# Qualitative Evaluation of a Novel 3D Volumetric Radiotherapy Segmentation Tool


## Abstract

Introduction

A novel 3D volumetric segmentation tool allows the user to outline using a small number of points on a range of planes. Unique 3D volumetric “sculpting” tools enable editing of the resulting structures across multiple slices concurrently. This paper reports the results of Radiation Oncologists’ pre-clinical evaluation of the tool.

Methods

Three clinicians outlined prostate and seminal vesicles on 14 datasets using the traditional slice-by-slice method and the new 3D tool. The project gathered focus-group feedback to gather rich data relating to clinician perceptions of the new 3D outlining paradigm. Emergent themes were identified and categorised for discussion.

Results

Radiation Oncologists reported high levels of satisfaction with the outlines arising from both paradigms. The volumetric sculpting was a challenge but participants enjoyed using points in orthogonal planes and felt that the paradigm had potential value in terms of speed and smooth volume creation.

Conclusion

This study has demonstrated that a 3D volumetric outlining system is felt to have potential value by Radiation Oncologists for accelerating clinician-directed prostate and seminal vesicle segmentation. The new tool was well-received and reported to be capable of producing very rapid and smooth volumes. The novelty of the approach required significant training input and a radically different approach of minimal point placement. Further testing of this software with a less time-poor cohort may be indicated in order to gain reliable quantitative data relating to the impact on segmentation time.

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### Introduction

Segmentation of target and critical structures for radiotherapy planning is associated with a range of challenges including inaccuracy[1,2] and time.[3,4] Njeh[5] cites segmentation inaccuracy as "the weakest link" in the treatment planning process while a recent paper[6] describes delays caused by segmentation as the "rate-determining step" in planning. While use of automatically generated outlines and implementation of training and protocols can improve speed and reduce inter-observer variation.,[7] this is often at the expense of clinical decision making. The initial development of a new 3D Radiotherapy Immersive Outlining Tool (3D-RIOT) has previously been reported.[8] The tool was developed to enable rapid generation of a user-defined outline as opposed to an automatically generated volume. Several studies have confirmed the limitations of auto-segmentation[9,10] with subsequent editing frequently limiting the time gains; particularly for large numbers of slices. There has been recent interest[11] in ensuring that clinicians are actively involved in the decision making process during segmentation. The 3D-RIOT software allows the user to create volumes rapidly using a small number of points on a range of planes. Unique 3D editing tools allow the clinician to "sculpt" or adjust the resulting structures volumetrically across multiple slices concurrently and, unlike other automatic or semi-automatic systems; the software facilitates full user control. Current research into minimal point voluming[11] relies on adapting existing structure models to fit user-defined points; while this is valuable for anatomically consistent configurations, it is less useful for complex or target structures that have been distorted by pathology. The new software is designed to bring the clinician back in control of segmentation by drawing on 3D visualisation and modelling tools rather than pre-defined models[8] to improve speed.

While the previous paper reported positive feedback related to the software and new paradigm this was based on a developmental tool. This paper reports the results of a Radiation Oncologists' pre-clinical evaluation of the 3D-RIOT software. The evaluation aimed to utilise thematic analysis of qualitative data in order to develop an emerging theory concerning the new paradigm. In particular the work aimed to determine the relative differences between the new and traditional methods of manual outlining.

### Method

Sample

A convenience sample of all 11 Radiation Oncologists experienced with prostate outlining working in a large metropolitan radiotherapy centre was identified and offered participation via email. Participants were provided with information relating to the study along with researcher contact details and asked to contact the researcher to provide consent if they wished to participate. Ethical approval for the project was provided by the university Human Research Ethics Committee.

## Outlining experience

The "traditional" process utilised the ITK-SNAP medical image segmentation software[12] which was new to the participants for a fair comparison. ITK-SNAP enabled users to contour manually on axial slices while viewing the resultant 3D volume. The 3D-RIOT software allowed users to create a 3D volume using a small number of points placed on different planes. Participants were initially provided with a two-hour training session comprising of a presentation of both the 2D and 3D software and "at-elbow" guided outlining. Additional training was available on request. Participants were asked to outline fourteen prostate and seminal vesicle Clinical Target Volumes (CTVs) each at their convenience over a period of six weeks. Half of the segmentations were performed with the traditional slice-by-slice method and half with the new 3D software tool. 2D and 3D outlining sessions were spread over the six weeks with each clinician aiming to perform 5 outlines in 2D in the first week, followed by 5 in 3D the week after until they had completed a total of 28. The regime of outlining for each clinician was identical. Datasets for the outlining were generated from a random selection of Stage 2b prostate patients previously treated with radical radiotherapy. All patients had BMI scores between 18.5 and 30 and prosthetic hip implant patients were excluded to ensure good image quality. All datasets were anonymised and duplicated to generate a matched sample for both 2D and 3D outlining.

