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CLINICAL INVESTIGATION

International Radiosurgery Oncology Consortium of the Kidney (IROCK) Contouring Guidelines for Renal Cell Carcinoma Treated With Stereotactic Ablative Radiation Therapy

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Purpose: Stereotactic ablative body radiation therapy (SABR) is an emerging indication for localized renal cell carcinoma (RCC), yet there is a need for standardizing contouring practices, as accurate target delineation is essential to ensure optimal outcomes. Our objective was to develop consensus guidelines for target volume contouring for RCC SABR.

Methods and Materials: An international panel of RCC SABR experts affiliated with IROCK was convened. All were asked to contour target volumes for 4 relevant clinical scenarios: a large tumor (>10 cm) with inferior vena cava tumor thrombus; a central tumor abutting the renal hilum; a local recurrence following nephrectomy; and an ablation cavity recurrence after radiofrequency ablation. Participants also contoured 2 investigational renal substructures: renal cortex and renal hilum. Contours by case were analyzed using a Simultaneous Truth and Performance Level Estimation algorithm (95% CI). Consensus contours and guidelines statements were discussed and refined over 2 consensus meetings. Measures of variance and agreement, including dice similarity coefficients (DSCs), Mean Distance to Agreement, and Hausdorff Distance, were measured for each case.

Results: In total, 16 radiation oncologists participated. The median DSC was 0.85, and the median Mean Distance to Agreement/Hausdorff Distance were 2.17 mm/9.00 mm, respectively. The median DSC was greater than 0.70 for each case, suggesting "good agreement" among participants. Based on the consensus discussion, any tumor thrombus or ablation cavity should be included in the target volume; organ at risk dose constraints should take priority over target coverage in planning; and the ipsilateral renal cortex should be defined as the ipsilateral renal parenchyma, excluding the target volume, the renal pelvis, renal vasculature, and proximal ureter.

Conclusions: We present the first international consensus contouring guideline for RCC SABR. There was strong agreement among experts, yielding high-fidelity consensus contours and guidance statements for each scenario. These results can be used as a guide for radiation oncologists interested in using SABR to treat patients with localized RCC.

Introduction

The current standard of care for localized, nonmetastatic renal cell carcinoma (RCC) is surgical resection via partial or radical nephrectomy (RN). Radiation therapy has become increasingly studied as an alternative to surgery for patients with localized RCC, especially as the incidence of RCC is rising due to incidental findings of renal masses in older or medically comorbid patients.[1] Stereotactic ablative body radiation therapy (SABR) has been demonstrated to be safe and provide excellent local control and short-term survival outcomes based on recent international meta-analyses and a prospective, multi-institutional phase II trial.[2-4] SABR has been demonstrated to provide similar outcomes to other ablative modalities and, as such, should be considered a viable option in patients for whom surgery may pose a significant risk to their health and quality of life.

As the enthusiasm of RCC SABR increases, there remains variability with respect to contouring, treatment planning, and SABR delivery among radiation oncologists. In an international meta-analysis from the International Radiosurgery Oncology Consortium of the Kidney (IROCK), several different prescription doses and fractionation patterns were used for RCC SABR.[3] Furthermore, when examining recently published clinical trial protocols for RCC SABR, variability also existed in radiation planning details, including patient setup, prescription dose, delineation of the target volumes, organ at risk (OAR) dose constraints, and image verification.[2,5,6]

As such, there is a need to align best practices and address variations in treatment planning for this emerging indication. Consequently, a contouring guideline addressing 4 specific treatment scenarios unique to RCC SABR was felt to be beneficial. To this end, we assembled an international panel of radiation oncologists experienced in the use of SABR for localized RCC. Our objective was to develop consensus guidelines on target volume delineation and radiation planning recommendations. The purpose of this contouring consensus was to both aid in clinical practice and provide a standardized approach for future multi-institutional trials evaluating SABR for localized RCC.

Methods and Materials

This study was granted exemption from institutional research ethics board review, given that the diagnostic and radiation planning images involved were used to improve the quality of radiation therapy delivery and were previously acquired as part of usual clinical care.

Initially, a small working group (AD, SS, RJMC, and AS) identified relevant cases to consider for the contouring consensus. These cases represent relevant clinical scenarios for which RCC SABR is used in real-world clinical practice and were cases where there would be some uncertainty about the ideal target volume delineation, even among RCC SABR experts. Four cases of patients with RCC treated with SABR were included and representative diagnostic images are shown in Figure E1: Case 1, a patient with a RCC greater than 10 cm in size with inferior vena cava (IVC) tumor thrombus; Case 2, a patient with a central RCC abutting the renal hilum; Case 3, a patient with a local recurrence after previous RN; and Case 4, a patient with residual disease after previous radiofrequency ablation (RFA).

