**ORIGINAL RESEARCH**

# The Educational Impact of Web-based Platforms for Therapeutic Radiology in Sub-Saharan Africa

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## Abstract

**Purpose:** This study explores the effectiveness of remote contouring training for therapeutic radiology in three Sub-Saharan African countries (Nigeria, Tanzania, Cameroon) using a web-based platform (ProKnow).

**Methods and Materials:** A 2-hour real-time video didactic lecture and demonstration of the left parotid tumor contouring on axial CT images was delivered using the ProKnow system and a video conferencing software. Participants were granted week-long access to practice contouring of the left parotid volume after the session. Effectiveness of the remote training was evaluated with a self-assessment questionnaire administered before and after the training. Areas of competence assessed included: (i) ability to identify anatomic structure on axial CT; (ii) ability to contour a parotid volume; (iii) ability to delineate tissues; (iv) dose-volume histogram evaluation (DVH); (v) plan evaluation; (vi) port film evaluation; (vii) cone-beam CT evaluation (CBCT). A comparative statistical analysis was undertaken to evaluate for significant changes in the average self-competence score for the various competency areas before and after intervention. The post-class survey also contained questions to determine the acceptability of the ProKnow system for training and image-guided radiotherapy planning among the participants and their access to the necessary internet services.

**Results:** There was statistically significant improvement in all skill parameters needed to contour parotid volumes on axial CT scan. Percent improvement in average self-competency scores ranged from +14.3% for DVH evaluation to +32.8% for treatment plan evaluation. Although in varying degree, 95% of participants indicated the remote training session was relevant to their clinical practice and training. Also, in varying degrees, all indicated that the web-based tool will be helpful to their professional development; that the web-based platform (ProKnow) was easy to navigate and use; and that they would recommend the resource. Most respondents (84%) had access to strong or moderate internet connectivity to integrate the web-based tools into their clinical practice and training.

**Conclusion:** Web-based interactive contouring atlases have utility in global health, as they can serve as self-directed and remote training tools for oncology and radiology staff, which could improve the accuracy of their treatment planning and ultimately impact the quality of therapeutic radiology.

## Introduction

The use of ionizing radiation for cancer treatment has undergone extraordinary development in the past century propelled by advancements in medical imaging (1,2). An inherent goal of radiation therapy is to deliver a large enough dose to the tumor to eradicate all cancer cells or to palliate symptoms, while minimizing injury to normal tissue. Integration of imaging modalities such as computed tomography (CT), magnetic resonance (MR) imaging, and positron emission tomography (PET) into the radiation treatment planning process has set a high standard for more precise delineation of target and accurate radiation volumes (1,2). Thus, a radiation oncologist is expected to have a comprehensive understanding of radiologic anatomy, as well as a functioning knowledge to interpret a variety of imaging modalities to delineate and deliver high-quality radiation treatment. However, formal radiology and anatomic contouring training opportunities are lacking in many low and middle-income countries (LMICs), as there is a shortage of radiologists and radiation oncologists with the expertise (3).

In recent times, prospects of bridging the training gap through international collaborations with organizations, institutions, and experts in developed countries have sparked global health interest among radiology and radiation oncology residents (4–8). However, a common issue expressed at global health summits, seminars and symposia is that people want to participate in global health but do not know how. Often, specialist physicians eager to impart knowledge and skills are limited by the cost and time-space barrier (9). This points to the need for a platform for facilitating participation, converting this upsurge in interest into greater concerted action and impact (10).

One possible platform model discussed at the American Association of Physicists in Medicine conference is the successful collaboration-driven model of Harvard Catalyst, which fosters a culture of collaboration in 31 Harvard-affiliated institutions, hospitals, and community partners. A similar platform could integrate the above key elements with information and communication technology (ICT) in an optimal way to catalyze high-impact global health collaborations (10).

In 2016, we implemented the Global Health Catalyst (GHC) at Harvard Medical School, which would incorporate components covering activities in cancer care, research, and education, and involve institutions from both developed countries and LMICs. In 2018, Global Health Catalyst worked with several stakeholders to develop and assemble advanced information and communication tool (ICT) platforms that could supplement training and ease the clinical burden of health professionals in LMICs (11–13). So far, a constellation of web-links and software toolbox for global cancer care and training is available on a web-portal known as eCancer4all (14), designed to be a premier comprehensive cancer center on the cloud for global health.

