Radiation Planning Assistant - A Web-based Tool to Support High-quality Radiotherapy in Clinics with Limited Resources

Laurence Edward Court[1], Ajay Aggarwal[2], Hester Burger[3], Carlos Cardenas[4], Christine Chung[1], Raphael Douglas[1], Monique du Toit[5], Anuja Jhingran[1], Raymond Mumme[1], Sikudhani Muya[6], Komeela Naidoo[5], Jerry Ndumbalo[6], Tucker Netherton[1], Callistus Nguyen[1], Adenike Olanrewaju[1], Jeannette Parkes[3], Willie Shaw[7], Christoph Trauernicht[5], Melody Xu[8], Jinzhong Yang[1], Lifei Zhang[1], Hannah Simonds[9], Beth M. Beadle[10]

[1] The University of Texas MD Anderson Cancer Center [2] Guy's and St. Thomas' Hospital [3] Groote Schuur Hospital and University of Cape Town [4] University of Alabama at Birmingham [5] Tygerberg Hospital and Stellenbosch University [6] Ocean Road Cancer Institute [7] University of the Free State [8] University of California-San Francisco [9] University Hospitals Plymouth NHS Trust [10] Stanford University

Corresponding Author

Laurence Edward Court

lecourt@mdanderson.org

Citation

Date Published

DOI

URL

Abstract

Access to radiotherapy worldwide is limited. The Radiation Planning Assistant (RPA) is a fully automated, web-based tool that is being developed to offer fully automated radiotherapy treatment planning tools to clinics with limited resources. The goal is to help clinical teams scale their efforts, thus reaching more patients with cancer. The user connects to the RPA via a webpage, completes a Service Request (prescription and information about the radiotherapy targets), and uploads the patient's CT image set. The RPA offers two approaches to automated planning. In one-step planning, the system uses the Service Request and CT scan to automatically generate the necessary contours and treatment plan. In two-step planning, the user reviews and edits the automatically generated contours before the RPA continues to generate a volume-modulated arc therapy plan. The final plan is downloaded from the RPA website and imported into the user's local treatment planning system, where the dose is recalculated for the locally commissioned linac; if necessary, the plan is edited prior to approval for clinical use.

Introduction

The global number of cancer cases is expected to grow to approximately 24.6 million by 2030, with the largest burden in low- and middle-income countries (LMICs)[1]. Radiotherapy is a cost-effective, curative, and palliative treatment for cancer, providing benefits to approximately 50% of patients with cancer and to 60-70% in low-income countries where patients are more likely to present at a late stage[2,3]. However, access to radiotherapy worldwide is limited[4]; for example, no countries in Africa have the radiotherapy capacity to meet their estimated need[5]. Several studies have estimated these impending shortages and what would be required to meet upcoming needs[6,7].

The Lancet Oncology Commission made the compelling case that investment in radiotherapy capacity improvements would not only save lives but would also bring positive economic benefits[3]. They also specifically pointed out that automation of radiotherapy contouring and treatment planning may help clinical teams scale their efforts by significantly reducing the time spent on these tasks by oncologists and physicists, respectively, making the goals more attainable.

Our research group has been working in collaboration with clinical teams at MD Anderson and at hospitals across the world to develop web-based automated tools. This suite of tools (called the RPA) provides Artificial Intelligence-based contouring (outlining tumors and nearby organs on CT scans) and radiotherapy treatment planning (which defines exactly how the radiation is delivered). This web-based platform offers the advantage of reduced time and resources needed to prepare high-quality plans for each patient.

Our experience with an early version of an AI-based tool at MD Anderson has shown that automated contouring

can save up to 2 h per patient-a significant streamlining of the workflow. This means that current clinical staff will be able to scale their effort, treating more patients with higher-quality radiotherapy. By offering these tools via a fully automated, web-based service (Radiation Planning Assistant [RPA], RPA.mdanderson.org), we can minimize the cost to the patients and providers and maximize the reach of this tool.

We have been developing the RPA for 6 years, and several significant changes have been made since we first published on the RPA workflows[8]. These include developing the RPA into a web-based tool, thus reducing the costs associated with installation and maintenance, and improving the system's robustness. Other improvements include changes in the user interfaces to improve usability and reduce the risk of error[9] and expanding treatment options (specifically, radiotherapy planning for post-mastectomy breast[10] and metastases to the brain[11]). Thus, the protocol described here is substantially more advanced than the initial version previously published.

The RPA uses a one-step process to create contours and plans in situations in which editing of the contours is not generally necessary to create the treatment plan. This includes four-field box treatment planning for cervical cancer (based on bony landmarks or automatically generated soft tissue contours)[12,13,14,15], tangential or supraclavicular fields for post-mastectomy breast cancer[11], and opposed laterals for whole-brain treatments[16]. In the near future, we expect to add craniospinal treatments for pediatric cancers[17], three-field treatments for rectal cancer[18], and treatment planning for various palliative cases (vertebral bodies, hips, and ribs)[19], as well as lung and bladder cancers. Currently, more advanced treatments, specifically volume-modulated

arc therapy (VMAT), require a two-step process in which automatically generated contours are edited prior to treatment planning[13,20]. However, the quality of deep learning-based autocontouring is such that we expect to change these planning approaches to a one-step process in the future. This protocol focuses on one-step planning.