Following case selection, specific contours for each case were chosen. Given that upper abdominal OAR contouring guidelines based on computed tomography (CT) and magnetic resonance imaging (MRI) existed in the literature

already,[7,8] it was decided that the focus of this study should be on target volume contouring for RCC SABR. In addition, to make the study more internationally applicable, we decided that target volumes for this study should be based on CT imaging exclusively, given that MRI in the treatment position is not always available for radiation planning at every center that provides SABR for RCC patients. Participants were asked to contour the internal gross tumor volume (iGTV) for each case, which represents the gross tumor volume accounting for internal motion. The iGTV structure has been used in radiation therapy trials for other cancers, such as lung cancer, for which internal motion is commonly accounted.[9] In the context of SABR treatments, where a margin to account for microscopic spread is generally not used, the iGTV and the internal target volume were identical. In addition, contours for 2 novel OARs were considered, namely the renal cortex and renal hilum. These 2 anatomical structures may have theoretical relevance to RCC SABR toxicity and have not previously been included in OAR consensus guidelines. To limit the contours required from each participant, the renal cortex and hilum contours were only requested from participants for Case 2.

Further to case and contour selection, a focused questionnaire addressing specific radiation planning details was developed for each case—participants were asked regarding details on patient setup, imaging modalities used for treatment planning and daily treatment verification, respiratory motion mitigation strategies, mandatory versus optional OARs for treatment planning, and details on dose prescription and objectives.

An international panel of radiation oncologists was then formed from the IROCK meeting during the 2023 Annual Meeting of the American Society for Radiation Oncology in San Diego, California. The main criterion for inclusion within the panel was prior experience with RCC SABR, with at least ten cases treated previously. No other criteria were required, although we did strive to include as many international physicians as possible, with various technologies available at their respective institutions. An additional request was sent to previous IROCK contributors who met the inclusion criterion but who could not attend the American Society for Radiation Oncology meeting. The clinical history of each case was distributed to all participants. Clinical images, including diagnostic CT and CT simulation images, were distributed using the EduCase online contouring platform (RadOnc eLearning Center, LLC., https://www.educase.com/). This platform allowed participants to contour on Digital Imaging and Communications in Medicine (DICOM) images using a web browser, with contours available later for download and analysis by the working group. Radiation planning details were submitted by participants using an electronic questionnaire.

Participant contours for each case were exported from EduCase as DICOM-Radiation Therapy structure files. We then used a Simultaneous Truth and Performance Level Estimation (STAPLE) algorithm to determine the 95% consensus contour for each case.[10] The STAPLE algorithm allows contours completed by experts to be combined through weighted voting. Specifically, an estimate of the ground-truth contour is created by a weighted average of the expert contours, and, with each successive iteration, the weightings of each expert are modified based on the accuracy of their contours with the ground-truth contour of the previous iteration. The STAPLE algorithm was performed in R, using the "stapler" package (https://cran.r-project.org/package=stapler). In addition, a qualitative analysis was completed of the responses from the radiation planning questionnaire to ascertain common themes and similarities in clinical practice.

The consensus contours and qualitative analysis were then discussed during 2 online meetings with the participants in May and June 2024. Edits were made to the consensus contour for each case based on participant feedback, using the 3D Slicer software (https://www.slicer.org/). Consensus statements were created and refined based on responses from the questionnaires and from discussions during these meetings.

Further analyses were conducted to measure the variance of each participant's contours from the final consensus contours. These include the dice similarity coefficient (DSC), the Mean Distance to Agreement (MDA), and the Hausdorff Distance (HD). The DSC measures the overlap between 2 contours, with values between 0 and 1, with a higher DSC indicating greater agreement. The MDA and HD represent the mean and maximum distances between points on the 2 contours, with units of millimeters, with higher MDA and HD representing lower agreement. A 2-way analysis of variance (ANOVA) analysis was also conducted to ascertain whether there were any statistical differences between the DSC, MDA, and HD when accounting for the 4 different cases and the participants.

Results

A total of 16 participants were involved in the contouring consensus. All participants had used SABR to treat 10 or more patients with localized RCC previously, with 14 of 16 participants having treated 10 or more patients in the 12 months before the start of the current study. Participants represented an international group from the United States, Canada, Australia, the Netherlands, and India. All 16 participants completed target volume contours for each case, whereas 12 and 13 participants completed separate renal cortex and renal hilum volumes for Case 2, respectively. The remaining participants did not consider the renal cortex or hilum as a relevant OAR. The CT simulation axial image set for each case, with overlaid consensus target contours, participant target contours, and OAR contours are shown in Figures 1-4.

Following the development of consensus contours, consensus guideline statements were developed on aspects of contouring and radiation planning relevant to each case. For Case 1, there was significant discussion on the extent of