An integral component of eCancer4all is cancer imaging and internet-based programs for both the training and practice of contouring and tumor delineation in radiation planning. Contouring is a process in radiotherapy simulation that entails defining the borders of normal organs with intent to produce a clinical target volume (CTV), an area corresponding to disease risk and organ exclusion. Tumor delineation entails the process of defining and outlining tumor boundaries by the physician, radiologist, or radiation oncologist for effective and targeted radiation therapy. Radiation therapy follows a step-by-step process. The first step is an initial consultation, where the radiation oncologist discusses treatment options with a referred patient and a treatment plan is adopted. The second step is the simulation, where the clinician outlines or maps the exact area to be treated through a contouring and tumor delineation exercise. A CT scan or other imaging technique, such as PET or MRI, is used to verify the anatomy and ensure the accuracy of the area of the body to be treated with radiation. If needed, immobilization devices such as a face mask or a leg mold will be made at this time. The third stage is treatment planning. At this time, the radiation oncologist works with dosimetrists and medical physicists to creates a unique plan of treatment considering the diagnosis, the type of radiation machine that will be used, the amount of radiation needed and the number of treatments to be given. The fourth stage is the radiation treatment process, which could take weeks. Finally, patients usually have follow-up appointments after the treatment.

The simulation process requires a mastery of the anatomy and imaging modality used. Web-based radiotherapy contouring platforms such as eContour (15), EduCase (16), Anatom-e (17), and ProKnow (18) presently function as supplemental resources for residents in training and all practitioners desiring continuous medical education on refresher cases for therapeutic radiology. Randomized trials in the United States, Europe, and Russia have shown these programs to be as effective as traditional didactic lectures aimed at teaching and testing radiation oncology contouring skills (19–22). However, the capacity for such platforms to address the need for contouring training and clinical practice of tumor delineation in low-resource regions is yet to be explored.

In this study, we conducted a collaborative e-contouring training initiative between radiation oncologists in the United States and Sub-Saharan Africa using the ProKnow system as a platform. We then evaluated the effectiveness of this program with pre- and post-intervention questionnaires that assessed changes in the participants' self-confidence in their skills to contour and analyze contours of a normal left parotid gland. Using the same questionnaire method, we further evaluated the prospects for implementing the e-platform for training residents in low-resource countries.

## Methods and materials

We conducted a 2-hour live video lecture and training on contouring the left parotid gland on axial CT images. The lecture was delivered remotely from Boston, Massachusetts