## Data collection

After completion of outlining, all participants were invited to participate in a 2-hour focus group discussion to help develop the theoretical underpinning of the new paradigm when compared to traditional methods. Focus group interviews are frequently used in radiotherapy evaluation research to gather the perspectives of a specific group of users.[13] The value of a focus group lies in the interaction and the common experience; in this case the challenges and benefits of a radically new outlining process. A structured approach was adopted and informed by the findings of a previous pilot focus group with registrars.[8] Questions related to participant opinion of various aspects of the volumetric outlining software and paradigm as well as seeking suggestions for future improvement as seen in Table 1. Mainly positive stemmed questions were used initially and follow-up questions were designed to gather responses related to benefits and challenges to gain a balanced perspective. The focus group discussion was moderated by an experienced independent researcher (NE) to facilitate this balanced approach and to reduce the influence of bias.[13] One additional participant who had engaged with the software in a more limited extent could not attend the focus group but gave written responses to the questions. These responses were read out to the group during the discussion (NE) and included within the final analysis. The discussion was recorded (NE) on a digital recorder.

## Data analysis

Focus group discussions typically generate a large volume of verbal data[13] which needs to be transcribed and analysed. The interview recording was transcribed by an experienced researcher (PB) in order to provide an accurate record of the discussion. The process of transcription allows researcher immersion and encourages the identification of themes. Transcription was checked by an experienced and completely independent researcher (NE). Open coding assigned keywords to statements which then allowed collation of themes (PB). This thematic coding was also independently performed by a researcher external to the team (NE) in order to minimise researcher bias. After data analysis an independent observer (NE) performed confirmation checks of all stages of the data analysis including final coding and theme collation to reduce researcher bias.

**Results**

Three of the sample consented to participate in the focus group; these individuals were all experienced senior Radiation Oncologists with experience in prostate and seminal vesicle outlining. Qualitative data derived from the focus group was categorised into themes relating to the potential value and challenges of the paradigm, time pressures, training issues and future improvements. The following discussion summarises these themes along with illustrative comments in Tables 2-5.

**Discussion**

**Paradigm Issues**

Table 2 summarises the main issues identified by the participants in relation to the new paradigm. All participants clearly struggled with the 3D sculpting and it was unclear whether this arose from lack of available time, poor training or limitations of spatial awareness. There was a suggestion that users were just sculpting to create a smooth volume rather than strict compliance with the CT data. The 3D sculpting itself was clearly a challenge and far beyond any previous experienced techniques in outlining for the Radiation Oncologists. The procedural challenges of sculpting arise from incorrect visualisation of the volume-CT border and the novel volumetric nature of the editing tools. Underlying this was an acknowledgement that the 3D orientation aspects of the software were challenging. The results suggest that much more guidance and improved training with both the software and the 3D visualisation and orientation is vital. In wider radiotherapy practice the requirement for interpretation and use of non-axial planes is increasingly relevant with the introduction of MR-based IGRT.[14] Additional training in orthogonal and additional commonly used imaging planes indicated by this project may, therefore, have wider applications.

While the software will facilitate segmentation of highly irregular volumes if necessary; the tool is designed to generate more anatomically accurate smooth volumes by minimising the rapid changes in outline seen on many 2D generated structures (See Figure 1). While the group clearly appreciated the increased smoothness of outlines they did express concerns with confidence in their outlines as they were used to more variable contours.

**Potential value**

The participants all reported difficulties adjusting to the new paradigm and, in particular, to reducing the number of points required which is a significant departure from established practice. Table 3 summarises indicative comments. It was clear that once this adjustment had been made the participants found the 3D volume creation to be very fast and to result in clinically useful structures. Many comments related to the smooth nature of the created volumes that more readily resembled anatomical volumes as opposed to the more jagged outlines resulting from 2D segmentation. Figure

1 illustrates a clear example of the difference between the volume created by conventional 2D outlining and that created by the new paradigm which more closely resembles a real anatomical structure. Most clinical CT volumes generated by the traditional 2D process inevitably exhibit a jagged appearance with indentations and protuberances not seen in anatomical volumes. The smooth mesh growing paradigm ensures that these errant regions are not generated.

