RATIONALE OF UTILIZATION OF 3D PRINTING TECHNIQUES IN CLINICAL PRACTICE OF RADIATION ONCOLOGY: PAVING THE WAY FOR THE ESTABLISHMENT OFCLINICAL DIGITAL HEALTH MULTIDISCIPLINARY TEAM

Ahmed Nadeem Abbasi, Laraib Khan, Nasir Ali, Asim Hafiz, Sehrish Abrar, Abdul Qadir Jangda, Bilal Mazhar Qureshi

Section of Radiation Oncology, Department of Oncology, Aga Khan University, Karachi, Pakistan

PJR October - December 2021; 31(4): 254-257

ABSTRACT

Aim of precision radiotherapy in this era remains delivery therapeutic efficacy and minimizing toxicity for which various technical innovations have been pivotal. Regular multidisciplinary interactions between the teams of Radiation Oncology and Digital Health Innovations can lead to refinement of experimental technical ideas, leading to getting solutions for problems related to precision RT. 3D Printing is one of the areas which need to be explored further in the setting of a multidisciplinary board.

Key Words: 3D Printing, Radiation Oncology, Digital Health, Multidisciplinary Team, Brachytherapy, Quality Assurance

Manuscript

Precision in planning and delivery of Radiation Treatment (RT) is the hallmark of modern clinical practice of Radiation Oncology. To achieve homogenous dose to the designated target volume is the main objective of a successful RT plan. Another equally important objective of precision RT is to minimise collateral damage by minimizing RT doses to the Organs at Risk (OARs) which are situated close to the planning target volume (PTV). The discipline of Radiation Oncology has seen rapid technological advancement in all areas and components of this field. Radiation Oncologists, Clinical Medical Physicists, RT Technologists and Clinical Engineers are four main professional entities who make the core of this specialty. In the subsequent text we shall be deliberating on the rationale of utilization of 3DP in our routine radiation oncology clinical practice.

Precision Radiation Therapy (RT) techniques are evolving with the advent of new linear accelerators and other hardware along with new planning soft wares. Intensity modulated Radiation Therapy (IMRT) is a form of conformal radiation therapy in which a computer-aided iterative optimization process is used to determine customized nonuniform fluence distributions to achieve specified dosimetric and clinical objectives by optimally modulating the individual beamlets that make up the radiation beams. Image Guided RT refers to applications that incorporate imaging like Ultrasound, CT, MRI, etc into radiation therapy planning and delivery with the goal of improving treatment accuracy. The delivery of a rotational cone beam with variable shape and intensity is commonly called volumetric-modulated arc therapy (VMAT). In VMAT, the gantry rotates continuously,

Correspondence : Dr. Bilal Mazhar Qureshi
Section of Radiation Oncology,
Department of Oncology,
Aga Khan University, Karachi, Pakistan.
Email: bilal.mazhar.qureshi@gmail.com

Submitted 6 October 2021, Accepted 12 October 2021

with MLC leaves, gantry rotation speed, and dose rates varying throughout the arc. Stereotactic refers to using a precise three-dimensional mapping technique to guide a procedure. The term stereotactic radiosurgery (SRS) is used for stereotactically guided high dose, precisely directed conformal irradiation of a defined target volume in a single session but may be also used for 2 to 5 sessions. It can be delivered with Gamma Knife, Cyber Knife, Tomotherapy or proton beam systems.[1]

Recent advancements in Digital Health sector has helped almost all disciplines of medicine. We are strong proponents of multidisciplinary interactions and our group has published our experiences in the form of peer reviewed editorials.[2] In our teams opinion more interaction is required between professionals from the disciplines of digital health innovations and radiation oncology in order to innovate better ideas leading to practical solutions for gaps in our present day knowledge of precision RT. Digital Health innovations need to be reviewed in a multidisciplinary setting with more effective and efficient interactions between the professionals from relevant related specialties. One of the areas of interest for modern day Radiation Oncologist is 3D Printing technology. Three-dimensional (3D) printing also known as Additive Manufacturing (AM), creates physical objects from a geometrical representation by successive addition of material.[3]

We came across a systemic review of literature on this topic, which was published in August 2020 in the journal of Applied Clinical Medical Physics. MK Rooney et al had reviewed 103 manuscripts published from 2012 till 2019. Clinical significance and patient safety was not the criteria of this review. The systemic review looked into the uses of 3D printing technology in the practice of Radiation Oncology. This review had identified common barriers in the implementation of this technology in day to day routine clinical practice. There are many learning points in these 103 published papers. In short, we find the following six areas of application of 3D Printing in our Radiation Oncology Clinical practice. The numbers in parenthesis against these six categories represent the frequency of their utilization as extracted from these 103 published papers:

1) Quality assurance phantoms (26%),
2) Brachytherapy applicators (20%),
3) Bolus (17%),
4) Preclinical animal irradiation (10%),
5) Compensators (7%),
6) Immobilization devices (5%).