**Figure 1.** First time contour of the left parotid of a participating resident.
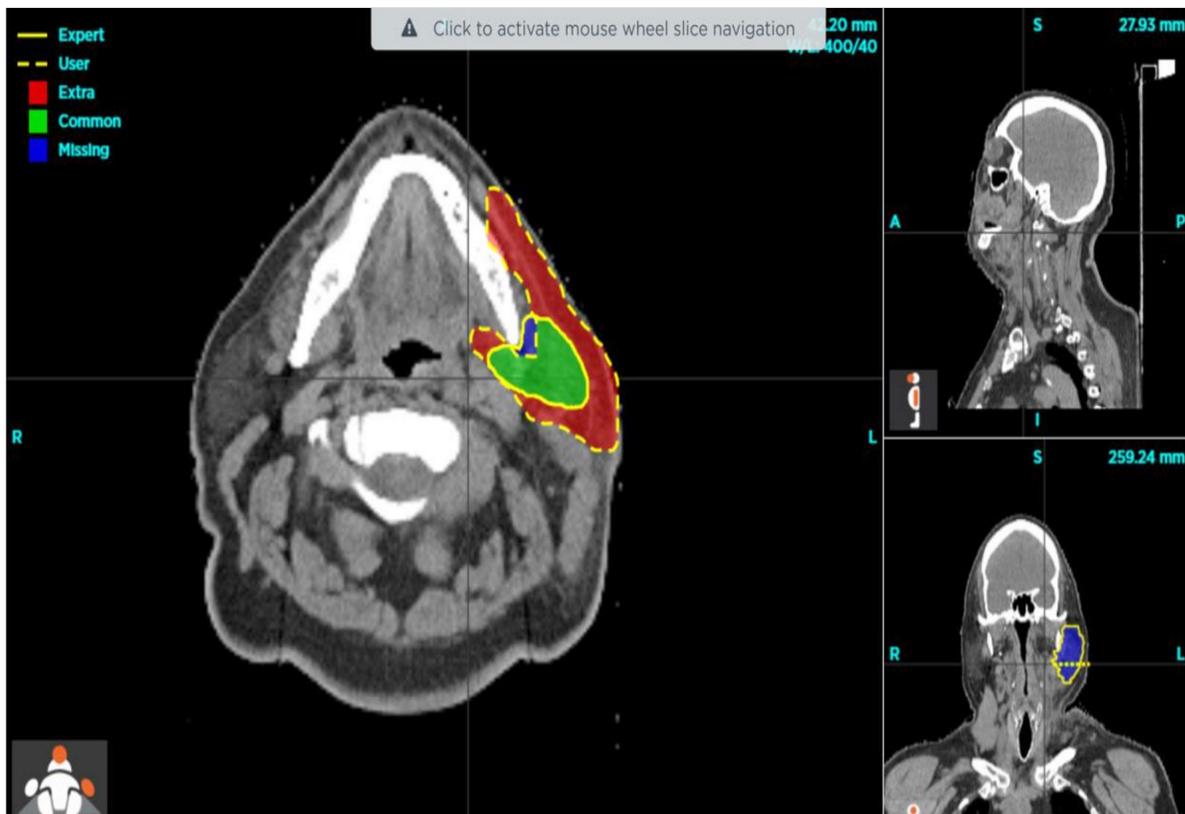


using PowerPoint slides, a live GoToMeeting video connection, with live contouring demonstrations using the ProKnow system. ProKnow™ (short for "profound knowledge") is a cloud-based system founded in 2016, specifically designed for quality anatomical contouring and data management. Its analytical modules ensure contouring accuracy, quantify and study plan quality metrics, identify best practices, and ultimately correlate tumor contouring methods and modalities with patient outcomes (18). GoToMeeting is an online desktop-sharing program for video conferencing. The amount of bandwidth that GoToMeeting uses depends on the features that are being used per session. Screen sharing and computer audio during a PowerPoint presentation with multiple slides typically require a bandwidth of 40Kbps (0.004Mbps), while webcam sharing requires an average of 700 Kbps (0.7 Mbps) (23). In general, a session requiring all three features will require at least 1 Mbps of bandwidth. Less bandwidth will still work, but the session performance may suffer because of it. More bandwidth provides a superior user experience (23).

Invitation requests were sent via a mass email to all radiation oncologists (RO), medical physicists (MP), and therapy radiographers (TR) in Nigeria, Tanzania and Cameroon using our database, developed with the support of various professional societies in each country. Participants who registered were granted access to attempt and practice parotid gland contouring using ProKnow software during and after the scheduled session. The scope of the lecture included: a review of the parotid gland, its anatomy and tissue types;

identification of the axial slice range (superior and inferior borders); a step-by-step contouring guide on the axial images; a review of special considerations for parotid radiation therapy, such as its sensitivity to radiation; and landmark studies that guide treatment dose. The didactic lecture was followed by a demonstration of tumor contouring with a left parotid case imported into the ProKnow system. Participants were granted week-long access to practice contouring of the left parotid volume after the session. Figure 1 is an example of parotid contouring by a Nigerian resident for the first time after the educational session. To evaluate the effectiveness of the training, a seven-question self-confidence assessment questionnaire was prepared and administered before and after the training. The questions assessed the participants' confidence in the necessary skills needed to contour a treatment plan. Areas of competence assessed included: (i) ability to identify anatomic structure on axial CT; (ii) ability to contour a parotid volume; (iii) ability to delineate tissues; (iv) dose-volume histogram evaluation (DVH); (v) plan evaluation; (vi) port film evaluation; (vii) cone-beam CT evaluation (CBCT). See Appendix 1 for pre- and post-training questionnaires. The post-class survey also contained questions to determine the acceptability of the ProKnow system for training and image-guided radiotherapy planning among the participants and their access to internet services.