Figure 1 shows the overall workflow for creating a radiotherapy treatment plan using the RPA, with more details on the different tasks shown in **Table 1**. In summary, the RPA requires a completed Service Request (which includes information such as the dose prescription and treatment approach) and a patient's individual CT scan. The Service Request must be accepted by a radiation oncologist. The CT scan must be accepted by a Clinical User to ensure that the RPA calculations are performed on the correct CT scan. Once the RPA has generated a plan, it should be downloaded

from the RPA website and imported into the user's treatment planning system, where the dose should be recalculated. This is necessary because the RPA calculates plans on standard beams (available for several linac models), which may not exactly match the beam characteristics of the local linac. This approach was taken to reduce cost, although customization may be needed if the local beams are significantly different from our standard beams. The users (treatment planner and radiation oncologist) may make edits to the plan. The plan then enters the user's typical clinical workflow, including local quality assurance checks. Finally, the user should upload their final (recalculated and edited) plan to the RPA website, where an automated comparison between the Final Plan and the RPA Plan is performed. This is a useful check of data integrity in the overall workflow.
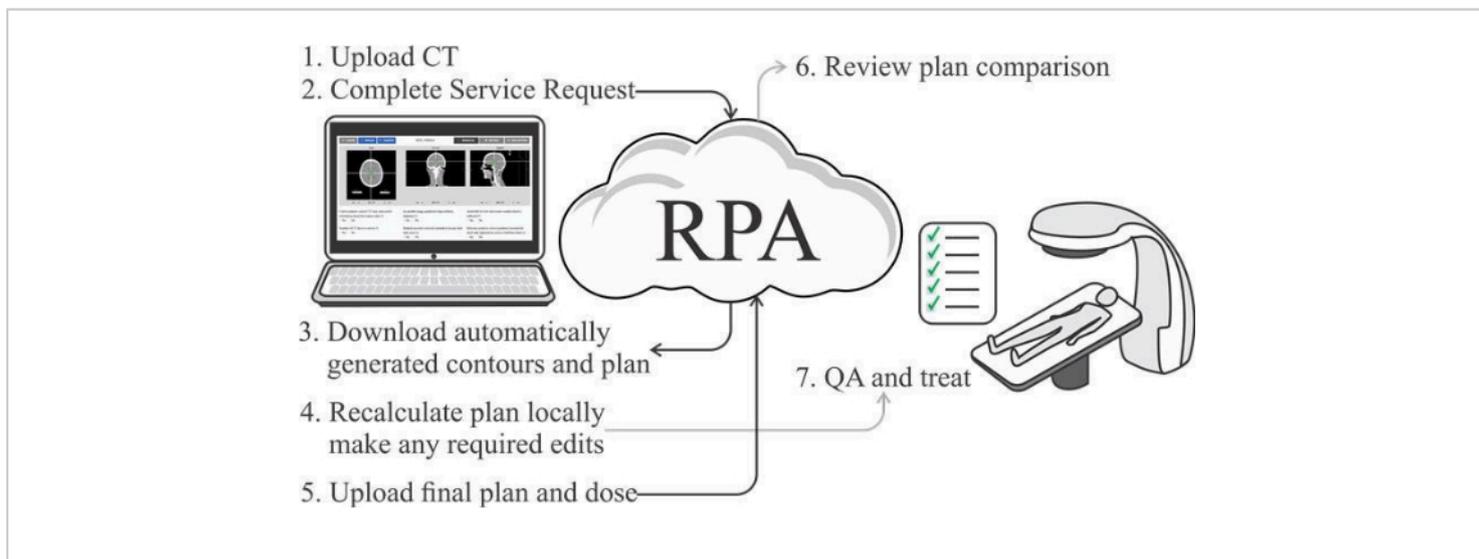

Figure 1: Workflow of the automated treatment planning process. Please click here to view a larger version of this figure.

Task # in Figure 1	Task description	Location
	Review the status of any past patients	Main dashboard
1	Complete a Service Request on the RPA website	Service Request dashboard
2	Upload a CT scan to the RPA website	CT scan dashboard
3	Check on the status of the patient	Main dashboard
	Review and download the RPA Plan	Main dashboard
4	Import the plan into the user's TPS, recalculate the dose, and make edits as necessary	Local TPS
5, 6	Upload the Final Plan to the RPA website	Plan comparison dashboard
	Review the automatic comparison of the Final Plan and the RPA Plan	Plan comparison dashboard
-	The plan enters the user's routine clinical workflow, including regular quality assurance	User's own software

Table 1: Overview of the tasks involved in creating an RPA Plan using the 1-step workflow. Local TPS: User's Treatment Planning System.