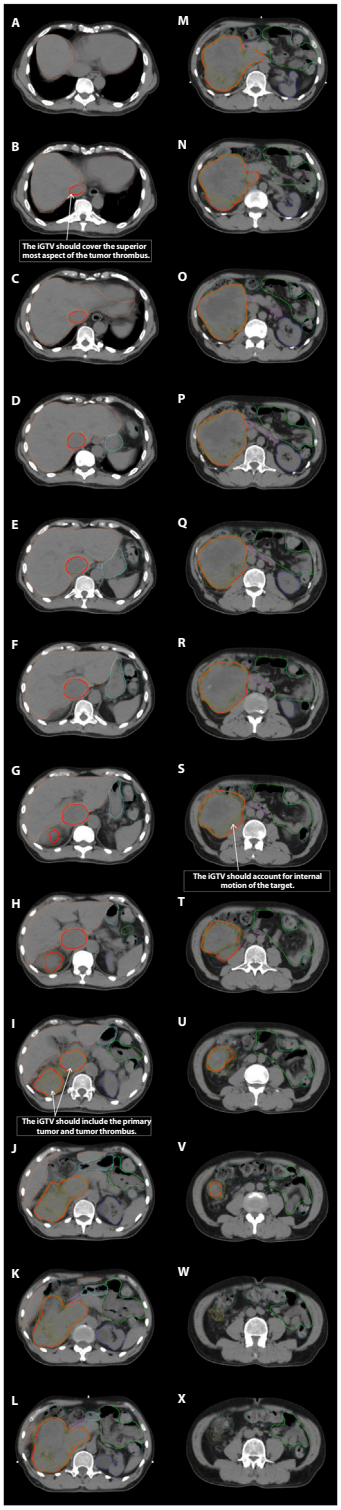

Fig. 1. Representative axial images (A—superior; X—inferior) of the CT simulation for Case 1. Red—Consensus target contour; olive—participant target contours; brown—chest wall; blue—contralateral kidney; gray—esophagus; cyan—stomach; magenta—duodenum; light green—small bowel; teal—large bowel; dark green—spinal canal; orange—liver; maroon—heart. *Abbreviations:* iGTV = internal gross tumor volume; CT = computed tomography.

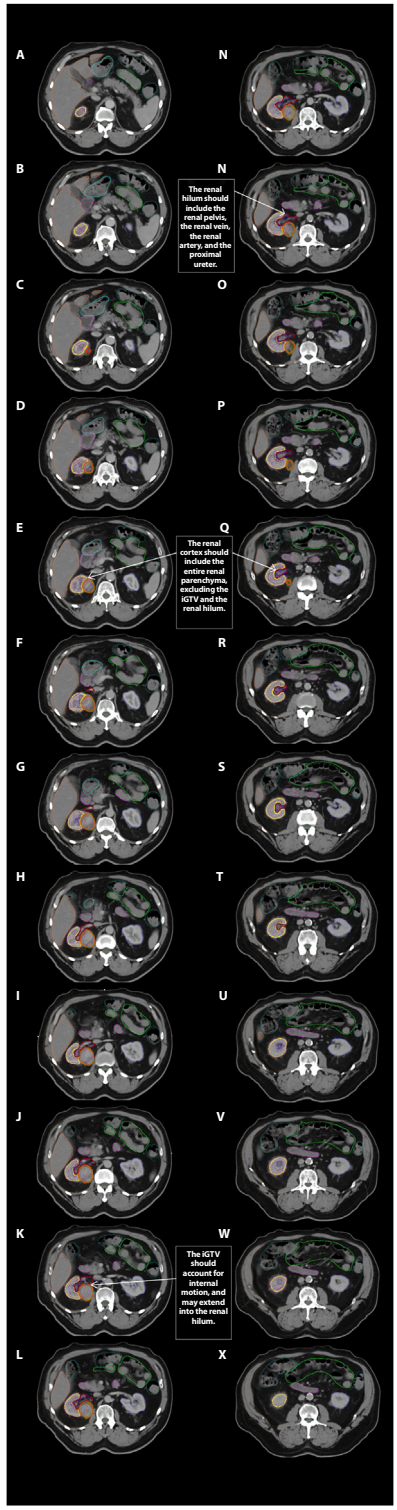

Fig. 2. Representative axial images (A—superior; X—inferior) of the CT simulation for Case 2. Red—Consensus target contour; olive—participant target contours; yellow—consensus ipsilateral renal cortex; purple—participant ipsilateral renal cortex; maroon—consensus ipsilateral renal hilum; dark blue—participant ipsilateral renal hilum; brown—chest wall; blue—contralateral kidney; cyan—stomach; magenta—duodenum; light green—small bowel; teal—large bowel; dark green—spinal canal; orange—liver. *Abbreviations:* iGTV = internal gross tumor volume; CT = computed tomography; OAR = organ at risk.