Statistical Analysis

Self-competence before and after training were self-reported and converted to a scoring metric, and a general average score for each component was calculated as a summation

**Table 1.** Reported Radiotherapy Contouring Resources in Sub-Saharan Africaww

| Reported Resource | Number | Percent |
|---|---|---|
| Jane Dobbs and colleagues | 4 | 19.1% |
| RTOG contouring atlases | 2 | 9.5% |
| Ecotour | 2 | 9.5% |
| Riaz and Lu | 1 | 4.8% |
| ESTRO consensus guideline | 1 | 4.8% |
| Others (Unnamed) | 3 | 14.3% |
| None | 8 | 38.1% |

of scores divided by the total number of respondents. A score of 5 indicates that a respondent is strongly confident in his/her ability to perform each task relating to parotid treatment planning; 4 indicates confidence in ability; 3 is neutral; 2 indicates the respondent felt some inadequacies; and 1 is complete incompetence. Comparative statistical analysis was undertaken to evaluate whether a significant change in the average score occurred after the educational intervention. A two-tailed paired t-test was performed to evaluate any significant change in test value before and after the intervention. The $\alpha$ was set at 0.05. Only respondents who completed both pre-test and post-test surveys where analyzed. All statistical analyses were conducted using Microsoft Excel.

## Results

### Radiotherapy Contouring Resources in Sub-Saharan Africa

Twenty-one participants reported on the resources used to guide contouring and tumor delineation (see Table 1). The most commonly utilized resource was *Practical Radiotherapy Planning* (4th ed.) by Jane Dobbs and colleagues (24), utilized by four (19.1%) of the respondents. Next most popular were the RTOG contouring atlases (25) and eContour web platform (15), each used by two (9.5% each) respondents. A respondent reported using T*arget Volume Delineation for Conformal and Intensity-Modulated Radiation Therapy*, edited by Lee, Riaz and Lu (26), as a primary resource, while another reported using ESTRO consensus guideline (27). Three (14.3%) respondents reported using other atlases and consensus guidelines which were unnamed, while eight (38.1%) reported using none. None had used ProKnow at the time of intervention.

### The Effectiveness of Web-based Training

Nineteen participants completed both the pre- and post-training self-competence assessment. Twenty-two pretraining surveys were completed before the lecture and training session. Nineteen post-training surveys were completed within one week after the session. The 19 participants included 14 radiation oncologists (10 residents and 4 consultants/attendees), 4 medical physicists, and 1 therapeutic radiographer. Eleven of the trainees participated from Nigeria, two from Cameroon, three from Tanzania, one from Rwanda, and two LMIC physicians were in the United

States at the time of the training. Figure 1 is the first-time left parotid contour of a Nigerian resident. The average self-competence score at pre-training was 3.5 for anatomic structure identification, 3.4 for contouring ability, 3.7 for DVH evaluation, 3.4 for treatment plan evaluation, 3.6 for tissue delineation, 3.0 for port-film evaluation, and 2.8 for CBCT evaluation. The average self-competence scores after training were 4.4, 4.3, 4.2, 4.5, 4.2, 3.9 and 3.2, respectively. Thus, while only a few respondents felt confident or strongly confident in their ability prior to the training exercise, there was a marked improvement for each parameter post-class, ranging from +14.3% for DVH evaluation to +32.8% for treatment plan evaluation (see Table 2 and Figure 2).

### Acceptance of Web-based Training Resource by Participants

ProKnow's web-based technology was well received by respondents. 95% indicated the remote training session (Parotid volume) was relevant to their clinical practice and training; 100% indicated the web-based tool will be helpful to their professional development; 100% indicated that ProKnow was easy to navigate and use, and 100% indicated they would recommend the resource. Most respondents had access to strong or moderate internet connectivity to integrate the web-based tools in their clinical practice and training (see Figure 3). Only three respondents were neutral on internet connectivity, and this same number were neutral on affordability (see Figure 3). While the contouring resource for parotid tumor was relevant in the Sub-Saharan region, most respondents indicated contouring training for breast cancer, prostate cancer, and uteri-cervix were more pertinent to their clinical practice.

