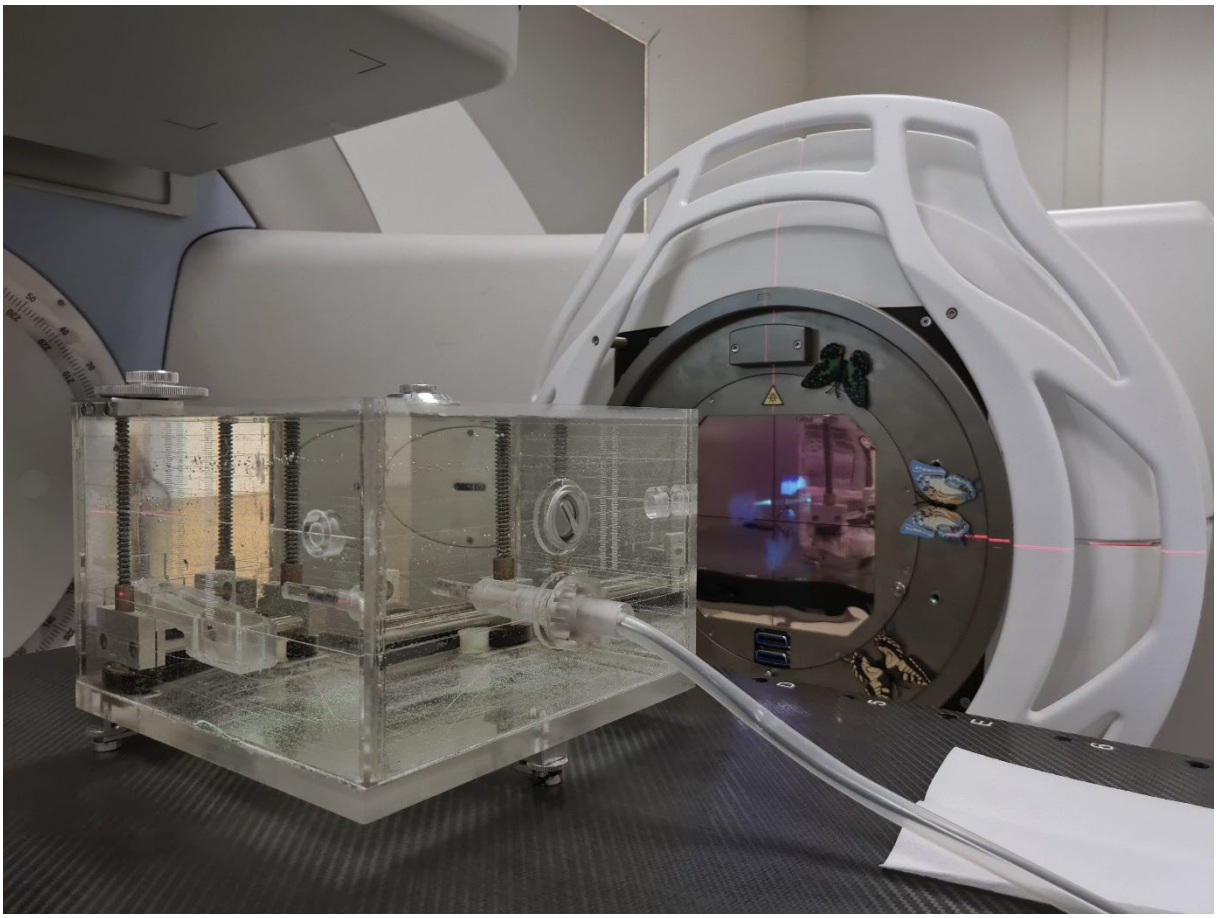


Image credit: Elisabeth Lindbo Hansen

2 The IVAR pilot (2018-2022)

The IVAR pilot was initiated in response to a request in 2017 [4] from the professional community of chief medial physicists[1] in Norway for a national auditing program. A project group for dosimetry audits was established in 2018 with representatives from four of the university hospitals in Norway and from the Dosimetry Laboratory[2] and KVIST[3] at DSA (alphabetically listed):

