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Implementation and Evaluation of an Online Anatomy, Radiology and Contouring Bootcamp for Radiation Therapists

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Abstract

Background: As new treatments and technologies have been introduced in radiation oncology, the clinical roles of radiation therapists (RTs) have expanded. However, there are few formal learning opportunities for RTs. An online, anatomy, radiology and contouring bootcamp (ARC Bootcamp) originally designed for medical residents was identified as a prospective educational tool for RTs. The purpose of this study was to evaluate an RT edition of the ARC Bootcamp on knowledge, contouring, and confidence, as well as to identify areas for future modification.

Methods: Fifty licensed RTs were enrolled in an eight-week, multidisciplinary, online RT ARC Bootcamp. Contouring practice was available throughout the course using an online contouring platform. Outcomes were evaluated using a pre-course and post-course multiple-choice quiz (MCQ), contouring evaluation and qualitative self-efficacy and satisfaction survey.

Results: Of the fifty enrolled RTs, 30 completed the course, and 26 completed at least one of the post-tests. Nineteen contouring dice similarity coefficient (DSC) scores were available for paired pre- and post-course analysis. RTs demonstrated a statistically significant increase in mean DSC scoring pooled across all contouring structures (mean ± SD improvement: 0.09 ± 0.18 on a scale from 0 to 1, p=0.020). For individual contouring structures, 3/15 reached significance in contouring improvement. MCQ scores were available for 26 participants and increased after RT ARC Bootcamp participation with a mean ± SD pre-test score of 18.6 ± 4.2 (46.5%); on a 40-point scale vs. post-test score of 24.5 ± 4.3 (61.4%) ($p < 0.001$). RT confidence in contouring, anatomy knowledge and radiographic identification improved after course completion ($p < 0.001$). Feedback from RTs recommended more contouring instruction, less in-depth anatomy review and more time to complete the course.

Conclusions: The RT ARC Bootcamp was an effective tool for improving anatomy and radiographic knowledge among RTs. The course demonstrated improvements in contouring

and overall confidence. However, only approximately half of the enrolled RTs completed the course, limiting statistical power. Future modifications will aim to increase relevance to RTs and improve completion rates.

Introduction

The field of radiation therapy has seen a vast growth in technology over the past decade. Innovative technologies such as multimodal volumetric imaging, real-time image guidance and motion management strategies have led to clinical improvement, but have increased the complexity of treatment delivery. Target and normal tissue contouring provide the foundation for contemporary treatment planning but unfortunately, a high degree of interobserver variability has been reported.[1,2] Variations in delineation can impact dosimetric optimization, dose-volume histogram (DVH) measurements and complication probabilities.[3] Inadequate contouring has also proven to have a direct impact on patient outcomes.[4,5] Ensuring delineation is standardized, consistent and accurate through training and education is essential for the safe delivery of modern-day radiotherapy.

Radiation therapists (RTs; also known as therapeutic radiographers) are often at the forefront of technological developments and as a result, their roles are dynamically evolving. With appropriate training, RTs are now performing clinical contouring for normal tissues as part of their daily practice.[6] Expanded RT roles are also prevalent on treatment units with the introduction of image guided radiotherapy (IGRT), as real-time image registration is now solely the RT's responsibility.[7] In addition, advanced practice RTs undertake delegated clinical tasks such as image registration approval and contouring of gross tumor volumes (that are then approved by the radiation oncologist) which have been shown to improve clinical efficiency.[8,9] Expanding and delegating RT roles garners many benefits, as tasks such as contouring are the most time-consuming for radiation oncologists.[10] With appropriate guidance and training, RTs can alleviate the physician workload, affording more time to dedicate to other tasks.

A fundamental part of a RT's role is to be skilled in clinical and radiographic anatomy, yet the depth of knowledge required in these areas has grown with rapidly evolving technology. Prior surveys have indicated that many RTs feel accountable for taking on new tasks, such as discerning soft tissue changes in computed tomography (CT) imaging, but are concerned that there has been little consideration regarding whether or not they are equipped to do so.[11]

A pre-existing, online, anatomy, radiography and contouring bootcamp (ARC Bootcamp) may provide an avenue to maintain and enhance RT knowledge and confidence in practice. The ARC Bootcamp was originally established as on-site, in-person multidisciplinary training for medical residents and was modelled after two previous pilot studies.[12,13] Among residents, the ARC Bootcamp achieved improvements in both knowledge and contouring, as well as self-reported confidence.[14] The course curriculum has since been further modified based on participant feedback and is now offered as an online course for medical residents (https://arcbootcamp.teachable.com/). Given the comprehensive, multidisciplinary nature of this course, it may also offer a widely accessible form of continuing professional education for RTs. This course could provide an avenue to help RTs maintain current knowledge, keep pace with changing practice and learn new skills to support role expansion.

The purpose of this study was to evaluate the effectiveness of the online RT ARC Bootcamp as a way to improve contouring accuracy as well as radiology and anatomy knowledge for RTs. Secondary endpoints were to seek participant feedback on course content in order to further adapt the course to suit RT educational needs.