The 3D mesh generation was felt to be particularly rapid for simple volumes. Although the 3D editing tools proved to be a challenge, comments indicated that the initial point-based phase may well be sufficient and could render this unnecessary provided a good protocol is in place. Although there were many comments relating to the shortcomings of the tool it was clear overall that participants felt that the paradigm had potential value in terms of speed and smooth volume creation and in particular the ability to utilise points in other planes was well received.

**Radiation Oncologist Challenges**

Participants acknowledged the steep learning curve associated with the new segmentation method. Comments in Table 4 indicated that this was influenced by clinical time pressures and that insufficient time had been devoted to training prior to data collection. A more detailed training manual, provision of at-elbow support and telephone support for the new software was suggested. Although much of this is beyond the scope of a “Proof-of-Principle” evaluation it does indicate that participants felt under-prepared for the data collection and that more intensive training is necessary with such a new paradigm. It was interesting to note the group’s suggestion that their age and levels of expertise and experience may have influenced their evaluation as seen in Table 5. The results from this evaluation strongly support further study gathering quantitative data from less time-pressured individuals who are less entrenched in standard outlining processes.

**Future improvements**

Improvements in 3D resolution were recommended with comments suggesting that this may have compromised confidence in outlining on non-axial planes. This was particularly challenging with the seminal vesicles at the base of bladder. Image resolution was commonly felt to be one of the biggest issues with the software although some of this may have resulted from efforts to match the resolution with the comparative 2D outlining software for parity. Although the method aimed to compare the software with a new 2D equivalent it was clear from comments that participants had inherently tended to provide comparison with the highly sophisticated clinical outlining software. For example, many of the suggested tools such as eraser circles were related to similar tools in the commercial planning system in use at the centre. Further evaluation may benefit from direct comparison with an established treatment planning system and increased resolution. More advanced control tools were also requested and this is currently under development. Although not identified by the participants as an issue, the software currently only supports CT-based segmentation and future versions will benefit from introduction of multi-modality outlining tools.

**Limitations**

Focus group comments were drawn from a small sample than planned. The relatively complex topology of the prostate and seminal vesicle volume did provide an additional challenge to the project compared to simpler volumes as used in other studies.[15] This may have influenced perceptions of the tool compared to published data.

**Conclusions**

The change in approach from a point-intensive conventional 2D outlining system and the use of alternative planes and 3D visualisation represented a challenge to the clinicians in this study. The 3D volumetric outlining system is felt to have potential value by Radiation Oncologists for accelerating clinician-directed prostate and seminal vesicle segmentation. The new tool was generally well-received and reported to be capable of producing very rapid and smooth volumes. The facility to incorporate data from multiple imaging planes simultaneously into the segmentation was felt to be particularly valuable. The findings support the initial outcomes from the previous study[8] that volumetric 3D segmentation has potential value in radiotherapy planning and provide additional insight into the potential benefits and challenges of the new paradigm from a Radiation Oncologist perspective.

The novelty of the approach required significant training input and it was clear that these individuals lacked the time to devote to this. In particular the software demanded a radically different approach of minimal point placement. It is evident that 3D-specific training and the provision of clear step-by-step protocols to reduce the requirement for 3D sculpting would be valuable. Further testing of this software with a less time-poor cohort is strongly indicated in order to gain reliable quantitative data relating to the impact on segmentation time; this work is currently ongoing.