This manuscript describes this one-step workflow for the RPA and presents some example results of the treatment planning process output. Currently, the following planning approaches use this one-step workflow: i) Four-field box treatment plans for cervical cancer patients (bony landmark-based apertures); ii) four-field box treatment plans for cervical cancer patients (soft tissue-based field apertures); iii) tangential and supraclavicular treatment plans for chest wall patients; iv) whole-brain treatment plans.

Protocol

All patient data used for evaluating the RPA were used retrospectively, with approval from The University of Texas MD Anderson Institutional Review Board. The RPA comprises a series of dashboards located to the left of the main menu of the RPA webpage (**Figure 2**). **Figure 2** shows the **main dashboard**. All dashboards have a similar look but focus on different tasks and personnel. The following protocol describes the key processes for the automatic creation of a treatment plan.
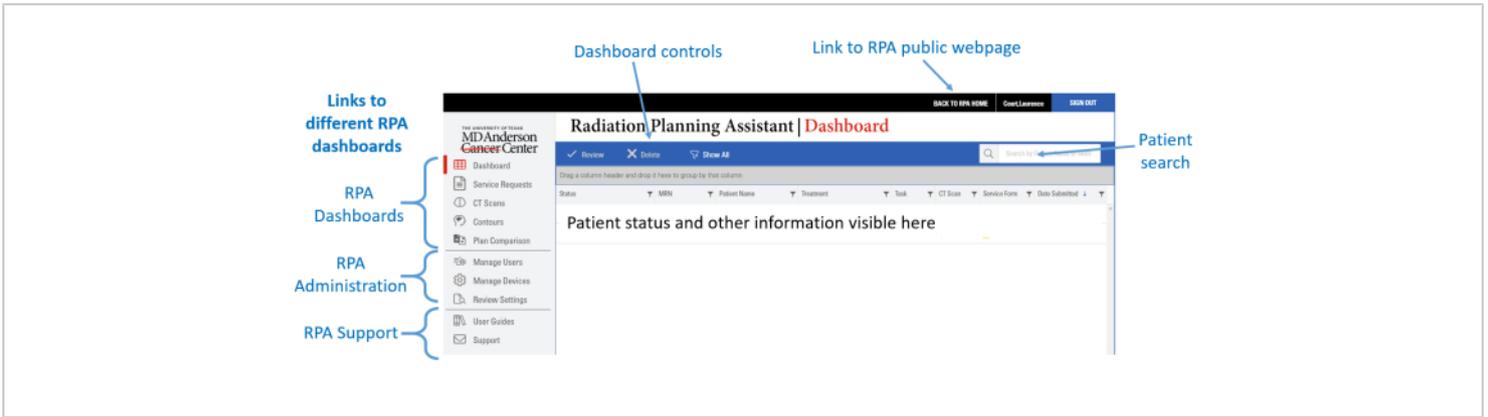
Figure 2: Screenshot of the RPA main dashboard. Please click here to view a larger version of this figure.

1. Complete Service Request

1. To create and accept a new Service Request for automatic planning:

   1. Go to the **Service Request** dashboard by clicking on the **Service Request channel**.

   2. Click on **New Form** to generate a new Service Request form.

   3. In Section 1: **Demographics**, complete the questions. Select the **treatment technique** from the **Treatment** pulldown. Click on the individual ⓘ in the **treatment technique** pulldown to access further details of the treatment technique.

   4. In Section 2: **Treatment-General Questions**, complete the questions. These questions are the same for all patients; their purpose is to actively engage the user in determining whether the RPA Plan is appropriate for the current patient.

   5. Section 3: **Treatment-Specific Questions**, complete the questions for the selected treatment approach, including details of the treatment targets and prescription.

   6. Click on **submit**. Once the Service Request PDF has been automatically generated, select the patient in the **patient** list (on the **Service Request dashboard**). Review the Service Request PDF (**Figure 3**), scrolling if necessary, and click on **Accept** to approve the Service Request.

   NOTE: This PDF must be accepted by a radiation oncologist before the RPA will initiate automated contouring and planning. The status of the RPA Plan can be determined on the Service Request page, as shown in **Table 2**. An example Service Request that was created for a soft tissue-based 4-field plan for cervical cancer is shown in **Figure 3**.

Status	Summary
Pending Review	The Service Request for this patient has already been created and is waiting for the radiation oncologist to Accept it.
Accepted	The Service Request for this patient has been Accepted. The status of this patient in the Service Request dashboard will not change until a CT scan for this patient is Accepted.
Rejected by User	The User rejected the Service Request.
Submitted	This case has been submitted to the RPA–more details on this patient's status can be found on the main dashboard.
RPA System Error	Processing by the RPA was initiated, but the RPA encountered an error and was unable to complete its task.

Table 2: Patient status categories for the Service Request Dashboard.

Figure 3: An example Service Request created for a soft tissue-based 4-field plan for cervical cancer. Please click here to view a larger version of this figure.