Methods

Study Population

Study participation was voluntary and offered to RTs internationally. RTs were eligible for inclusion if they were licensed and agreed to commit approximately two hours per week of their time to an eight-week, online, anatomy, radiology and contouring course. The bootcamp was only offered in English. Undergraduate RT students were not eligible to participate.

Study recruitment was facilitated by social media and “tweets” sent out via Twitter™ to promote enrollment. An email was also sent out locally to cancer centres within Ontario, Canada, to encourage participation. Interested applicants were directed to contact the study team via email. The [BLINDED FOR REVIEW] Health Sciences Research Ethics Board (HSREB) and the [BLINDED FOR REVIEW] reviewed and approved this study. Additionally, the protocol underwent review at [BLINDED FOR REVIEW] as a requirement for a graduate degree program.

Course Design

The ARC Bootcamp is a comprehensive online course consisting of approximately seven hours of interactive video lectures delivered by anatomists, radiation oncologists, surgeons and radiologists. It also features multiple opportunities to practice contouring using EduCase™ contouring software (https://www.educase.com). The bootcamp was originally intended for radiation oncology residents and was modified to suit RT needs by eliminating lectures that were felt to be beyond the scope of RT practice. Module content was developed by a multidisciplinary planning committee and was designed to meet specific learning objectives. Areas of study included head and neck, thorax, abdomen, male pelvis and female pelvis. Course content was released weekly and participants were able to complete the lectures at their own pace. It was anticipated the course would take approximately eight weeks to complete by dedicating two hours per week. An additional two weeks were allotted in the event that an individual required more time to complete the course.

Data Collection

The first module of the RT ARC Bootcamp consisted of introductory videos that provided instructions to complete the pre-course multiple-choice quiz (MCQ), the self-efficacy survey and the pre-course contouring assessment. Demographic information was collected at the beginning of the MCQ. The MCQ was used to establish pre-course knowledge in anatomy and radiology and was developed as part of the original resident course by physicians and content experts. Forty timed multiple-choice questions were delivered, and participants were allotted 45 seconds per question. The highest achievable score was 100% (40/40) and the lowest score achievable was 0% (0/40).

Immediately after the MCQ, participants were asked a series of questions evaluating self-efficacy. Participants were asked how they rated their confidence level in their current ability to contour various organs. Structures were chosen based on clinical relevance for RT contouring and corresponded to specific material presented in the RT ARC Bootcamp. Additional domains of assessment included confidence levels in anatomy, radiographic identification and attitudes towards relevant clinical tasks. To our knowledge, no validated scales exist pertaining to RT confidence in clinical tasks, therefore a new scale was developed using a 7-point Likert-scale ranging from strongly disagree (“1”) to strongly agree (“7”). Questions were modelled after the previous course surveys as well as a self-efficacy scale developed for student radiographers.[15] Materials were reviewed by two clinical specialist RTs and one clinical educator for content validity. The aforementioned assessments were hosted via [BLINDED FOR REVIEW]’s secure Qualtrics Survey platform. To assess contouring skills, participants were given a pre-course contouring evaluation facilitated by a third-party platform, EduCase™. Fifteen organs were chosen for assessment by a team of content experts, consistent with the pre-existing resident version of the ARC Bootcamp. Participants were instructed to time themselves and complete the assessment within 30 minutes.

Once all course modules were completed the post-course MCQ was delivered with identical questions in a scrambled format. The post-course self-efficacy survey was identical to the pre-course survey and additional questions to evaluate course utility were included. Questions were designed to explore participant feelings towards content relevance, efficacy, ease of use, attitudes, intentions for use and recommendations. Utility questions were modelled after similarly described domains for technology acceptance models in medical education apps.[16] After survey completion, participants were directed to perform the final post-course contouring evaluation which was identical to the pre-course assessment.

Statistical Analysis

A sample size calculation was prospectively performed. Using a paired t-test, to detect a mean difference of 15% in contour score improvement, with 80% power, a sample size of 45 participants was determined (standard deviation = 0.35). An additional five positions were allotted in anticipation of participation loss over time. Enrollment was therefore limited to 50 RTs and prioritized by the order in which email contact was received. Participation was limited to six participants per cancer centre to ensure equitable enrollment.

Normal tissue contours were evaluated by calculating a dice similarity coefficient (DSC). Participant contours were compared to expert contours which were performed jointly by a radiation oncologist and radiologist. The following formula was used to calculate the DSC:

$$\text{DSC}= \frac{2\ x\ Area\ of\ overlap}{Total\ pixels\ combined} = \frac{2\ (A \cap B)}{A+B}$$

A DSC score ranges from 0 to 1, with a score of 1.0 indicative of perfect agreement, while a DSC score of 0 indicates no agreement. Paired pre- and post-course DSC scores were evaluated using the Wilcoxon signed-rank test.

Analysis of MCQ scores, self-efficacy and utility responses were performed using a paired t-test for paired pre- and post-course data. Evaluation of contouring comfortability was performed using a chi-square test. Assessment of associations between reported data and demographic variables (ie., years of experience) were evaluated using the Wilcoxon rank sum test. All statistical analysis was performed using SAS version 9.4 software (SAS Institute, Cary, NC, USA) using two-sided statistical testing at the 0.05 significance level.