Aniko Balazs (until 2019), Karin Eklund (from 2019 to 2022), Jomar Frengen, Hans Bjerke (until 2019), Turi Danielsen, Linda Holth Djupvik (until 2020), Elisabeth Lindbo Hansen, Per Otto Hetland, Lukas Hirschi, Nina Iren Hoven (until 2022), Camilla Hægeland (in 2018), Brede Dille Pedersen (from 2019), Veronika Tømmerås (until 2018), and Harald Johan Valen (in 2018).

The group was initially appointed by the professional community of chief medical physicists. Subsequently, the project has been coordinated by DSA and regarded by DSA as a subgroup of the KVIST working group on dosimetry[4]. Equipment costs have been covered by DSA, and travel costs associated with each audit by the home institutions of the participants.

2.1 Protocol

The IVAR auditing protocol was developed by the project group for dosimetry audits in the first half of 2018 (Appendix A). The protocol uses a box water phantom for reference dosimetry according to IAEA TRS-398 [5]. A simplified torso water phantom (IVAR) subsequently receives the following TPS planned conventional fields:

- → One field
- → Two opposing fields
- → Four-field box

Subsequently, the protocol involves delivering a VMAT plan to the IVAR phantom. This plan is developed by local physicists using the local TPS on a DICOM structure-set for a prostate cancer case. There are two dose levels constrained by pre-established protocol criteria. During the audits a Farmer-type ionization chamber is used to measure absorbed dose to water for the reference dosimetry, for the TPS planned conventional fields at isocenter, as well as for the VMAT irradiations at three different locations:

- → Isocenter, in the volume DOSE1: a cylindrical volume with a diameter of 20 mm and a height of 20 mm in the high dose level area.
- → Point 2, in the volume DOSE2: a cylindrical volume of the same size as DOSE1, centered 40 mm cranial to the isocenter, lying between the two parts of the target volume with the lowest dose level.
- → Point 3, in the volume DOSE3: a cylindrical volume of the same size as DOSE1, centered 20 mm caudal to the isocenter in the high dose level area.

The protocol includes dose homogeneity criteria for the volumes surrounding the measurement points (DOSE1-DOSE3). Especially for Point 2, this would otherwise be lying in an area of large dose gradient.

[1] The chief medical physicists in Norway have a forum called Sjeffysikermøtet.
[2] The Dosimetry Laboratory at DSA is Norway's national reference laboratory in the field of ionizing radiation, responsible for the units gray (Gy), sievert (Sv) and becquerel (Bq).
3 The KVIST group at DSA works closely with all the country's radiation therapy centers to ensure quality and safety for patients.
[4] The KVIST working group on dosimetry was first established in 2001 and active to 2014 before it again was re-established in 2018.

2.2 Results

One linac was audited at each radiation therapy center at energy 6 MV. Results have been published as DSA Technical Documents [6-10] with permission from the audited centers. The absorbed dose to water measured by the auditing team under reference conditions showed relative deviations from the reference dosimetry of the audited centers in the range from -0.9 % to +0.6 % (Figure 1). The standard uncertainty of the relative deviation was estimated to 1.4 %.

For the TPS planned conventional fields, measured absorbed doses to water showed relative deviations from TPS planned doses of:

- → One field, -2.4 % to 0.2 %
- → Two opposing fields, -1.4 % to 0.4 %
- → Four-field box, -1.3 % to 0.1 %

During VMAT irradiations, measured absorbed doses to water showed relative deviations from TPS planned point doses in the ranges of:

- → Isocenter, in the volume DOSE1, -3.4 % to 0.5 %
- → Point 2, in the volume DOSE2, -4.5 % to 1.3 %
- → Point 3, in the volume DOSE3, -2.4 % to 0.6 %

Deviations from TPS calculated volume mean or volume median doses (Figure 1) were generally within the ranges of the point doses.