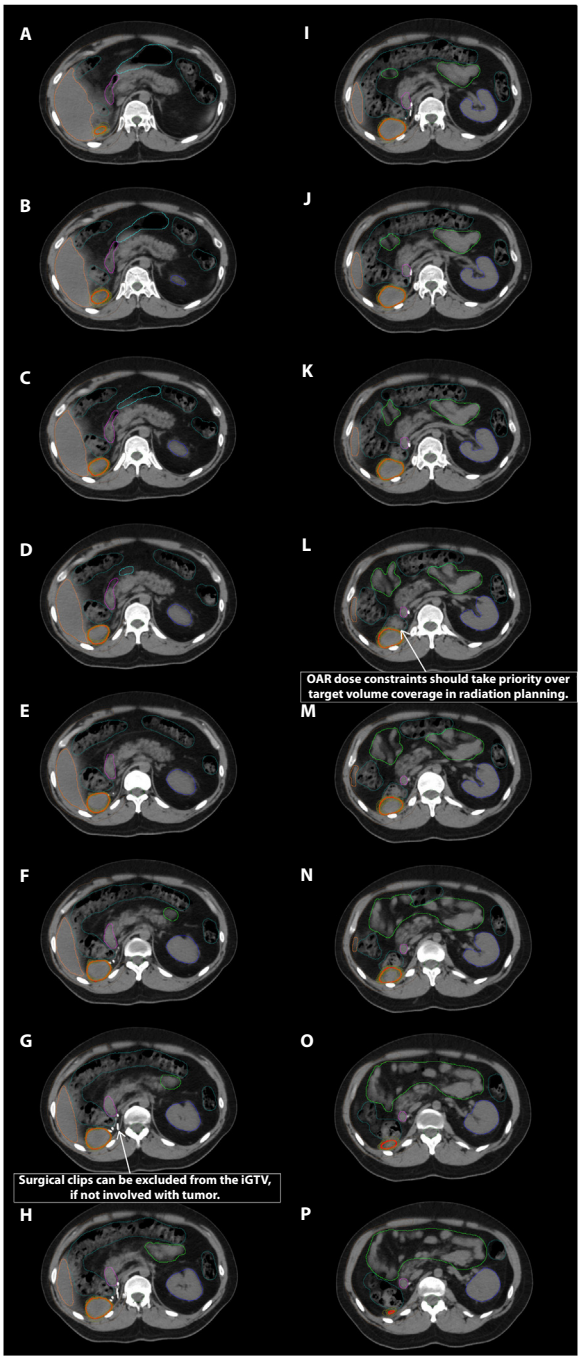

Fig. 3. Representative axial images (A—superior; P—inferior) of the CT simulation for Case 3. Red—Consensus target contour; olive—participant target contours; brown—chest wall; blue—contralateral kidney; cyan—stomach; magenta—duodenum; light green—small bowel; teallarge bowel; dark green—spinal canal; orange—liver. *Abbreviations:* iGTV = internal gross tumor volume; CT = computed tomography; OAR = organ at risk.

the IVC thrombus to be included in the target volume. Many participants had experience treating IVC tumor thrombi, and 1 participant also discussed their use of SABR as neoadjuvant therapy of tumor thrombus before RN.[11] As

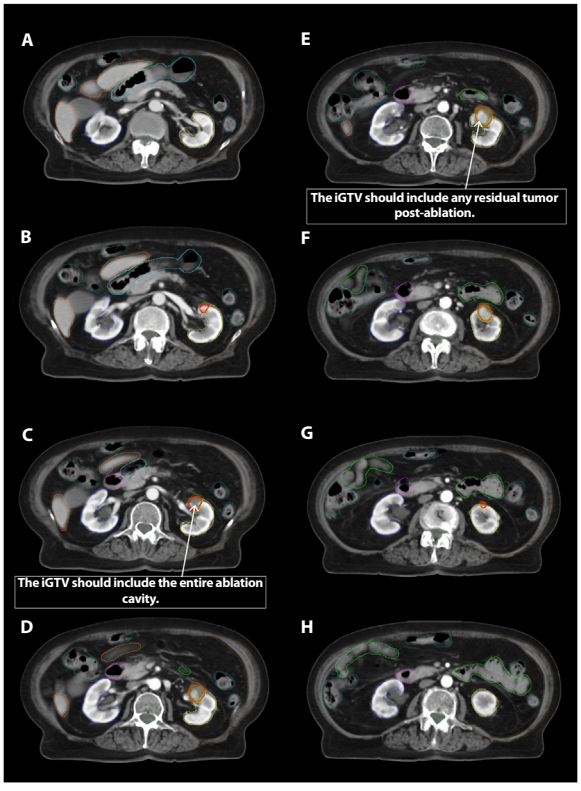

Fig. 4. Representative axial images (A—superior; H—inferior) of the CT simulation for Case 4. Red—Consensus target contour; olive—participant target contours; brown—chest wall; yellow—ipsilateral renal cortex; blue—contralateral kidney; cyan—stomach; magenta—duodenum; light green—small bowel; teal—large bowel; dark green—spinal canal; orange—liver. *Abbreviations:* iGTV = internal gross tumor volume; CT = computed tomography.

such, the panel reached consensus that all gross tumors should be included in the target volume, including the primary tumor and any tumor thrombus (Fig 1B and I). In addition, the panel recommended that all diagnostic imaging should be reviewed by expert radiologists prior to RCC SABR, to differentiate between tumor thrombus and bland thrombus, and recommended that bland thrombus should be excluded from the target volume. Contrast-enhanced MRI and/or contrast-enhanced CT (ideally with multiphasic contrast imaging) were strongly encouraged as diagnostic tools to help differentiate between bland and tumor thrombus.