Open text responses were coded using the HyperResearch software (version 4.5.2). Participant answers were coded into substantive categories using descriptions of attitudes and beliefs. Thematic analysis was then performed using the coding data and a matrix was developed to further draw connections among themes.

Results

Fifty RTs from approximately 23 institutions in five countries (Canada, USA, United Kingdom, Ireland and Australia) enrolled in the RT ARC Bootcamp. The target sample size was met within six days and approximately 35 additional interested applicants were denied a position in the course once accrual was full. Demographic information was collected from 50 pre-course questionnaires [Table 1]. Of the 50 RTs, 66% had ≤ 15 years of experience. Almost all participants were treatment-unit trained (96%), with 30 (60%) and 22 (44%) trained in CT simulation and dosimetry respectively. The majority of RTs had combined training on both the unit and CT simulation (56%) and the remainder reported single or combined training in CT, brachytherapy, treatment units and/or dosimetry. Approximately half of participants (54%) reported contouring as a part of their clinical duties.

Of the 50 who enrolled, 30 (60%) completed the course and 26 (52%) of those completed at least one post-test evaluation [Figure 1]. Approximately 25% of non-completers ceased activity by the second week. Highest completion rates were attained by RTs who were unit- and CT-simulation-trained as well as RTs who were unit and dosimetry trained.

Nineteen paired pre-tests and post-tests were available for contouring evaluations. Overall, pooling all structures together, there was a statistically significant improvement in DSC scoring (mean ± SD: 0.09 ± 0.18, p=0.020). Pre-course and post-course DSC scores for individual structures showed numeric improvement, with the exception of the right vocal cord and gallbladder, but many did not reach statistical significance [Table 2]. No correlation was seen between years of experience or areas trained in for DSC score improvements.

Twenty-six participants completed both the pre-course and post-course MCQ, as well as the self-efficacy and utility surveys. There was a statistically significant improvement in mean ± SD MCQ scores of 6.0 ± 4.3, on a 40-point scale [pre-test score of 18.6 ± 4.2 (46.5%) vs. post-test score of 24.5 ± 4.3 (61.4%) ($p < 0.001$) (Figure 2)]. There was no correlation between

MCQ score improvement and years of experience. Additionally, no correlation was found between MCQ scores and improvement in contouring scores, suggesting that these two assessments measured different competencies.

Overall, participants reported increased confidence in their ability to contour across all structures ($p < 0.001$). Among all sites (head and neck, thorax, abdomen, male pelvis and female pelvis), confidence in anatomy knowledge, ability to identify organs on CT imaging and ability to identify veins and arteries on CT imaging significantly increased ($p < 0.001$). Participant feelings towards performing relevant clinical activities improved after RT ARC Bootcamp participation [Table 3]. No correlation was found between years of experience or areas trained and confidence levels. At the onset of the study, 38.5% of participants indicated they were not comfortable contouring as part of their clinical duties, which decreased to 11.5% upon course completion ($p=0.025$).

Most of the participants agreed that the course content was relevant to their clinical practice (median: 6, interquartile range [IQR]: 5-6) and that they could apply what they learned (median: 6, IQR: 6-7) [Figure 3]. In addition, many felt that the RT ARC Bootcamp improved their contouring skills (median: 6, IQR: 5-6) and was an effective way to review anatomy (median: 6, IQR: 5-7). A high degree of agreement was observed when participants were asked if the RT ARC Bootcamp helped them achieve their continuing education goals (median: 6, IQR: 6-7). A majority of participants agreed that the RT ARC Bootcamp website was easy to use (median: 6, IQR: 6-7) and indicated that the course was a positive experience (median: 6, IQR: 6-7). Most RTs agreed that they had difficulty completing the course in the allotted amount of time (median: 5, IQR: 4-6). The highest reported agreement was observed when RTs were asked if they would refer back to this course over time (median: 7, IQR: 6-7).

A prominent and recurring theme in the open text responses was feedback relative to the course content. Many participants expressed positive attitudes towards the multidisciplinary nature of the RT ARC Bootcamp such as:

"I like how the anatomy lab, radiology and contouring sections were integrated" and "I greatly appreciated the side-by-side comparison of cadaveric images vs. radiography".

In contrast, many participants noted the course content was "*too in depth*" for what an RT would be required to know within their scope of practice. In addition, some participants expressed difficulty completing the course in the allotted amount of time, specifically in reference to the ongoing pandemic. Two participants requested more specific content in head and neck lymph node levels and breast lymph nodes. Feedback regarding interactive contouring was positive, and many RTs found the ability to practice beneficial. Some participants requested the addition of more practice contouring cases, as well as specific sites they would have found useful. The addition of more contouring-specific instruction with demonstrations was also emphasized in the open answer responses. Others found the RT ARC Bootcamp website easy to use but had difficulty knowing when to use the contouring software. Overall attitudes towards the course were positive, and many participants felt it was a "*great course*" and enjoyed participating. Modifications to the RT ARC Bootcamp were developed based on participant feedback and data analysis and can be found in Table 4.