2. Upload CT scan and accept for automated planning

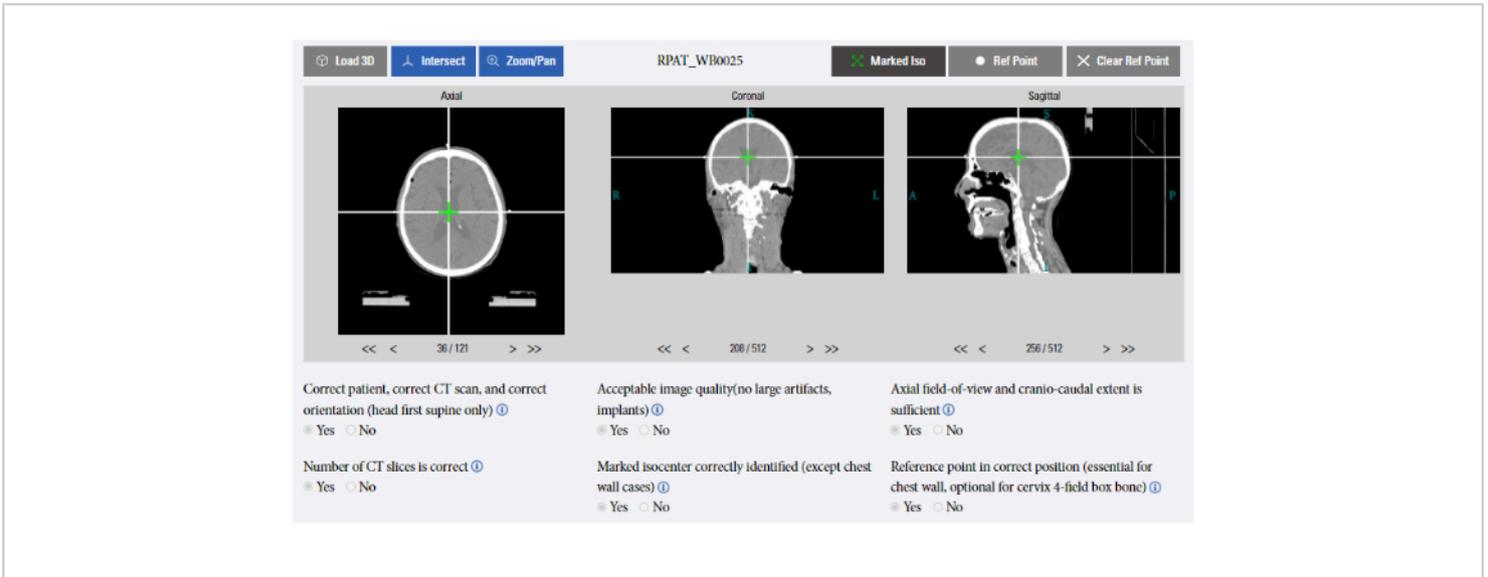**Figure 4** shows a screenshot of the CT review workspace. To upload and review a CT scan:

Figure 4: A screenshot of the CT review workspace. Please click here to view a larger version of this figure.

1. Go to the **CT Scans dashboard** by clicking on the **CT Scans channel**.

2. Click the **Upload CT** button. Select the folder where the CT scan (DICOM format) is stored using the folder explorer that automatically opens. Follow the prompts to confirm the selection.

3. Review the uploaded CT scan by selecting the patient in the patient list to open the CT viewer for this patient (**Figure 4**), and then use the following controls:

   1. Load the entire 3D CT image set by clicking on **Load CT**.
      NOTE: Other navigation tools are not active until this is complete.

   2. Scroll between slices in all views, and use any of the following tools:

      1. Click on **<, >** buttons below each CT view to move to the next slice.

   2. Click on **<<, >>** buttons below each CT view to move five slices in the selected direction.

   3. Mouse scroll wheel: Move the cursor over any CT view and then use the mouse scroll wheel to scroll between slices.

   4. Click the **Intersect** button to overlay a crosshair on each CT view (axial, coronal, and sagittal). Click on any of the three views to move the crosshair to this point-the other views will follow accordingly. Click the **Intersect** button to turn this tool on/off.

   5. Click the **Zoom/Pan** button. Further review the image using the mouse wheel to zoom the view where the cursor is positioned or right-click and hold down on a CT view and then move the mouse to pan.

6. Click on **Marked Iso** to move the CT views to the marked isocenter (based on automated detection of three radiopaque markers).

   NOTE: This button is inactive if the 3D CT image set has not been loaded (click Load 3D to resolve this) or if the RPA was unable to detect a marked isocenter (as identified with a three-point setup).

4. Click on the **Ref Point** button to add a reference point.

   1. Move the three views to the desired Reference Point location using the **intersect** tool.

   2. Click on the **Ref Point** button to add a Reference Point.

   3. If a Reference Point has already been selected, clicking on **Ref Point** will move the three views to this point.

      NOTE: This button adds a Reference Point to an image if a Reference Point does not exist. It can also move the CT image views to the Reference Point if one already exists. A new Reference Point can only be selected for CT scans that have not been accepted. Below are the steps to add a Reference Point:

   4. To select a new Reference Point, first clear the current Reference Point by clicking on **Clear Ref Point** and then add a new one. The RPA only Accepts one Reference Point.