For Case 2, there was discussion on the necessity of renal substructure contours, such as renal cortex and renal hilum. Although the dose to ipsilateral and uninvolved renal parenchyma (including renal cortex and medulla) during SABR has been correlated with an impact on renal function in multiple studies, neither the renal cortex specifically (as a substructure of the renal parenchyma) nor the renal hilum and vasculature have been separately correlated.[12-14] In addition, it is unclear whether limiting the dose to the renal hilum would reduce the risk of an adverse event such as

renal artery stenosis or ureteric stricture, which, anecdotally from the panel's experience, seem to be rare at the radiation dose used. Further, by including these substructures in the radiation planning process, there may be an inclination to avoid radiation dose deposition to these substructures during planning, which may consequentially cause higher dose to other areas of renal parenchyma. As such, the panel favored that the ipsilateral renal parenchyma should be defined as the entire ipsilateral kidney, excluding the following: iGTV, renal pelvis, renal vasculature, and proximal ureter (Fig 2E and Q). The renal hilum should not be contoured as a dose-limiting OAR but could be drawn as an optional contour. If contoured, the renal hilum should include the renal pelvis, renal vasculature, and the proximal ureter (Fig 2N).

For Case 3, there was significant discussion on how to account for OARs in RCC SABR planning. In this case, there was a large bowel near the target volume, which is a frequent occurrence in RCC SABR planning (Fig 3L). There were several strategies that the panel discussed to mitigate the risk of toxicity from this treatment. First, the panel felt that the target volume should include the entire tumor nodule, but not include elective regions without macroscopic tumor, such as the nonadjacent surgical clips (Fig 3G). Second, the treating radiation oncologist can consider several patient preparation maneuvers, such as having the patient remain nil-per-os for multiple hours prior to simulation and treatment to reduce the variability of the stomach size and location; or taking simethicone, alpha-galactosidase, or a bowel preparation regimen to reduce the variability of the size and location of bowel loops. Third, when there is difficulty meeting both OAR dose constraints and target volume dose objectives during radiation planning, the OAR dose constraints should be prioritized. This can be achieved with a heterogeneous dose coverage of the target volume, using a steep dose gradient. Fourth, planning OAR volumes (PRVs) can be considered. Lastly, adaptive radiation therapy technologies can be considered, if available, as this may allow for better sparing of nearby OARs.

For Case 4, the consensus discussion revolved around the extent of the RFA cavity to include in the target volume. If the target were limited to the tumor nodule only, there could be an increased risk of further tumor recurrence within the cavity, outside the SABR treatment field, which would be difficult to retreat. Therefore, the panel felt that including the recurrent tumor nodule and the entire RFA cavity was reasonable for this case, as the cavity was small and far from OARs (Fig 4C and E). For larger ablation cavities, it may be difficult to spare dose to OARs. In this scenario, the entire ablation cavity should still be in the target volume; however, OAR dose constraints should be prioritized in a similar fashion as in the third case.

Two other themes that emerged in the consensus discussion were the optimal imaging modalities for contouring and the use of imaging contrast for radiation planning. Although 4-dimensional CT simulation scans were provided to participants, many did suggest the use of additional imaging modalities, such as MRI, to best contour targets and OARs. Our intention initially was to include only CT images to allow as many participants as possible to participate, as MRI in the treatment position is not always available for radiation planning at every center that provides SABR for RCC patients. In addition, the panel felt that CT-based contrast at the time of simulation imaging was an important consideration for patients receiving RCC SABR, as it can help differentiate between tumor and normal renal parenchyma. In patients who have reduced glomerular filtration rate or for whom the treating radiation oncologist is worried about contrast-induced nephrotoxicity, the panel would recommend referral to nephrology prior to RCC SABR for medical optimization of renal function and/or intravenous hydration prior to and after CT contrast administration.

These consensus statements are summarized in Table 1, and key consensus statements are placed beside representative images of each Case in Figure 5. The participants reviewed each statement, and revisions were made until there was uniform (100%) agreement. When reviewing the responses to the questionnaire, all participants did not add a margin to the iGTV to account for microscopic spread and, as such, we would not recommend a separate internal target volume contour for radiation planning. For all 4 cases, the most common PTV margin recommended by the participants was a uniform expansion of 5 mm on the iGTV. This recommendation was based on the patient being treated in a supine position, with a vacuum cushion for immobilization, using a 4-dimensional CT at simulation to account for respiratory motion, intravenous contrast for tumor delineation, and the use of a cone-beam CT for daily setup prior to treatment. Variation in the PTV margin may exist based on institutional technology and processes, including the use of MRI at the time of simulation or for adaptive treatments.

There were several dose prescriptions, objectives, and OAR constraints recommended by the participants in this study, including using 1, 3, or 5 fractions for RCC SABR. Although certain constraints remain institution-specific, suggested OAR constraints and coverage objectives based on the Focal Ablative Stereotactic Radiosurgery for Cancers of the Kidney (FASTRACK-II)[2] and Assessment of Quality of Life and Outcomes in Patients Treated with Stereotactic Body Radiotherapy for Primary Renal Cell Carcinoma (AQuOS-II) (clinicaltrials.gov NCT05023265) protocols, as well as other renal SABR publications, are shown in Table 2.