Discussion

To our knowledge, this study represents the first of its kind evaluating a multidisciplinary, online contouring course for RTs. Findings from this study demonstrate that the RT ARC Bootcamp was an effective resource for improving anatomy, radiology and contouring knowledge among RTs. Participants reported significantly higher levels of self-confidence in domains of contouring, anatomy knowledge and radiographic identification after course completion. Confidence levels when performing various clinical tasks also increased after participation. Overall, participants were satisfied with the course and felt the RT ARC Bootcamp was a positive experience. Open answer responses demonstrated key areas for course improvement. However, the course completion rate was lower than anticipated, reducing the statistical power of this study, and suggesting that methods to improve engagement would be beneficial.

Results from this study are similar to the in-person findings of the resident version of the ARC Bootcamp, which also demonstrated statistically significant improvement across all contouring structures.[14] However, our study reported suboptimal improvement among individual structures. DSC scores for 12/15 structures trended towards improvement, but statistically significant improvements were found in only 3/15 structures. This is likely attributed to the reduced statistical power of our study, as initial calculations anticipated data from 45 participants.

Multidisciplinary online learning platforms have both advantages and disadvantages. In the past, cadaveric learning has been the gold-standard for anatomy education. More recently there has been a de-emphasis on this method due to limited availability of resources and small niche of learners who benefit from it.[17] Instead, multimodality approaches have increased in popularity and given the current circumstances of the global pandemic, online education offers a realistic and necessary alternative to traditional teaching. Integrative approaches have demonstrated success in the literature, with interactive e-contouring interventions establishing superior concordance to currently available materials.[18] Online learning offers advantages such as networking opportunities, flexibility, accessibility and cost-savings for learners.[19, 20] In contrast, the autonomous nature of online education puts it at risk for learner disengagement, as evidenced by the decreased participation in the RT ARC Bootcamp over time. Factors shown to improve participation include educational programs that are easy to use, interactive and relevant to learner motivations.[21] Given the demonstrated improvements, the RT ARC Bootcamp may offer an accessible continuing educational resource for RTs with some adaptations to increase engagement.

There are limitations to both the online delivery platform of our study and to the study design itself. Our study had a 48% participation loss over time among survey responses and 62% among contouring assessments; much higher than the originally anticipated 10%, decreasing the generalizability of the results and reducing the statistical power. RTs who did not complete the RT ARC Bootcamp were not represented in the data analysis. Our study was at risk of bias as it is unknown whether poor compliance was due to external factors or dissatisfaction with the course. Compared to other online courses, however, this completion rate is high. Reported completion rates from massive open online courses (MOOCs) ranges from 1% to 36% with a median rate of approximately 6%.[22,23] In the context of continuing education, there are similarities between the RT ARC Bootcamp and MOOCs; both are voluntarily sought out by the learner and students have individual motivations for participating. Completion rates in a similar, smaller scale, contouring study were reported to be higher when participants were offered monetary incentives.[24] The RT ARC Bootcamp study may have garnered a higher completion rate if participants were provided external motivation, although this is not realistic when considering real-world application of the course. Adapting the program to participant feedback will improve the likelihood of completion as intrinsic learner motivation will be the primary driver for RT ARC Bootcamp enrollment in the future.

There are several limitations of this study to consider in the context of global application. The course was only offered in English and was therefore not accessible to RTs in other languages. Participation in the RT ARC Bootcamp also required internet access with a high bandwidth and some participants identified difficulty accessing the software. Given time constraints of our study, no follow-up was performed evaluating knowledge retention. Focus on short-term results and lack of consideration for long-term performance has been noted as a drawback among contouring interventions.[25] In addition, the generalizability of our results could be strengthened if the study was performed as a randomized controlled trial. It is unknown whether participants could have achieved the same levels improvement without access to the RT ARC Bootcamp, but instead with dedicated time to the course ideology.

Conclusion

The findings from this study demonstrate that participation in a multidisciplinary, online anatomy, radiology and contouring bootcamp was effective at improving contouring among RTs. High rates of knowledge improvements were reported, as well as improved confidence in contouring, anatomy knowledge and radiographic identification. In addition, participants expressed a high level of satisfaction with the course. Modifications to the RT ARC Bootcamp that adopt participant feedback may improve engagement and completion rates.

References

1. Loo SW, Martin WMC, Smith P, Cherian S, Roques TW. Interobserver variation in parotid gland delineation: a study of its impact on intensity-modulated radiotherapy solutions with a systematic review of the literature. *Br J Radiol.* 2012;85(1016):1070-1077. doi:10.1259/bjr/32038456.

2. Cloak K, Jameson MG, Paneghel A, et al. Contour variation is a primary source of error when delivering post prostatectomy radiotherapy: Results of the Trans-Tasman Radiation Oncology Group 08.03 Radiotherapy Adjuvant Versus Early Salvage (RAVES) benchmarking exercise. *Journal of Medical Imaging and Radiation Oncology.* 2019;63(3):390-398. doi:10.1111/1754-9485.12884.

3. Wright JL, Yom SS, Awan MJ, et al. Standardizing Normal Tissue Contouring for Radiation Therapy Treatment Planning: An ASTRO Consensus Paper. *Practical Radiation Oncology.* 2019;9(2):65-72. doi:10.1016/j.prro.2018.12.003.