## Discussion

Challenges to the delivery of radiotherapy services in developing countries are manifold. In a 2017 needs assessment using the Directory of Radiotherapy Centers (DIRAC) database maintained by the International Atomic Energy Agency, only 23 of 52 African countries have a radiotherapy unit, which provides coverage for only 36% of the patients in need of radiotherapy within the continent (28,29). Radiotherapy access is generally low in all LMICs, ranging from 2.3% to 98.8% (median 36.7) (29). In stark contrast, radiotherapy access is 92% and 195% in Europe and North America, respectively (28). The quality of care is also affected by the unavailability

**Table 2.** Pre-and-post-evaluation scores and analysis.

| Competences Area | Strongly Agree | | Agree | | Neutral | | Disagree | | Strongly Disagree | | Percent (%) Improvement in Average SelfCompetence score | t-test (α =0.05) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre | Post | Pre | Post | Pre | Post | Pre | Post | Pre | Post | | |
| **Anatomic Structural Identification** | 1 | 8 | 10 | 10 | 7 | 1 | 0 | 0 | 1 | 0 | +23.9% | 0.0000004 |
| **Contouring Ability** | 3 | 8 | 4 | 9 | 10 | 2 | 1 | 0 | 1 | 0 | +28.1% | 0.0000002 |
| **DVH Evaluation** | 3 | 9 | 9 | 6 | 6 | 3 | 0 | 1 | 1 | 0 | +14.3% | 0.00012 |
| **Plan Evaluation** | 1 | 9 | 11 | 10 | 4 | 0 | 0 | 0 | 3 | 0 | +32.8% | 0.000034 |
| **Tissue Delineation** | 3 | 9 | 6 | 7 | 7 | 2 | 1 | 1 | 2 | 0 | +25% | 0.0000004 |
| **Port Film Evaluation** | 1 | 5 | 5 | 8 | 8 | 5 | 3 | 1 | 2 | 0 | +29.8% | 0.00000005 |
| **CBCT Evaluation** | 1 | 4 | 3 | 3 | 6 | 7 | 9 | 5 | 0 | 0 | +18.9% | 0.00015 |

**Figure 2.** Differences in self-assessment score before and after training session
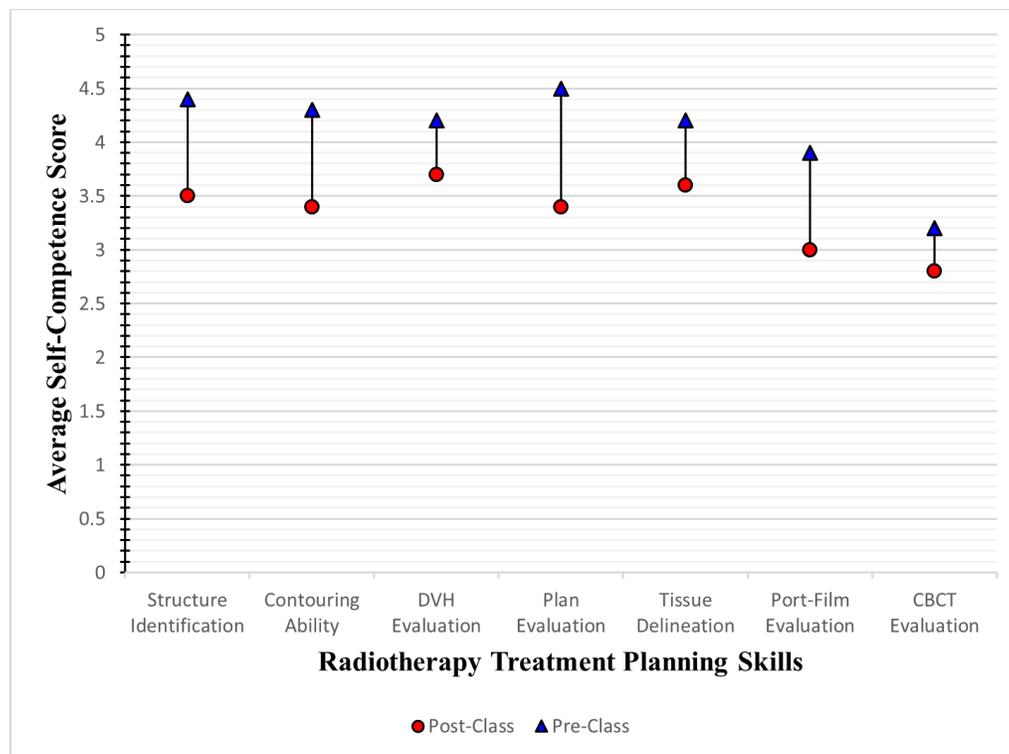