The metrics comparing the participants' contours with the consensus contours for each case are shown in Table 3. Overall, the median DSC was 0.85 (range, 0.40-0.95), the median MDA was 2.17 mm (range, 0.71-10.82), and the median HD was 9.00 mm (range, 4.00-89.31). The median DSC was greater than 0.70 for each case, suggesting "good agreement" among the participants.[15] Using a 2-way ANOVA analysis, the DSC, MDA, and HD were statistically different between the 4 cases ($P < .05$ for all 3). In this same analysis, the DSC and HD were not statistically different between participants

Table 1 Consensus statements for contouring and radiation planning for each case

Case	Consensus Recommendations
Case 1 *Ren al tumor greater than 10 cm, with IVC tumor thrombus*	• Both the primary tumor and entire tumor thrombus should be included within the iGTV contour. • Bland thrombus should be excluded from the iGTV.
Case 2 *Central renal tumor, abutting the renal hilum*	• The iGTV contour should include all tumor visible on simulation imaging and should account for internal motion. • An ipsilateral renal cortex contour should include the ipsilateral kidney minus the iGTV, the renal pelvis, the renal vasculature, and the proximal ureter. • An ipsilateral renal hilum contour, including the renal pelvis, renal vasculature, and proximal ureter, can be contoured at the discretion of the treating radiation oncologist.*
Case 3 *Local recurrence of renal tumor postnephrectomy*	• The iGTV should include all visible gross tumor. The iGTV does not need to include surgical clips.
Case 4 *Residual renal tumor post-radiofrequency ablation*	• The iGTV should include the visible gross tumor recurrence, as well as the entire ablation cavity.
All Cases	• MRI can be considered in conjunction with, or as an alternative to, CT imaging for accurate delineation of the iGTV. • Contrast should be considered for any CT or MR imaging used for RCC SABR delivery. If the patient has medical comorbidities that increase the risk of contrast-induced nephrotoxicity, a referral to nephrology for medical renal optimization and/or intravenous fluid prior to contrast administration should be considered. • OAR dose constraints should be prioritized over target volume dose objectives during RCC SABR planning. • The dose hotspot should be placed within the iGTV during RCC SABR planning.

Abbreviations: CT: computed tomography; iGTV: internal gross tumor volume; IVC: inferior vena cava; MR: magnetic resonance; MRI: magnetic resonance imaging; OAR: organ at risk; RCC: renal cell carcinoma; SABR: stereotactic ablative body radiation therapy.
* A renal hilum contour should not be used as a dose-limiting OAR to compromise target coverage; currently, we are not aware of any evidence that doing so reduces impact on renal function or the incidence of adverse events such as renal artery stenosis.

($P = .07$ and $P = .45$, respectively), whereas there was a statistically different MDA between participants ($P = .03$).

Discussion

The accumulation of high-quality evidence supporting SABR for localized RCC necessitates standardization of contouring practices. Accurate target delineation is essential to ensure that optimal outcomes are achieved for patients receiving this curative-intent treatment. Our work leveraged the expertise of an international panel of experts affiliated with IROCK. Together, we systematically developed consensus contouring guidelines on target volume delineation for SABR in 4 relevant clinical scenarios of localized RCC: a large tumor with IVC thrombus, a central tumor abutting the renal hilum, a local recurrence after RN, and a local recurrence after RFA. There was strong agreement among experts, yielding high-fidelity consensus contours and corresponding guidance statements for each clinical scenario. Therefore, our work represents the first international consensus contouring guideline to inform target delineation for RCC SABR.

This guideline complements previous work from IROCK, including clinical guidelines and consensus statements,[16-18] as well as previous consensus documents on contouring for upper abdominal malignancies.[19-21] Similar to these previous contouring consensus guidelines, our study used a STAPLE analysis to quantify consensus contours; measured the variability in contouring using standard metrics, such as DSC, MDA, and HD; and included consensus statements that will provide guidance to radiation oncologists on contouring situations with greater variability. Unique to this study is the inclusion of cases specific to RCC SABR, and consideration of renal substructure contouring for planning. The ipsilateral renal parenchyma and renal hilum are being investigated in prospective clinical trials, such as the AQuOS-II trial, which may help determine the importance of these contours for SABR radiation planning for localized RCC. As such, this study will provide a comprehensive resource for clinicians who are starting or increasing their use of SABR for RCC and facilitate standardization of treatment practices for future clinical studies.

Quantitative analysis of the participants' contours versus consensus contours using STAPLE, DSC, and other metrics revealed "good agreement" overall for each case, that is, the