4. Furman MJ, Whalen GF, Shah SA, Kadish SP. Gastric perforation following stereotactic body radiation therapy of hepatic metastasis from colon cancer. *Pract Radiat Oncol.* 2013;3(1):40-44.. doi:10.1016/j.prro.2012.03.005.

5. Peters LJ, O'Sullivan B, Giralt J, et al. Critical impact of radiotherapy protocol compliance and quality in the treatment of advanced head and neck cancer: results from TROG 02.02. *J Clin Oncol.* 2010;28(18):2996-3001. doi:10.1200/JCO.2009.27.4498.

6. Cante D, Petrucci E, Piva C, et al. Delineation of the larynx as organ at risk in radiotherapy: a contouring course within "Rete Oncologica Piemonte-Valle d'Aosta" network to reduce inter- and intraobserver variability. *Radiol Med.* 2016;121(11):867-872. doi:10.1007/s11547-016-0668-8.

7. Bell LJ, Oliver L, Vial P, et al. Implementation of an image-guided radiation therapy program: Lessons learnt and future challenges. *Journal of Medical Imaging and Radiation Oncology.* 2010;54(1):82-89. doi:https://doi.org/10.1111/j.1754-9485.2010.02142.x.

8. Harnett N, Bak K, Lockhart E, et al. The clinical specialist radiation therapist (CSRT): A case study exploring the effectiveness of a new advanced practice role in canada. *J Med Radiat Sci*. 2018;65(2):86-96. doi: 10.1002/jmrs.281.

9. Lim LH, Pang EPP, Jadva-Patel H, Wong SMM. Perceptions on site-specific advanced practice roles for radiation therapists in Singapore – A single centre study. *Technical Innovations & Patient Support in Radiation Oncology.* 2020;13:17-20. doi:10.1016/j.tipsro.2019.11.010.

10. Vorwerk H, Zink K, Schiller R, et al. Protection of quality and innovation in radiation oncology: the prospective multicenter trial the German Society of Radiation Oncology (DEGRO-QUIRO study). Evaluation of time, attendance of medical staff, and resources during radiotherapy with IMRT. *Strahlenther Onkol.* 2014;190(5):433-443. doi:10.1007/s00066-014-0634-0.

11. Gillan C, Li W, Harnett N. Radiation therapist perspectives on cone-beam computed tomography practices and response to information. *Journal of Radiotherapy in Practice.* 2013;12(3):237-244. doi:10.1017/S1460396913000149.

12. D'Souza L, Jaswal J, Chan F, et al. Evaluating the impact of an integrated multidisciplinary head & neck competency-based anatomy & radiology teaching approach in radiation oncology: a prospective cohort study. *BMC Med Educ.* 2014;14:124. doi:10.1186/1472-6920-14-124.

13. Labranche L, Johnson M, Palma D, D'Souza L, Jaswal J. Integrating anatomy training into radiation oncology residency: considerations for developing a multidisciplinary, interactive learning module for adult learners. *Anat Sci Educ.* 2015;8(2):158-165. doi:10.1002/ase.1472.

14. Jaswal J, D'Souza L, Johnson M, et al. Evaluating the impact of a Canadian national anatomy and radiology contouring boot camp for radiation oncology residents. *Int J Radiat Oncol Biol Phys.* 2015;91(4):701-707. doi:10.1016/j.ijrobp.2014.11.009.

15. Kitching J, Cassidy S, Eachus P, Hogg P. Creating and validating self-efficacy scales for students. *Radiol Technol.* 2011;83(1):10-19. Accessed Jul 19, 2020. https://pubmed.ncbi.nlm.nih.gov/21908776/

16. Briz-Ponce L, García-Peñalvo FJ. An Empirical Assessment of a Technology Acceptance Model for Apps in Medical Education. *J Med Syst.* 2015;39(11):176. Accessed Jul 22, 2020. doi:10.1007/s10916-015-0352-x.

17. Estai M, Bunt S. Best teaching practices in anatomy education: A critical review. *Annals of Anatomy-Anatomischer-Anzeiger.* 2016;208:151-157. doi:10.1016/j.aanat.2016.02.010.

18. Gillespie EF, Panjwani N, Golden DW, et al. Multi-institutional Randomized Trial Testing the Utility of an Interactive Three-dimensional Contouring Atlas Among Radiation Oncology Residents. *International Journal of Radiation Oncology, Biology, Physics.* 2017;98(3):547-554. doi:10.1016/j.ijrobp.2016.11.050.

19. Setia S, Tay JC, Chia YC, Subramaniam K. Massive open online courses (MOOCs) for continuing medical education – why and how? *Adv Med Educ Pract.* 2019;10:805-812. doi:10.2147/AMEP.S219104.

20. Stambough JB, Curtin BM, Gililland JM, et al. The Past, Present, and Future of Orthopedic Education: Lessons Learned From the COVID-19 Pandemic. *The Journal of Arthroplasty.* 2020;35(7, Supplement):S60-S64. doi:10.1016/j.arth.2020.04.032.

21. Wong G, Greenhalgh T, Pawson R. Internet-based medical education: a realist review of what works, for whom and in what circumstances. *BMC Med Educ.* 2010;10:12. Accessed May 5, 2021. doi:10.1186/1472-6920-10-12.