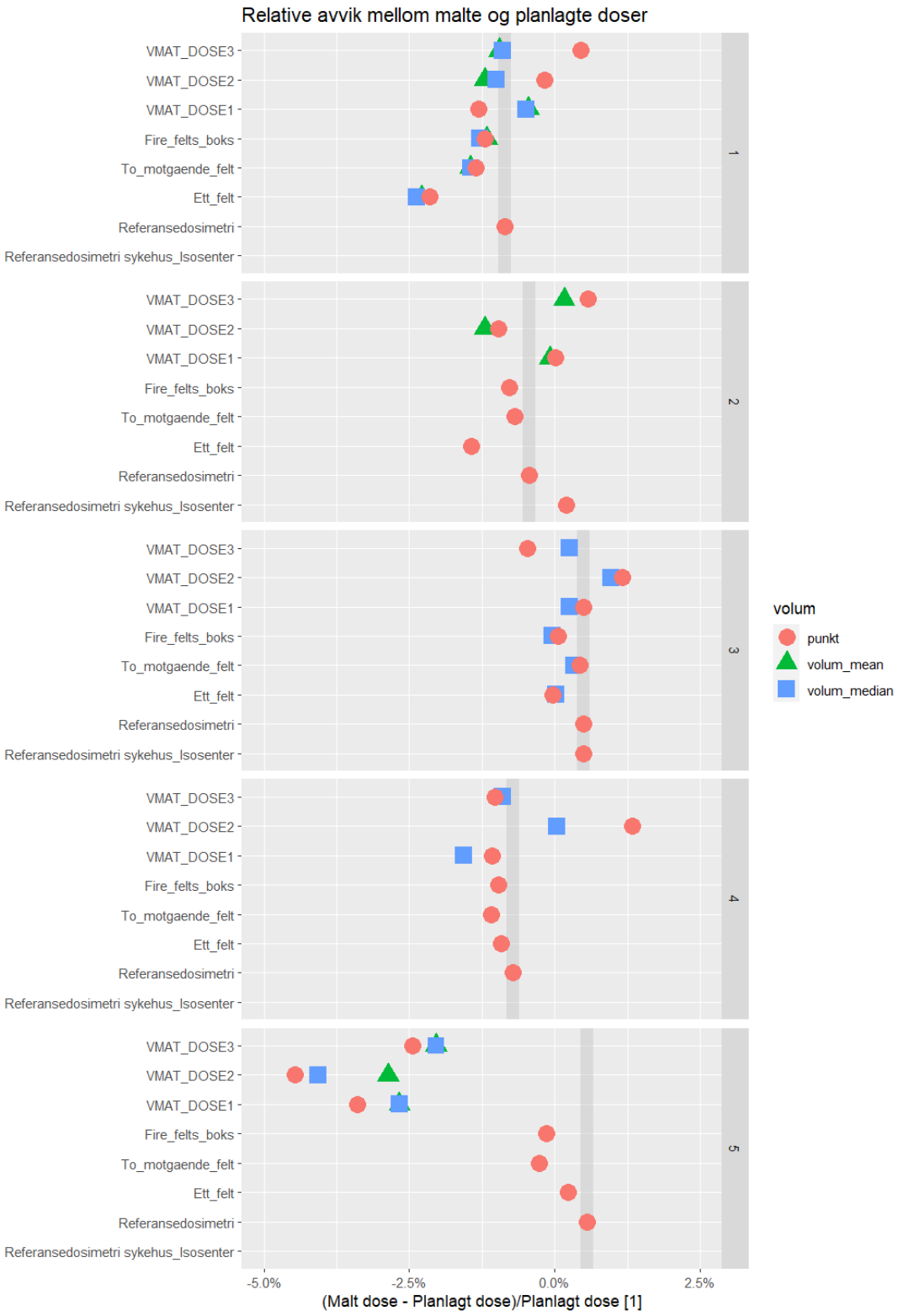


Figure 1: Relative deviations between absorbed doses to water measured by the auditing team and reported by the audited radiation therapy centers (1-5) either based on linac output calculated from their own reference dosimetry (Referansedosimetri, also marked by the vertical grey bar) or extracted from their TPS. Malt dose means measured dose and Planlagt dose means either linac output or TPS dose. Some of the centers ran a check of their own reference dosimetry on the day preceding the audit (Referansedosimetri sykehus_Isosenter) without adjusting their machine output calibration. The red circles are point doses, the green triangles are mean doses over a volume and the blue squares are median doses over a volume.