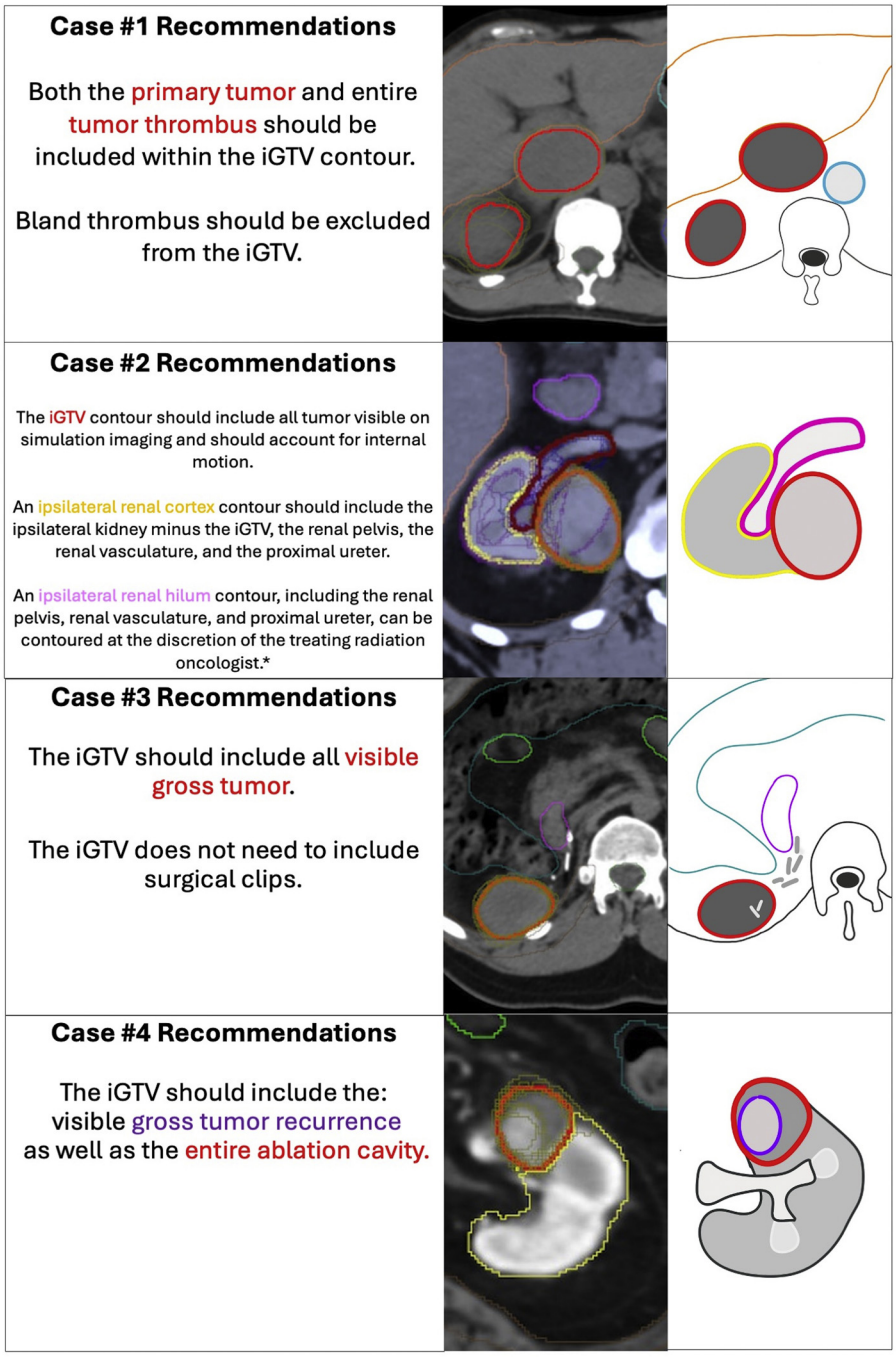

Fig. 5. Representative CT images and computer-drawn images to highlight the key consensus statements for each case. *Abbreviations:* iGTV = internal gross tumor volume; CT = computed tomography.

DSC was greater than 0.7 for each case. Although there are no standardized definitions of "good agreement" for MDA and HD, we felt that Case 2, Case 3, and Case 4 all had reasonable MDA and HD results, whereas the results for Case 1 were larger, but also reasonable, mainly due to some variability in the superior extent of IVC tumor thrombus inclusion and the size of the target volume. When comparing the DSC and HD by case and participant using a 2-way ANOVA analysis, there were statistically significant differences between cases, but not participants. For the MDA, there were statistically significant differences accounting for cases and participants. Overall, these findings suggest that the agreement depended on the complexity of the case, and there was variation in target contours from participants, even among experienced radiation oncologists. Greater variation was seen in Case 1 and Case 4, as participants included differing amounts of the IVC tumor thrombus and the post-RFA cavity in their target volumes, respectively. On the other hand, less variation was seen in Case 2 and Case 3 between participants.