22. Gil-Jaurena I, Callejo-Gallego J, Agudo Y. Evaluation of the UNED MOOCs Implementation: Demographics, Learners' Opinions and Completion Rates. *irrodl.* 2017;18(7). https://www.erudit.org/en/journals/irrodl/1900-v1-n1-irrodl03381/1042968ar/abstract/. Accessed Apr 23, 2021. doi:10.19173/irrodl.v18i7.3155.

23. Jordan K. Initial trends in enrolment and completion of massive open online courses. *The International Review of Research in Open and Distributed Learning.* 2014;15(1). doi:10.19173/irrodl.v15i1.1651.

24. Neppala P, Sherer M, Larson G, et al. An interactive contouring module improves engagement and interest in radiation oncology among preclinical medical students: Results of a randomized trial. *Practical Radiation Oncology.* 2018;8(4):e190-e198. doi:10.1016/j.prro.2018.01.001.

25. Cacicedo J, Navarro-Martin A, Gonzalez-Larragan S, De Bari B, Salem A, Dahele M. Systematic review of educational interventions to improve contouring in radiotherapy. *Radiotherapy and Oncology.* 2020;144:86-92. doi:10.1016/j.radonc.2019.11.004.

Figure Captions

Figure 1: Data collection methods and number of participants. Abbreviations: RT – radiation therapist

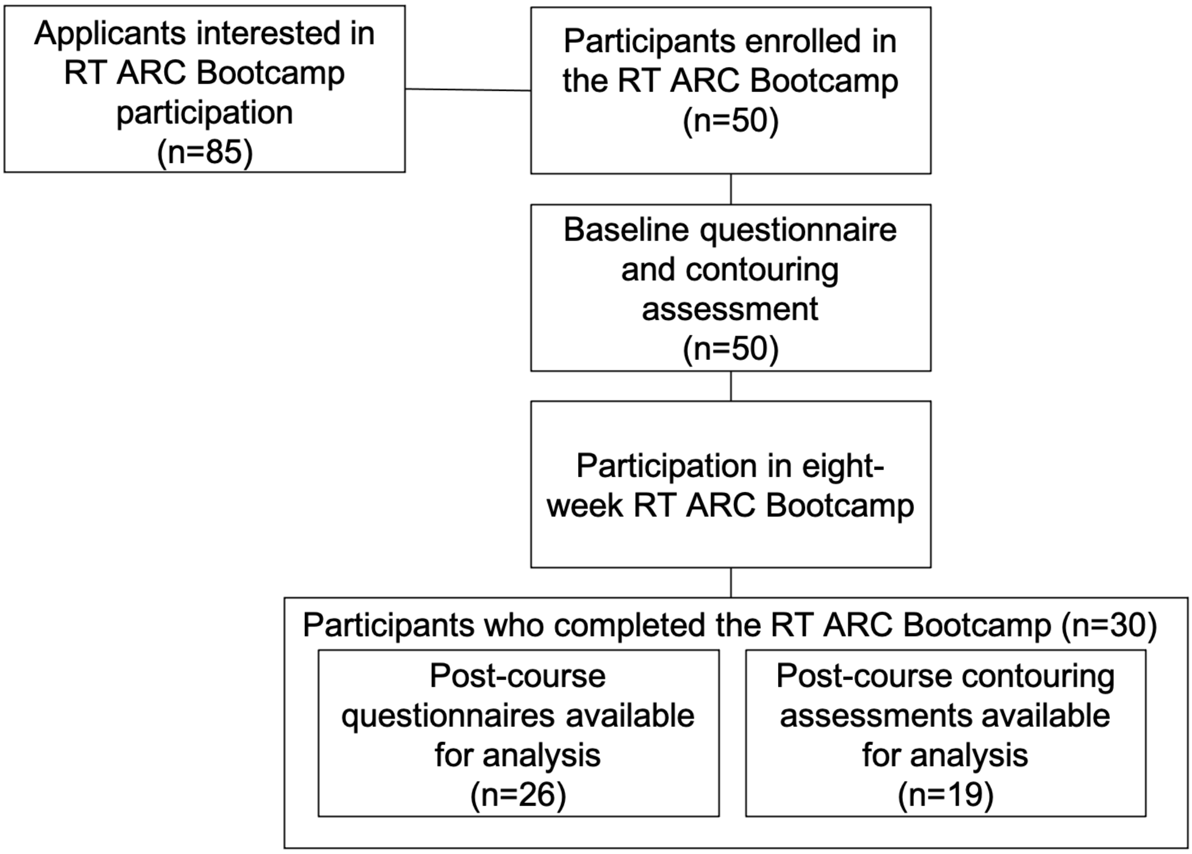


Figure 2: Pre- and post-course multiple-choice quiz scoring. Abbreviations: MCQ – multiple-choice quiz.