2.3 Conclusions

The IVAR pilot has demonstrated good agreement between the reference dosimetry of the auditing team and that of the audited radiation therapy centers. The agreement between measured doses and TPS doses was also good for the conventional fields, but with a slight tendency towards underdosing.

Clinics were not asked to submit information about corrections for dose attenuation in the couch. Corrections can be implemented differently, or they may be neglected since the effect is small. Procedures relating to couch corrections could contribute to a larger spread between measured doses and TPS doses for the conventional one field irradiations relative to the reference dosimetry.

We note that the largest deviations between measured doses and TPS doses occurred during the auditing of a radiation therapy center that was not in full compliance with the auditing protocol for the VMAT irradiations. This center had not included dose homogeneity criteria in their TPS for the volumes surrounding the measurement points. The Farmer-type chamber that measures absorbed dose to water in the phantoms can be sensitive to such dose gradients.

3 The NO-SHANE project (2025-2027)

The NO-SHANE project is designed to follow a protocol developed under the coordination of the IAEA [1,2]. The protocol is an end-to-end audit that follows an anthropomorphic phantom (SHANE) [11] through CT-scanning, dose planning and dose delivery for the clinical test case of a head-and-neck cancer. The phantom represents a typical human patient in anatomy, density and 3D structures. The protocol involves several small field dosimetry tests that are performed in the TPS by the radiation therapy center before an audit. These tests are then repeated on the linac with physical measurements during the on-site part of an audit. Measurements on-site are made by the auditing team using a small ion chamber and film dosimetry. The protocol contains well-defined pass/fail criteria that are based on peer-reviewed literature. The NO-SHANE project can therefore evaluate how Norwegian radiation therapy centers perform relative to such criteria.

Figure 2: The SHANE Phantom Patient for VMAT & IMRT - CIRS (cirsinc.com) purchased by DSA for national audits according to the IAEA protocol. Image credit: Elisabeth Lindbo Hansen

3.1 Recommendations

The NO-SHANE project has been under planning formally at DSA in the period from 2022 to 2023 with the result that the project is owned by the Medical Applications Section (MED) and coordinated by a project group consisting of members from the Dosimetry Laboratory (Elisabeth Lindbo Hansen) and KVIST (Turi Danielsen to 2024, Karin Eklund in 2024, Tone Kristin Saksgård and Ana María Acosta Roa from 2024).

The results of the IVAR pilot and plans for the NO-SHANE project were discussed at a meeting of the KVIST working group on dosimetry in the spring of 2023. In attendance were (alphabetically listed):

Johannes K. Bergvoll, David Byberg, Turi Danielsen, Karin Eklund, Per Otto Hetland, Elisabeth Lindbo Hansen, Jomar Frengen, Mathis Hasler, Lukas Hirschi, Christoffer Lervåg, Brede D. Pedersen, Kristine Perander, May Lise Salomonsen, Peter Skogholt, Harald Valen, Tor Arne Vestad, Ståle Ølberg.

It was generally agreed by the group that it would be beneficial for DSA to continue its work towards coordinating more advanced national dosimetry audits of Norwegian radiation therapy centers.

Based on these evaluations and considering experiences from auditing in other countries [12], it is the recommendation of the authors of the current report that dosimetry auditing following the protocol developed under the coordination of the IAEA [1,2] should be established in Norway in the form of the NO-SHANE project, coordinated by DSA.