5. Accept the CT scan. After reviewing the patient's CT scan as already described above, perform the following steps:

   1. Answer the questions below the CT images to minimize risk and reduce the occurrence of errors in the subsequent RPA calculations.

   2. Select **Accept** and follow the prompts.

      NOTE: This task can be performed by anybody identified as a Clinical User of the RPA. The status categories of current patients can be viewed on the CT Scans dashboard and are shown in **Table 3**.

Status	Summary
Pending Review	The CT scan has undergone initial processing and is waiting for the user to review and Accept the scan.
Accepted	The CT scan for this patient has been Accepted. Please note that the status of this patient in the **CT Scan dashboard** will not change until a Service Request is Accepted.
Rejected by User	The CT scan was rejected by the user.
Submitted	This case has been submitted to the RPA–more details on this patient's status can be found on the **main dashboard**.
RPA System Error	Processing by the RPA was initiated, but the RPA encountered an error and was unable to complete its tasks.

Table 3: Patient status categories for the CT Scans dashboard.

3. Monitor planning progress

The status categories of current patients can be viewed on the

main dashboard (Table 4). To perform a preliminary review of

any completed RPA plan and download it for use:

Status	Summary
No Accepted CT Scan	This patient has no Accepted CT scan (but an Accepted Service Request is available).
No Accepted Service Request	This patient has no Accepted Service Request (but an Accepted CT scan is available).
Queued	The data for this patient have been sent to the RPA system and are queued for processing.
Processing	Initial processing of this patient's data is underway.
Processing–contouring	The RPA Contours are being generated.
Processing–contouring report	The RPA Contours Report is being generated.
Complete–RPA contours	Contours generated by the RPA are complete and ready for the user to download and edit (2-step workflows only).
Pending contour review	Planning contours (i.e. contours after the user has made edits/additions) have been uploaded back to the RPA and the Plan Contours Report has been generated. The user needs to Accept this report (from the **contours dashboard**).
Queued–plan contours	The planning contours (i.e. contours after the user has made edits/additions) are queued for processing prior to the RPA Planning process.
Queued–preplan	This patient's plan is queued for the planning process.
Processing–preplan	Preplanning processing is underway.
Queued–optimization	This patient's plan is queued for the plan optimization process.
Processing–optimization	Plan optimization is underway.
Queued–QA	This patient's plan is queued for the automated quality assurance (QA) process.
Processing–QA	The plan QA is underway.

Processing–plan report	The Final Plan report is being processed.
Complete–RPA Plan	The RPA Plan is complete and ready for download.
Fail–RPA fail	An RPA process has failed.

Table 4: Patient status categories for the main dashboard.

1. Review a completed RPA plan by selecting the patient and then selecting **Review** at the top of the **main dashboard**. Review the RPA Plan Report (PDF) for that patient that automatically opens in a new tab.
   NOTE: The RPA Plan Report PDF can also be accessed from the download window.

2. Download a completed RPA Plan by clicking on the **download icon**. Wait for a window to open and the DICOM files, along with the RPA Plan Report (PDF), will be downloaded for import into the treatment planning system.

4. Importing the RPA Plan into the User's treatment planning system and reviewing for clinical use

NOTE: Once the RPA plan is downloaded (DICOM files), the following steps should be completed in the user's treatment planning system:

1. Import the patient's CT scan into the local TPS. This is the original scan that was uploaded to the RPA.

2. Import the RPA Plan and RPA contours into the local TPS.

3. Recalculate the dose using the local commissioned dose calculation algorithm and the **used fixed MU** option.

4. Compare the imported contours and calculated dose with those in the RPA Report (to check for correct import).

5. Review the plan for appropriateness and edit as necessary.
   NOTE: This step may include editing field shapes and renormalizing the fields. It is very important that the clinical team review the final plan in their treatment planning system and make any edits before clinical use.

5. Uploading the Final Plan to the RPA website and reviewing the automatic comparison of the Final Plan and the RPA Plan

Patients for whom an RPA Plan has been generated will appear in the **plan comparison dashboard**. The **plan comparison dashboard** provides the status categories shown in **Table 5** for current patients. To upload the final User Plan and review an automatic comparison of the User Plan and the RPA Plan:

Status	Summary
Pending Plan Upload	This status displays when a case has been generated.
Processing	The plan comparison is processing.
Pending Plan Upload–RETRY	Plan comparison is not possible. The user should review the uploaded files and retry. Possible reasons for this status include uploading the incorrect files.
Comparison Ready–Pass	The Plan Comparison Report is ready for review. All plan comparisons passed the criteria. Some comparisons may be flagged–the user should review the report.
Comparison Ready–Fail	The Plan Comparison Report is ready for review. Some comparisons failed the set criteria–the user should carefully review the report and determine the cause.

Table 5: Patient status categories for the plan comparison dashboard.