Table 2 Suggested dose objectives and OAR constraints for renal SABR planning

	1 Fraction	3 Fraction	5 Fraction
PTV	D99% = 100%	D99% = 100%	D99% ≥ 95%
	125% ≤ Dmax ≤ 143%	125% ≤ Dmax ≤ 143%	Dmax ≤ 140%
	CI, 100% < 1.2	CI, 100% < 1.2	CI, 100% ≤ 1.2
	4.0 ≤ CI 50% ≤ 5.0	4.0 ≤ CI 50% ≤ 5.0	
ITV			D99% ≥ 100%
Spinal Canal	D0.03 cc < 12 Gy	D0.03 cc < 18 Gy	V23 Gy < 0.35 cc V14.5 Gy < 1.2 cc PRV Dmax < 25.3 Gy
Skin	D1.5 cc < 18 Gy	D1.5 cc < 30 Gy	Dmax < 39.5 Gy V36.5 Gy < 10 cc
Small bowel (+ 3 mm PRV)*	D0.03 cc < 26 Gy D5 cc < 22.5 Gy Aim for <13 Gy to the full circumference of the bowel loop Dmax covering full circumference of bowel wall ≤ 12.5 Gy	D0.03 cc < 30 Gy D30 cc < 12.5 Gy Dmax covering full circumference of bowel wall ≤ 22.5 Gy	Dmax < 35 Gy D5 cc < 19.5 Gy
Large bowel (+ 3-mm PRV)*	ALARA D1.5 cc < 26 Gy	ALARA D1.5 cc < 42 Gy	Dmax < 38 Gy V25 Gy < 20 cc
Stomach (+ 3-mm PRV)*	D1.5 cc < 15.4 Gy D5 cc ≤ 22.5 Gy	D0.03 cc < 30 Gy D5 cc ≤ 22.5 Gy	Dmax < 32 Gy V25 Gy < 5 cc V18 Gy < 10 cc
Liver	None	D700 cc < 15	Liver-PTV Dmean < 18 Gy
Ipsilateral kidney minus ITV†	ALARA (minimize >50% isodose)	ALARA (minimize >50% isodose)	ALARA (minimize >50% isodose)
Contralateral kidney	V10 Gy ≤ 33%	V10 Gy ≤ 33%	V10 Gy ≤ 33% Dmean < 11.3 Gy
"Uninvolved" renal parenchyma			CV 200 cc ≤ 17.5 Gy
Bilateral kidneys			V16.8 Gy<67%

* PRV is optional for luminal GI structures, but recommended based on FASTRACK-II protocol[2] especially if PTV abuts or overlaps these OARs.
† Minimize high-dose regions (>50% isodose) outside the ITV but within the ipsilateral kidney.
Abbreviations: ALARA = As Low As Reasonably Achievable; CI = Conformity Index; CV = critical volume; The PRV (Planning Risk Volume) is defined as a 3-mm isotropic expansion, D XX % or D XX cc = Dose to the hottest XX % or hottest XX cc of the volume; FASTRACK-II = Focal Ablative Stereotactic Radiosurgery for Cancers of the Kidney; GI = Gastrointestinal; Gy = Gray; ITV = internal target volume; OAR = organ at risk; PRV = planning risk volume; PTV = planning target volume; SABR = stereotactic ablative body radiotherapy; V YY % or V YY Gy = Volume receiving at least YY % or YY Gy.

There are a few limitations to this study. First, as mentioned previously, only CT-based images were provided to the participants for this exercise. If MRI was provided as well, some of the variation seen in contouring may have been reduced. Second, although a post-hoc 2-way ANOVA analysis was conducted, participants were not required to recontour target volumes after the 2 consensus meetings. Our hope is that the variation seen in this study would be reduced if participants had contoured the targets again after the 2 consensus meetings, but we did not feel that measuring this in our study would have been informative given the degree of agreement already demonstrated. Third, although the cases were meant to represent clinical scenarios that radiation oncologists encounter in practice, there could still be barriers that hinder the adoption of these guidelines. Specifically, strong multidisciplinary collaboration with other specialties, such as urology, interventional and diagnostic radiology, and nephrology, will allow for novel indications of SABR for localized RCC to be explored. In addition, radiation planning for SABR requires precise and advanced technology. As such, at institutions where there is poor collaboration with other specialties, or advanced technology is not available, we anticipate that it would be difficult to implement these guidelines. Finally, although this study does represent international expertise of RCC SABR, these results have yet to be validated in prospective trials, and contouring recommendations may change from the results of future trials.

Table 3 Metrics of variance between the participants' contours and the consensus contours

Case	DSC* (median, IQR)	MDA* (mm) (median, IQR)	HD* (mm) (median, IQR)
1	0.85, 0.79-0.85	6.69, 5.88-8.79	64.60, 64.44-86.40
2	0.90, 0.84-0.93	1.55, 1.00-2.09	7.92, 5.35-9.98
3	0.91, 0.88-0.93	1.42, 1.18-1.89	6.18, 6.00-7.12
4	0.75, 0.60-0.79	2.50, 2.12-2.99	9.00, 9.00-12.39

* Higher DSC represents greater agreement between the participants' contours and the consensus contours, whereas higher MDA and HD represent less agreement between these contours.
Abbreviations: DSC = dice similarity coefficient; HD = Hausdorff distance; MDA = Mean Distance To Agreement.

Conclusion

This study provides the first international contouring consensus guideline for RCC SABR, addressing 4 relevant clinical scenarios of localized RCC. Contours were in good agreement between the 16 expert participants and led to the development of guidance statements with unanimous consensus. This study is timely, given the rapid accumulation of supporting evidence for RCC SABR, and provides guidance for standardization among radiation oncologists for the essential task of accurate target delineation for this emerging indication for SABR.

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