The chief aims of the NO-SHANE project should be:

- → To gain national experience in running VMAT end-to-end audits,
- → To evaluate the performance of Norwegian radiation therapy centers relative to international criteria according to the IAEA protocol,
- → To publish the results of the project in the peer-reviewed literature,
- → To recommend whether end-to-end auditing should be stablished as a permanent program in Norway after the conclusion of the project, and
- → To, in that event, suggest national criteria for such an audit.

4 References

[1] International Atomic Energy Agency. Dosimetry audit networks (DAN) database: On-site 'end-to-end' dosimetry audits, cited 2024 Jun 03. Available from: https://dosimetry-audit-networks.iaea.org/Home/EndToEndAudits

[2] Kazantsev P, Lechner W, Gershkevitsh E, Clark CH, Venencia D, Van Dyk J, Wesolowska P, Hernandez V, Jornet N, Tomsej M, Bokulic T, Izewska, J. IAEA methodology for on-site end-to-end IMRT/VMAT audits: an international pilot study. Acta Oncologica, 59(2), 141–148, 2019. https://doi.org/10.1080/0284186X.2019.1685128

[3] International Atomic Energy Agency. Accuracy Requirements and Uncertainties in Radiation therapy. Human Health Series No. 31, Vienna: IAEA, 2016.

[4] Minutes from the KVIST reference group meeting held 2017 Mar 22 at Gardermoen, Norway Referat_Refgruppe_22-03-2017_endringer etter utsendelse.doc

> *"I etterkant av NACP hadde sjeffysikerne et møte, der dosimetrisk revisjon var ett av temaene. Det ble enighet om å starte opp en gruppe som består av fysikere fra de «fire store», dvs. HUS, OUS, SOH og UNN, samt KVIST som kan bidra med å koordinere arbeidet. I utgangspunktet er det tenkt at gruppen skal etablere et system for dosimetrirevisjoner, og starte opp med relativt enkle oppsett for å komme i gang. På sikt er målet å gjøre revisjon av komplekse behandlingsteknikker (IMRT/VMAT). KVIST vil kalle inn til videokonferanse, der man bør avklare prosjektet mot dosimetritilsynet som skal føres fra Strålevernet."*

[5] International Atomic Energy Agency. Absorbed Dose Determination in External Beam Radiotherapy. Technical reports series 398. Vienna: IAEA, 2000.

[6] Danielsen T, Frengen J, Hansen EL, Hetland PO, Pylypchenko, Y. Dosimetry audit at St. Olavs hospital HF, Trondheim University Hospital. Technical Document no. 28. Østerås: Norwegian Radiation and Nuclear Safety Authority, 2023. Language: Norwegian.

[7] Danielsen T, Frengen J, Hansen EL, Hetland PO, Pedersen BD, Sylvarnes R. Dosimetry audit in radiotherapy at the University Hospital of North Norway, Tromsø. Technical Document no. 27. Østerås: Norwegian Radiation and Nuclear Safety Authority, 2023. Language: Norwegian.

[8] Eklund K, Danielsen T, Djupvik LH, Hansen EL, Hetland PO, Hirschi L, Valen HJ. Dosimetry audit in radiotherapy at Helse Bergen HF, Haukeland University Hospital. Technical Document no. 19. Østerås: Norwegian Radiation and Nuclear Safety Authority, 2021. Language: Norwegian.

[9] Balazs A, Danielsen T, Djupvik LH, Hansen EL, Hetland PO, Hirschi L, Hoven NI. Dosimetry audit in radiotherapy at OUS HF, Radiumhospitalet. Technical Document no. 18. Østerås: Norwegian Radiation and Nuclear Safety Authority, 2021. Language: Norwegian.