1. Select the patient and then click on **Upload Plan**.

2. Select the DICOM structure file, plan, and dose files for upload.

3. Review the Plan Comparison Report by first selecting the patient. Then, review the Plan Comparison report (**Figure 5**) which opens at the bottom of the screen, (an example is shown in **Figure 5**).

Figure 5: An example of the automatic plan comparison report. Please click here to view a larger version of this figure.

Representative Results

The purpose of the **main dashboard** (**Figure 1**) is to provide a quick overview of the status of current patients in the RPA, allow a quick review of completed plans, download completed plans for review and editing in the user's treatment planning system, and provide advanced patient navigation and sorting tools. For patients to appear here, they must have at least one of the following: (1) An Accepted CT scan or (2) an Accepted Service Form. The status categories of current patients can be viewed on the **main dashboard** (**Table 4**).

An example lateral field from a whole-brain radiotherapy plan is shown in **Figure 6**. An example lateral field from a bony landmark-based 4-field box plan for cervical cancer is shown in **Figure 7**. In both cases, the final plan must be downloaded and then imported into the user's treatment planning system where the results must be reviewed, edited, and recalculated. The RPA also creates a final Plan Report (PDF) that includes the Service Request (see the example in **Figure 3**), CT approval report, and other details of the treatment plan.

The purpose of the **Service Request dashboard** (**Table 2**) is to provide a quick status overview of the Service Request for current patients in the RPA, create a new Service Request, accept a completed Service Request, and edit a Service Request. Patients who have a submitted or Accepted Service Request are displayed on this dashboard, which is accessible to all users of the RPA. However, only users registered in the RPA system as radiation oncologists can Accept a Service Request.

The purpose of the **CT dashboard** (**Table 3**) is to provide a quick status overview of CT scans for current patients in the RPA, upload new CT scans, review and Accept CT scans, and add Reference Points to CT scans. Reference points are added to guide the RPA in some specific situations, such as when the user wants to use a non-standard superior border for simple 4-field box plans for cervical cancer. Patients for whom a CT scan has been uploaded are shown here. Any user can view the **CT dashboard**, but only users registered as Clinical Users can Accept the CT scans.

Once the user has confirmed their final plan, they can export it from their TPS and upload it to the RPA. The purpose of this process is to provide a way to check that the data were properly communicated between different devices.

Patients for whom an RPA Plan has been generated will appear in the **plan comparison dashboard**. The **plan comparison dashboard** provides the status categories shown in **Table 5** for current patients.
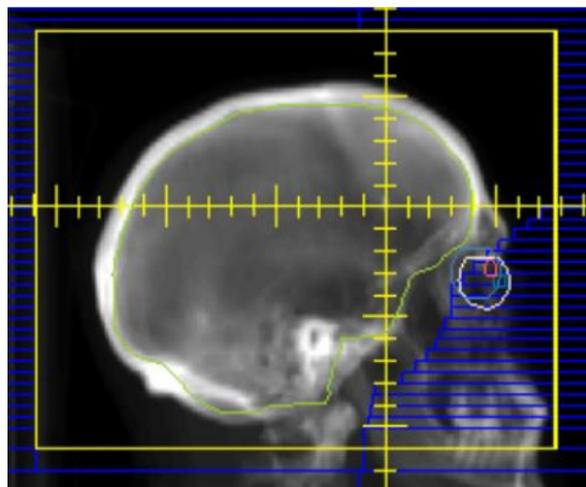
Figure 6: Typical lateral field for whole-brain radiotherapy. This view shows the projections of the structure contours as well as the positions of the main collimators (yellow) and the multi-leaf collimators (blue). Please click here to view a larger version of this figure.
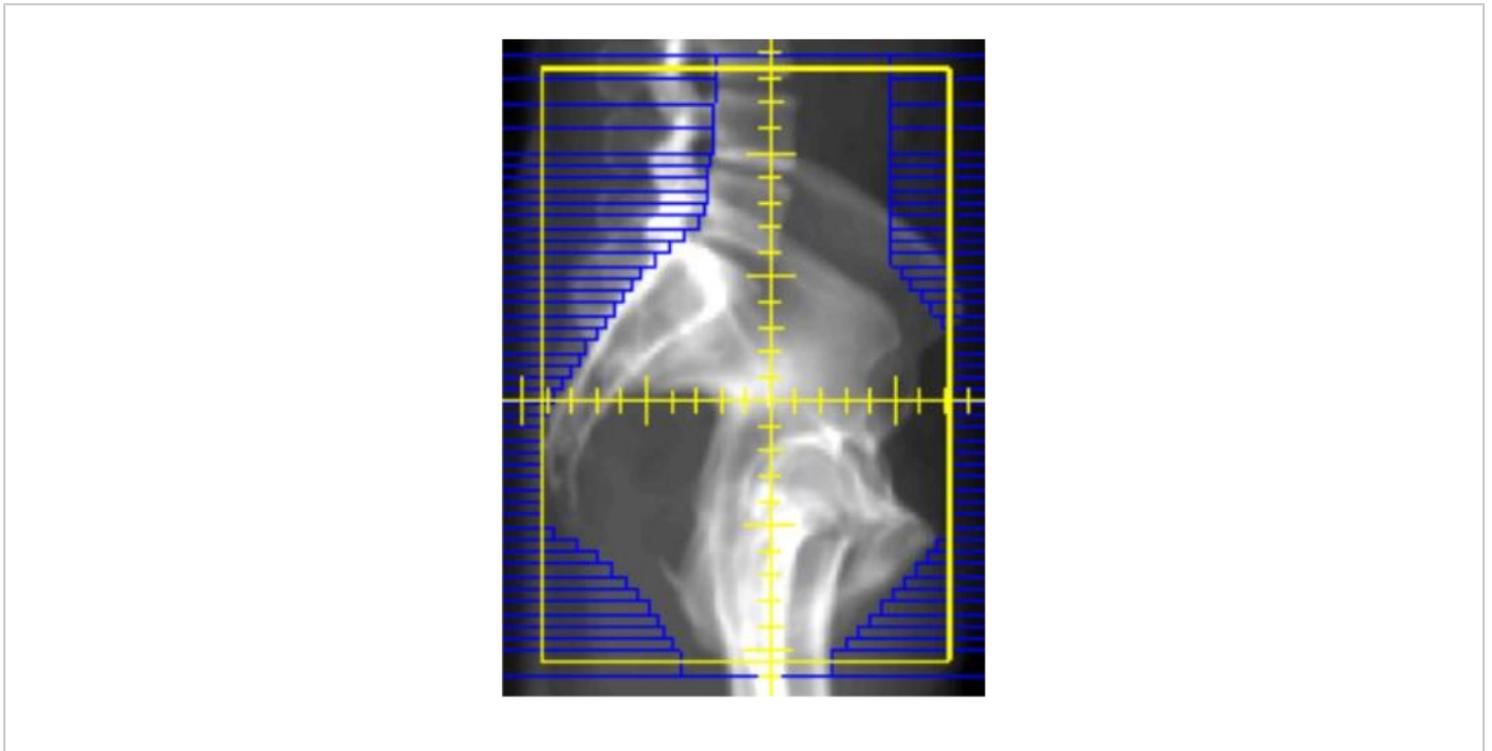
Figure 7: An example lateral field from a bony landmark-based 4-field box plan for cervical cancer. This view shows the positions of the main collimators (yellow) and the multi-leaf collimators(blue). Please click here to view a larger version of this figure.