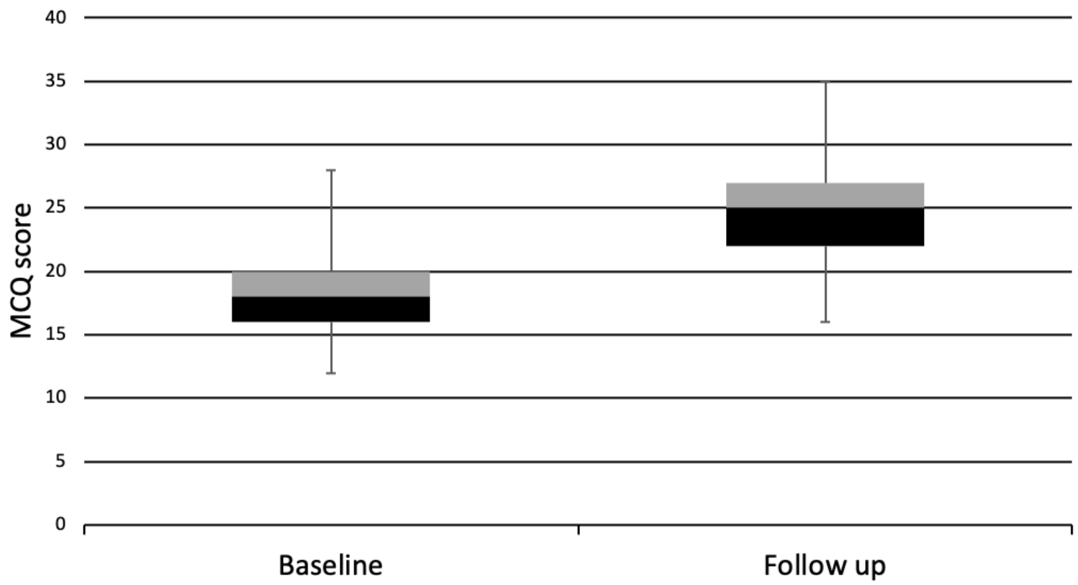
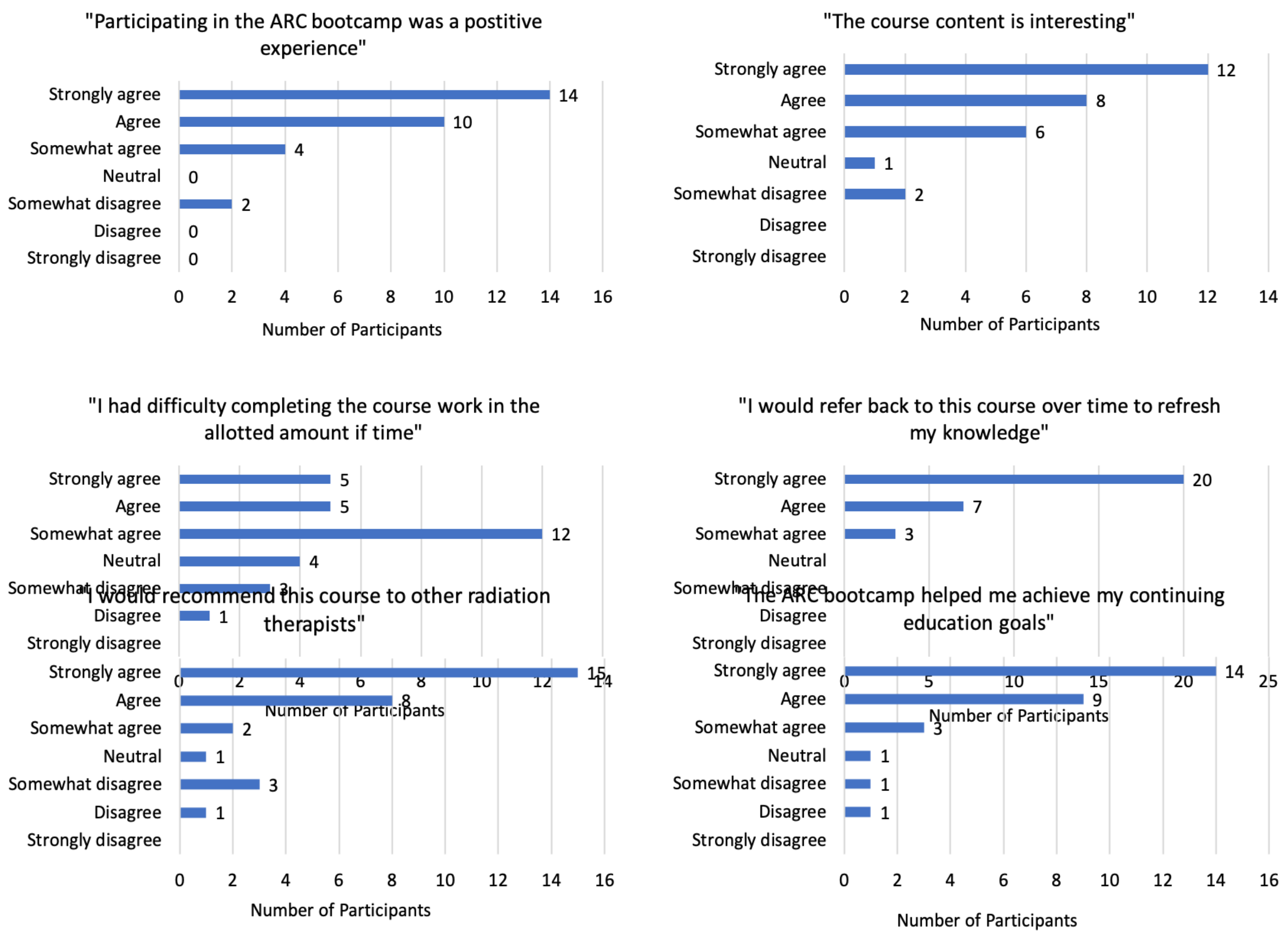


Figure 3: Participant attitudes towards the RT ARC Bootcamp.