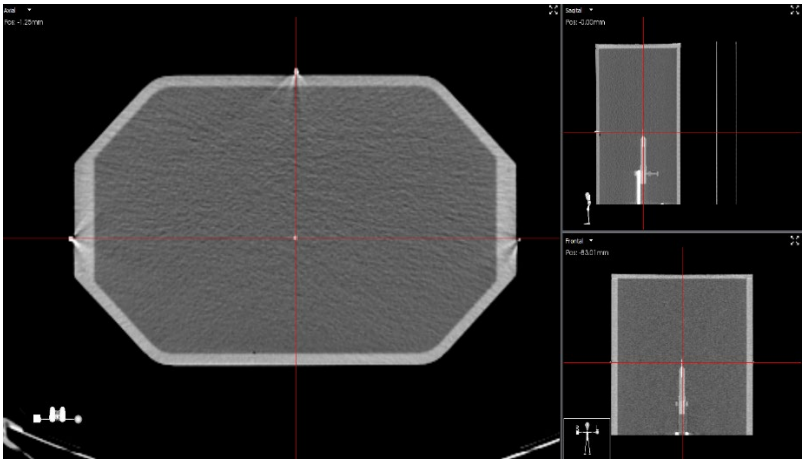
[10] Balazs A, Bjerke H, Danielsen T, Djupvik LH, Hansen EL, Hetland PO, Hoven NI. Dosimetry audit in radiotherapy at OUS HF, Ullevål Hospital. Technical Document no. 17. Østerås: Norwegian Radiation and Nuclear Safety Authority, 2021. Language: Norwegian.

[11] Phantom Patient for VMAT & IMRT - CIRS (cirsinc.com), https://www.cirsinc.com/products/radiation-therapy/phantom-patient-for-vmat-imrt/ [url, retrieved 05.08.2024].

[12] Clark CH, Jornet N, Muren LP. The role of dosimetry audit in achieving high quality radiotherapy. Phys Imaging Radiat Oncol. Mar 21;5:85-87, 2018.

5 Appendix A: IVAR protocol

1. Isosenter settes ut fra markeringskulene på fantomet slik angitt i bildet: (CT-snitt/z=0)

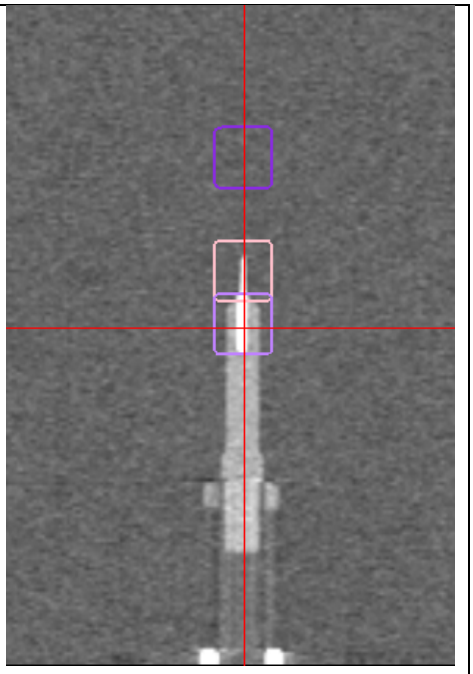


2. Tetthetsmatrise/oppløsning for doseberegning: 2.5mm
3. Behandlingsbord: bruk samme korreksjon som dere ville gjort klinisk
4. Energi: R6 (for alle planene)
5. Kontroller ytterkonturen. Generer en ny hvis behov.
6. Struktur Kammer: tettheten til denne strukturen settes til vann
7. Lag følgende konvensjonelle planer:
    - Ett felt på dyp
        i. Gantryvinkel: 0°
        ii. Feltstørrelse: 10cm x 10cm
    - To motgående felt
        i. Gantryvinkel: 0° og 180°
        ii. Feltstørrelse: 10cm x 10cm
        iii. Benytt lik vekting for feltene
    - 4-felts boks
        i. Gantryvinkel: 0°, 90°, 180° og 270°
        ii. Feltstørrelse: Form feltet til PTV77 med MLC.
        iii. Benytt lik vekting for alle fire feltene