Discussion

This protocol outlines the steps in creating automated treatment plans using the RPA. The key steps are (1) CT upload and approval, (2) Service Request completion and approval, (3) plan download and importation into the user's TPS and recalculation of the dose and plan editing, and (4) upload of the final edited plan for comparison with the RPA Plan. The order of the CT approval and Service Request approval are interchangeable. Some plans, specifically volume-modulated arc therapy plans for head and neck and cervical cancer, are created in a two-step process in which additional user interactions and the contours and plans are generated separately. Overall, however, the processes are similar, and we expect that these advanced treatment

planning approaches can be changed to a one-step process in the future. The overall clinical acceptability that can be expected from these tools, and from tools that are under development for future versions can be found in our published work[10,12,14,15,16,17,18,19,20,21,22].

These tools have several limitations, as described in our earlier work, which investigated risk when deploying the Radiation Planning Assistant in radiotherapy clinics[9,23]. Although the user interface has been designed to minimize the risk of inappropriate data entry, such as CT images that do not have sufficient field-of-view or errors in manual data entry, there is still potential for error. Specifically, human error, automation bias (over-reliance on the results), and software error are of concern[9]. Careful review and, if necessary,

editing of the automatically generated contours and plans, is essential for the safe use of the Radiation Planning Assistant. In general, these reviews should follow the same process as is followed for the review of clinical plans by physicists and radiation oncologists, although this may be supported by the use of checklists developed specifically to supplement manual review of automatically created treatment plans[24].

There are situations where the RPA will not be able to generate a plan and will report an error to the user. In almost all cases, this will be caused by the RPA encountering unexpected data that it cannot interpret, such as insufficient field-of-view or patient positioning (e.g., if a CT image was taken using a supine protocol, but with the patient in a prone position). The user may be able to identify the problem based on where the error is reported. In most cases, these situations can only be remedied by manual contouring or planning. The RPA Team may also be able to review log files to identify the problem.

The RPA has been designed and developed specifically to bring high-quality autocontouring and autoplanning tools to clinics with limited resources, especially those in low- and middle-income countries. We are currently working through the regulatory, legal, and administrative processes that will lead to the RPA being used clinically. Once that happens, we expect to carefully monitor the use and make changes to the workflow or user interfaces in response to any unanticipated risks or other user feedback. The goal is to provide tools that support radiotherapy services, such that local clinical teams can scale their efforts, improving access to high-quality, consistent radiotherapy plans. We hope that this will lead to improved patient outcomes, as well as reduced wait times. Although the current portfolio is limited to cancers of the head and neck, breast, and cervix, as well as whole brain irradiation for brain metastases, we are working on additional treatments that will be incorporated in future versions[17,18,19].