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**Figure Legend**

Figure 1: Target volume created by conventional (left) and volumetric outlining (right)

**Table 1: Focus group questions**

| Lead Question | Follow-up |
|---|---|
| How easy was the 3D-RIOT software to use? | What made the software easy to use?<br>What aspects made it less easy to use?<br>What would have made it easier to use? |
| How happy are you with the resulting outlines? | Why is this? |
| How comfortable were you with 3D orientation and visualisation of the volume? | What factors helped or could have improved this? |
| How long do you think it took you to become reasonably proficient with the 3D-RIOT tool? | To what extent did the training provided help you to use the outlining tools?<br>What additional training would have helped you? |
| Does "Use of orthogonal planes for point identification" have potential value for improving the outlining process? | Why?<br>Or if not; what would need to change first? |
| Does "Rapid volume generation from a small point set" have potential value for improving the outlining process? | Why?<br>Or if not; what would need to change first? |
| Does "3D volume editing" have potential value for improving the outlining process? | Why?<br>Or if not; what would need to change first? |
| Do you foresee a role for any of these paradigms or tools in outlining practice? | |
| How might these tools change the way you outline prostate tumours? | |
| What else would you like to provide feedback on in relation to this project? | |

**Table 2: Illustrative user comments related to the volumetric outlining paradigm**

| Theme | Comment | User |
|---|---|---|
| Sculpting | You'd generate it but then you'd go back to the slices to verify if that was the case and then that was the purpose of the sculpting but we weren't quite comfortable with the sculpting side of things | P1 |
| | I mean what I sort of found when I was trying to sculpt I was sculpting to try and make it nice and round I wasn't sculpting it based on the image because I couldn't really….if there was a dimple I'd pull the dimple out just to make it nicer without respect to the image | P2 |
| | I wasn't very adept at sculpting and I think that probably I seemed to make things worse when I sculpted I was better off just deleting and start again. | P2 |
| | I think I got quite proficient with doing rounded hole-less structures but I just don't think I was proficient with sculpting | P2 |
| | I wonder whether the yield is going to come in the fact that you can actually 3D volume rather than the sculpting… I suspect although the sculpting is like the exciting bit in practice if you could volume in 3 planes and get the right shape that would be enough. That would be very good. And I don't know that the value of sculpting is demonstrated to me at the moment. I think it's exciting and fun, but if you can get the first bit right you mightn't need the sculpting. | P2 |
| Points | Because it was like a revelation: put fewer points – oh OK. Because we think more points will mean more accuracy so that was a bit of an oxymoron | P2 |
| | the simple thing if anything that it demonstrated to you that a small number of points actually does reliably create the volumes you want | P3 |

**Table 3: Illustrative user comments related to potential value of volumetric outlining**

| Theme | Comment | User |
|---|---|---|
| Speed | it was quicker doing the actual prostate volumes as obviously it's so consistent across the prostate volume | P1 |
| Shape | I LOVE you know when you press the button and you get this beautiful shape | P2 |
| | You do want the volume to be as smooth as possible for IMRT and that's actually quite hard to do. | P3 |
| | It DOES make nice smooth outlines, the 3D, much smoother than we can achieve with Pinnacle | P2 |
| | On that side of things if you were doing a 3D reconstruction of something you would welcome a nice smooth side of things there | P1 |
| | there may have been 1 or 2 occasions that I was happy with the 3D volume that was generated but when you actually look at the outline it was going in and out but when you looked at the 3D construction it was nice and smooth | P1 |
| 3D | We sort of try and do it now with imaging in 3 planes and I that useful to be able to go between them and so I was very attracted to that | P2 |
| | as long as we're confident that what we're seeing there is really what we want to be seen and then I think it's a great step to go up to being able to visualise in 3D | P3 |

**Table 4: Illustrative user comments related to training**

| Theme | Comment | User |
|---|---|---|
| Training | I was pretty time-pressured so I didn't really have the luxury of playing so I don't really think I really got the facility of the sculpting aspects as best as I could have. | P2 |
| | but because our time is very limited its put us down there on the learning curve… I really kept on struggling with it right the way through | P3 |
| | I know with probably the first 2 ones I did in 3D side of things there I had a look at the time that I wasted voluming and how many times I deleted it that I basically gave up. So the first couple of volumes I didn't like my volumes at all…and that's whereby in the analysis side of things you'd almost have to take the second half of things once you got familiar with | P1 |

**Table 5: Illustrative user comments related to methodological challenges**

| Theme | Comment | User |
|---|---|---|
| Time | The sort of way we approached it at the end of a busy day coming to spend an hour or two, even a couple to 3 hours after work and the human factors come into that, you know, frustration and antipathy towards the program and all sorts of things…at the end of an 8 hour 10 hour day probably not getting the best of us sitting here 2 hours afterwards | P3 |
| Age | Maybe that’s why its important to get a spectrum of age-related opinions on this | P3 |
| | that’s because we’re old fogies and can’t get our head round it | P2 |