Tables

Table 1: Demographic information collected from questionnaires.

Variable	Pre-course (n=50) n (%)	Post-course (n=26) n (%)
Years of experience		
< 5	12 (24.0%)	6 (23.1%)
6-10	10 (20.0%)	7 (26.9%)
11-15	11 (22.0%)	7 (26.9%)
> 15	17 (34.0%)	6 (23.1%)
Highest level of education		
Diploma or equivalent	3 (6.0%)	1 (3.9%)
Bachelor’s degree	33 (66.0%)	16 (61.5%)
Master’s degree	14 (28.0%)	9 (34.6%)
Areas trained in as a radiation therapist*		
Treatment unit training	48 (96.0%)	26 (100%)
Any CT simulation training	30 (60.0%)	16 (61.5%)
Any dosimetry training	22 (44.0%)	12 (46.2%)
Any brachytherapy training	4 (16.0%)	3 (11.5%)

*Percentages do not add to 100% since RTs could be trained in more than one competency listed; CT – computed tomography.

Table 2: Summary of pre-course and post-course dice similarity coefficient (DSC) scores.

Structure	Pre-course DSC (mean ± SD)	Post-course DSC (mean ± SD)	P-value
Clivus	0.43 ± 0.25	0.63 ± 0.21	< 0.001*
Sphenoid sinus	0.67 ± 0.32	0.76 ± 0.23	0.113
Left cochlea	0.21 ± 0.33	0.31 ± 0.35	0.065
Right lateral pterygoid muscle	0.44 ± 0.36	0.61 ± 0.34	0.090
Left lens	0.83 ± 0.06	0.84 ± 0.06	0.829
Epiglottis	0.54 ± 0.27	0.62 ± 0.24	0.396
Right submandibular gland	0.59 ± 0.34	0.72 ± 0.27	0.182
Left optic nerve	0.56 ± 0.18	0.57 ± 0.22	0.891
Right vocal cord	0.49 ± 0.29	0.43 ± 0.35	0.611
Superior vena cava	0.79 ± 0.31	0.79 ± 0.31	0.580
T12 spinous process	0.58 ± 0.28	0.61 ± 0.30	0.212
Gallbladder	0.80 ± 0.08	0.75 ± 0.27	0.768
Left adrenal gland	0.26 ± 0.35	0.54 ± 0.35	0.015*
Right common iliac artery	0.52 ± 0.30	0.69 ± 0.27	0.087
Left external iliac artery	0.46 ± 0.38	0.67 ± 0.27	0.032*

DSC – dice similarity coefficient; SD – standard deviation; *p-value < 0.05.

Table 3: Summary of participant reported attitudes towards relevant clinical tasks using a 7-point Likert-scale (1: strongly disagree, 2: disagree, 3: somewhat disagree, 4: neither agree nor disagree, 5: somewhat agree, 6: agree, 7: strongly agree).

Survey Question	**Pre-course Attitudes Median (IQR)**	**Post-course Attitudes Median (IQR)**
"I sometimes feel out of my depth when evaluating CT images"	5.0 (3.0-6.0)	4.0 (3.0-5.0)
"I find it difficult to know when to urgently communicate abnormal findings to the radiation oncologist when image matching"	3.5 (2.0-5.0)	3.0 (2.0-4.0)
"I am confident I know key guidelines and potential areas of variability/error when contouring"	2.5 (2.0-5.0)	5.0 (5.0-5.0)
"I am confident I know where to start and stop contouring normal tissues on a CT image"	3.0 (2.0-5.0)	5.0 (5.0-5.0)

IQR – interquartile range; CT – computed tomography

Table 4: Suggested modifications to the RT ARC Bootcamp based on participant feedback and findings.

Recommendations	**Rationale**
Additional contouring instruction and practice opportunities	• Lack of statistically significant improvements for individual contouring structures. • Participant feedback. (Ex. "…more time could have also been spent with more contouring lectures where instructors have videos of themselves contouring")
Modifications to anatomy-based lectures	• Repeated feedback from participants indicated the course content was extensive and too in depth. • Lack of engagement and high rate of early attrition may be related to course content and lack of relevance to RT practice.
Longer program duration	• Participants reported difficulty completing the course within the allotted amount of time. • Low rates of course completion.
Frequent updates to course content	• Baseline scoring indicating RTs are not comfortable performing certain tasks in practice suggests educational resources are needed to keep pace with changing technology. • Many RTs felt they would refer back to this course over time.

	• Participant feedback regarding future technology. (Ex. "…it would have been nice to have more MRI cases, especially since radiation therapy is heading in that direction in the future!")

RT – radiation therapist; MRI – magnetic resonance imaging