Majority of the studies are pre-clinical. Thirteen percent papers were found to be representative of clinical practice which was published in terms of case series or case reports. Most common clinical reports mentioned the benefits of using 3D Planning in Brachytherapy. The authors concluded that over a period of 8 years a progressive rise in the usage of this technology is being observed.[4]

Head and Neck Radiation treatment planning poses special challenges due to proximity of various Organs at Risk (OAR) in close by vicinity of our planning target volume(PTV) We face this issue on a daily basis in our clinical practice as more than half of our patients treated in our tertiary referral university Radiation Oncology facility are Head and Neck squamous cell carcinomas. A study of dosimetric evaluation is being published which clearly demonstrated the possible rational of using 3D printed oral positioning stents which will enable to achieve better reproducibility of set up of treatment on daily basis. 3D printing will lead to avoidance of using wax stent, which sometimes leads to loosening of set up parameters. can be beneficial.[5] Precision radiation treatment in locally recurrent rectal cancers is also a challenging area of precision RT planning. A recently published manuscript had covered this issue of reduction of cold dose spots in the planning target volume via the utilization of 3D printing.[6] Similar inferences were quoted by other research group as well who were involved in locally recurrent rectal cancer patients RT.[7]

Mettke et al had shared their very first clinical experience of using customized fixation masks prepared on 3D technology. They also endorse the significant advantage of utilizing this process during simulation of patients of RT.[8] Total skin electron therapy is a specialized technique of radiation treatment which is used in cases of mycosis fungoides. Radiation dose variation over various different areas of the body is a characteristic of this technique. A technical report published in June 2021 issue of journal of technical innovations and patients support in radiation oncology, deliberated on scalp hair pre-

servation approach via scalp shielding. A special 3D printed scalp shield was used which was found to be patient friendly and was effective in minimizing untoward cutaneous local side effects of scalp RT.[9] A number of studies and brief communique mentioned the effective usage of 3D printing template in head and neck cancer treatment. As stated earlier Head and Neck cancers Radiotherapy always poses a challenge to the RT planning team. We have gone through these published studies and we are quite convinced that in future the utilization of 3D printing techniques will increase in clinical radiation oncology practice.[10,11,12] Tongue immobilization is imperative during RT of certain tumors, for example, in certain cases of Nasopharyngeal Carcinomas where quite extended fields of Radiation are used. This immobilization is commonly achieved via various custom made devices. In a published manuscript authors have shared their experience of using 3D printing for an IMRT plan.[13]

Another very promising and interesting area of potential clinical benefit lies in the production of individualized Bolus. Bolus is used in order to increase the RT dose at the surface of area of interest. Traditionally it was formed by tissue equivalent material so that the isodoses of certain prescribed photon and or electron energy will stay the same at a given field size. In a study published in study published in Medical Dosimetry and Radiation and environmental biophysics journal, analysis was made on the physical and dosimetric factors pertaining to 3D printed bolus.[14,15] Customized bolus is being used in the same manner in close proximity to critical structures, like ophthalmic apparatus. A thin bolus made up of, 3D printing generated copper-plastic composite material was tested via all clinical dosimetric parameters and found to be useful when placed to fit in between the skin of patient and mask made up of thermoplastic material.[16]

The usage of high dose rate brachytherapy delivery equipment is increasing day by day in our outpatient based clinical practice. Further improvement in our planning, dosimetry and delivery can potentially achieved with 3D printing technology.[17] A clinician can envision many innovative theoretical indications of 3D printing utilization in brachytherapy practice. Novel Vaginal Applicator designing and modifications enables the operator to plan and deliver a more homogenous isodose plan and an effective Intensity Modulated Brachytherapy treatment.[18]

Conflict of Interest: None

References

1. E. C. Halperin, D. E. Wazer, C. A. Perez, L. W. Brady, Perez & Brady's Principles and Practice of Radiation Oncology, 7th ed., Philadelphia (PA), USA: LWW/Wolters Kluwer, 2018.

2. Abbasi AN. Establishment and maintenance of quality of site-specific multidisciplinary tumor boards in Pakistan;JColl Physicians Surg Pak 2016; 26(10): 805.