Disclosures

Acknowledgments

References

1. Ferlay, J. et al. Cancer incidence and mortality worldwide: Sources, methods and major patterns in GLOBOCAN 2012. *International Journal of Cancer.* **136** (5), E359-E386 (2015).

2. Elmore, S. N. C. et al. Global palliative radiotherapy: a framework to improve access in resource-constrained settings. *Annals of Palliative Medicine.* **8** (3), 274-284 (2019).

3. Atun, R. et al. Expanding global access to radiotherapy. *The Lancet. Oncology.* **16** (10), 1153-1186 (2015).

4. Yap, M. L., Zubizarreta, E., Bray, F., Ferlay, J., Barton, M. Global access to radiotherapy services: have we made progress during the past decade? *Journal of Global Oncology.* **2** (4), 207-215 (2016).

5. Elmore, S. N. C. et al. Radiotherapy resources in Africa: an International Atomic Energy Agency update and analysis of projected needs. *The Lancet. Oncology.* **22** (9), e391-e399 (2021).

6. Datta, N. R., Samiei, M., Bodis, S. Radiation therapy infrastructure and human resources in low- and middle-income countries: present status and projections for 2020. *International Journal of Radiation Oncology, Biology, Physics.* **89** (3), 448-457 (2014).

7. Ward, Z. J., Scott, A. M., Hricak, H., Atun, R. Global costs, health benefits, and economic benefits of scaling up treatment and imaging modalities for survival of 11 cancers: a simulation-based analysis. *The Lancet. Oncology.* **22** (3), 341-350 (2021).

8. Court, L. E. et al. Radiation Planning Assistant - a streamlined, fully automated radiotherapy treatment planning system. *Journal of Visualized Experiments.* (134), 57411 (2018).

9. Nealon, K. A. et al. Using failure mode and effects analysis to evaluate risk in the clinical adoption of automated contouring and treatment planning tools. *Practical Radiation Oncology.* **12** (4), e344-e353 (2022).

10. Kisling, K. et al. Automated treatment planning of postmastectomy radiotherapy. *Medical Physics.* **46** (9), 3767-3775 (2019).

11. Xiao, Y. et al. Customizable landmark-based field aperture design for automated whole-brain radiotherapy treatment planning. *Journal of Applied Clinical Medical Physics.* **24** (3), e13839 (2022).

12. Kisling, K. et al. Fully automatic treatment planning for external-beam radiation therapy of locally advanced cervical cancer: a tool for low-resource clinics. *Journal of Global Oncology.* **5** 1-9 (2019).

13. Rhee, D. J. et al. Clinical acceptability of fully automated external beam radiotherapy for cervical cancer with three different beam delivery techniques. *Medical Physics.* **49** (9), 5742-5751 (2022).

14. Rhee, D. J. et al. Automated radiation treatment planning for cervical cancer. *Seminars in Radiation Oncology.* **30** (4), 340-347 (2020).

15. Rhee, D. J. et al. Automatic contouring system for cervical cancer using convolutional neural networks. *Medical Physics.* **47** (11), 5648-5658 (2020).

16. Xiao, Y. et al. Automated WBRT treatment planning via deep learning auto-contouring and customizable landmark-based field aperture design. *arXiv.* 2205.12189 [eess.IV] (2022).

17. Hernandez, S. et al. Automating the treatment planning process for 3D-conformal pediatric craniospinal irradiation therapy. *Pediatric Blood & Cancer.* **70** (3), e30164 (2023).

18. Huang, K. et al. Automation of radiation treatment planning for rectal cancer. *Journal of Applied Clinical Medical Physics.* **23** (9), e13712 (2022).

19. Netherton, T. J. et al. An automated treatment planning framework for spinal radiation therapy and vertebral-level second check. *International Journal of Radiation Oncology, Biology, Physics.* **114** (3), 516-528 (2022).

20. Olanrewaju, A. et al. Clinical acceptability of automated radiation treatment planning for head and neck cancer using the Radiation Planning Assistant. *Practical Radiation Oncology.* **11** (3), 177-184 (2021).

21. Rhee, D. J. et al. Automatic contouring QA method using a deep learning-based autocontouring system. *Journal of Applied Clinical Medical Physics.* **23** (8), e13647 (2022).

22. Rhee, D. J. et al. Automatic detection of contouring errors using convolutional neural networks. *Medical Physics.* **46** (11), 5086-5097 (2019).

23. Kisling, K. et al. A risk assessment of automated treatment planning and recommendations for clinical deployment. *Medical Physics.* **46** (6), 2567-2574 (2019).

24. Nealon, K. A., Court, L. E., Douglas, R. J., Zhang, L., Han, E. Y. Development and validation of a checklist for use with automatically generated radiotherapy plans. *Journal of Applied Clinical Medical Physics.* **23** (9), e13694 (2022).