    Normering: Mediandose i volumet DOSE1 (alternativt mean)

    Dose: 2Gy

    Registrer følgende doser for de konvensjonelle planene
    - Punktdosen i isosenter
    - Gjennomsnittsdosen med standardavvik i volumet DOSE1
8. Lag en VMAT-plan
    - Fraksjonering: 2.2Gy x 35 til totaldose 77Gy
    - Normering: Mediandose i volumet DOSE1 (alternativt mean)
    - Homogenitetskrav (homogen dose rundt målepunktene for å få pålitelige målinger):
        i. ±3% av gjennomsnittsdosen for aktuelt volum DOSE1, DOSE2 og DOSE3
    - Hjelpestrukturer kan lages for optimalisering
    - Definer følgende punkter:
        i. Punkt 2: 40 mm «kranialt» for isosenter (ligger i volum DOSE2) (snitt: +40)
        ii. Punkt 3: 20 mm «kaudalt» for isosenter (ligger i volum DOSE3) (snitt: -20)

	
Punkt 2	Punkt 3

- Optimaliseringsmål:

Priority	Dose	ROI/POI	Clinical goal	Value	Result	% outside grid
	Plan dose: SIB KVIST (...	CTV56	At least 54.00 Gy dose at 98.00 % volume	54.53 Gy	✓	0 %
	Plan dose: SIB KVIST (...	CTV56	At most 60.00 Gy dose at 3.00 % volume	59.65 Gy	✓	0 %
	Plan dose: SIB KVIST (...	CTV77	At least 75.00 Gy dose at 98.00 % volume	75.04 Gy	✓	0 %
	Plan dose: SIB KVIST (...	OR1	At most 40.00 Gy dose at 40.00 % volume	39.61 Gy	✓	0 %
	Plan dose: SIB KVIST (...	OR1	At most 63.00 Gy dose at 10.00 % volume	62.14 Gy	✓	0 %
	Plan dose: SIB KVIST (...	OR2	At most 40.00 Gy dose at 45.00 % volume	38.90 Gy	✓	0 %
	Plan dose: SIB KVIST (...	OR2	At most 63.00 Gy dose at 15.00 % volume	61.97 Gy	✓	0 %
	Plan dose: SIB KVIST (...	OR3	At most 24.00 Gy average dose	23.10 Gy	✓	0 %
	Plan dose: SIB KVIST (...	OR3	At most 50.00 Gy dose at 5.00 % volume	49.56 Gy	✓	0 %
	Plan dose: SIB KVIST (...	PTV56	At least 98.00 % volume at 53.20 Gy dose	98.48 %	✓	0 %
	Plan dose: SIB KVIST (...	PTV77	At least 95.00 % volume at 73.15 Gy dose	95.00 %	✓	0 %
	Plan dose: SIB KVIST (...	Ytterkontur	At most 50.00 Gy dose at 11.00 % volume	49.71 Gy	✓	0 %
	Plan dose: SIB KVIST (...	Ytterkontur	At most 80.85 Gy dose at 2.0 cm^3 volume	80.58 Gy	✓	0 %

- Hvis det er vanskelig å oppfylle optimaliseringsmålene bør homogenitetskravene til DOSE1, DOSE2 og DOSE3 prioriteres (for å få pålitelige målinger).

9. Registrer følgende doser for VMAT-planen
   - Gjennomsnittsdose med standardavvik for:
     i. DOSE1
     ii. DOSE2
     iii. DOSE3
   - Punktdose for:
     i. Isosenter
     ii. Punkt 2
     iii. Punkt 3
10. Lag kontrollbilder (2D kV og/eller CBCT) for å verifisere innstillingen av fantomet. Kontrollbildene trenger kun lages til en av planene da alle har samme isosenter.
11. Overfør planene til behandlingsmaskinen.

ISSN 2387-5240

dsa@dsa.no
+47 67 16 25 00
dsa.no

DSA

Direktoratet for
strålevern og atomsikkerhet