3. Wang Y, Blache R, Xu X. Selection of additive manufacturing processes. Rapid prototyping journal. Mar 2017.

4. Rooney MK, Rosenberg DM, Braunstein S, Cunha A, Damato AL, Ehler E, Pawlicki T, Robar J, Tatebe K, Golden DW. Three-dimensional printing in radiation oncology: A systematic review of the literature. Journal of applied clinical medical physics. Aug 2020; **21(8):** 15-26.

5. Cleland S, Chan P, Chua B, Crowe SB, Dawes J, Kenny L, Lin C, Obereigner E, Peet SC, Trapp JV, Poroa T. Dosimetric evaluation of a patient-specific 3D-printed oral positioning stent for head-and-neck radiotherapy. Physical and Engineering Sciences in Medicine. Jun 2021; **10:** 1-3.

6. Wang L, Wang H, Jiang Y, Ji Z, Guo F, Jiang P, Qiu B, Sun H, Fan J, Li W, Wang J. Dosimetric comparison of computed tomography-guided iodine-125 seed implantation assisted with and without three-dimensional printing non-coplanar template in locally recurrent rectal cancer: a propensity score matching study. Journal of Contemporary Brachytherapy. Feb 2021; **13(1):** 18.

7. Wang H, Peng R, Li X, Wang Y, Jiang Y, Ji Z, Guo F, Tian S, Sun H, Fan J, Wang J. The d

osimetry evaluation of 3D printing non-coplanar template-assisted CT-guided 125I seed stereotactic ablation brachytherapy for pelvic recurrent rectal cancer after external beam radiotherapy. Journal of Radiation Research. May 2021; **62(3):** 473-82.

8. Mattke M, Rath D, Häfner MF, Unterhinninghofen R, Sterzing F, Debus J, Giesel FL. Individual 3D-printed fixation masks for radiotherapy: first clinical experiences. International Journal of Computer Assisted Radiology and Surgery. May 2021; **22:** 1-7.

9. Rahimy E, Skinner L, Kim YH, Hoppe RT. Technical report: 3D-printed patient-specific scalp shield for hair preservation in total skin electron beam therapy. Technical Innovations & Patient Support in Radiation Oncology. 2021; **18:** 12-8.

10. Qiu B, Jiang Y, Ji Z, Sun H, Fan J, Li W, Shao Y, Jiang P, Wang J. The Accuracy of Individualized 3D-Printing Template-Assisted I125 Radioactive Seed Implantation for Recurrent/Metastatic Head and Neck Cancer. Frontiers in Oncology. Mar 2021; **11:** 1000.

11. Herpel C, Schwindling FS, Held T, Christ L, Lang K, Schwindling M, Moratin J, Zaoui K, Moutsis T, Plinkert P, Herfarth K. Individualized 3D-Printed Tissue Retraction Devices for Head and Neck Radiotherapy. Frontiers in Oncology. 2021; **11:** 332-7.

12. Diekhoff T, Scheel M, Kress W, Hamm B, Jahnke P. Dual-energy computed tomography of the neck-optimizing tube current settings and radiation dose using a 3D-printed patient phantom. Quantitative Imaging in Medicine and Surgery. Apr 2021; **11(4):** 1144.

13. Ju SG, Ahn YC, Kim YB, Park SG, Choi YM, Na CH, Hong CS, Oh D, Kwon DY, Kim CC, Kim DH. Development of a Tongue Immobilization Device Using a 3D Printer for Intensity Modulated Radiation Therapy of Nasopharyngeal Cancer Patients. Cancer Research and Treatment: Official Journal of Korean Cancer Association. Jan 2021; **53(1):** 45.

14. Biltekin F, Yazici G, Ozyigit G. Characterization of 3D-printed bolus produced at different printing parameters. Medical Dosimetry. Jun 2021; **46(2):** 157-63.

15. Jezierska K, Sekowska A, Podraza W, Gronwald H, Lukowiak M. The effect of ionising radiation on the physical properties of 3D-printed polymer boluses. Radiation and environmental biophysics. May 2021; **60(2):** 377-81.

16. Ehler ED, Sterling DA. 3D printed copper-plastic composite material for use as a radiotherapy bolus. PhysicaMedica. Aug 2020; **76:** 202-6.

17. Campelo S, Subashi E, Meltsner SG, Chang Z, Chino J, Craciunescu O. Multimaterial three-dimensional printing in brachytherapy: Prototyping teaching tools for interstitial and intracavitary procedures in cervical cancers. Brachytherapy. Nov 2020; **19(6):** 767-76.

18. Biltekin F, Akyol HF, Gültekin M, Yildiz F. 3D printer-based novel intensity-modulated vaginal brachytherapy applicator: feasibility study. Journal of contemporary brachytherapy. Feb 2020; **12(1):** 17.