of skilled staff and inadequate imaging services. For example, in the absence of CTs, many radiation oncologists in LMICs are often forced to treat cancer patients using anatomic landmarks (21). This method is prone to a higher chance of an inaccurate target delineation, higher rates of recurrence, suboptimal care, and possible adverse events secondary to radiation toxicities (21). On the other hand, many LMIC cancer centers with facilities for imaging lack the expertise for tumor delineation in radiotherapy delivery.

Moreover, the growing transitioning of radiotherapy-based planning and care from 2-D to 3-D imaging in some LMIC centers makes the need for radiation oncology health professionals skilled in this area an imperative. However, global health collaboration to train oncology and radiology staff poses a challenge. These challenges mostly entail cost of travel, time, and distance. For example, the cost of training a team consisting of four radiation oncologists, three medical physicists, and seven radiation therapists is between €1,850,000 and €2,516,000 in Europe (30,31). Less attention has been paid to web-based remote training models due to

**Figure 3.** Acceptance of web-based contouring tool and availability of internet bandwidth for their utility in Sub-Saharan Africa.
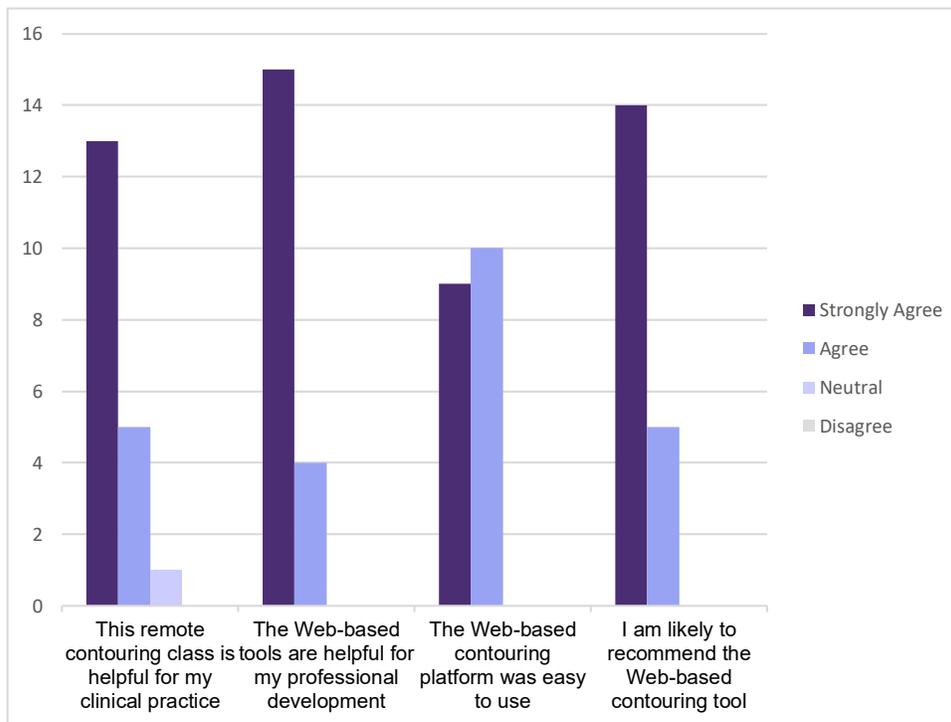


concerns over the availability and cost of bandwidth in most LMICs.

This study has demonstrated the availability and affordability of bandwidth that can enable the remote training of radiation oncologists and radiologists in Africa. Contrary to expectations, there is no indication that low access to internet bandwidth in Sub-Saharan Africa hampers the utilization of web-based tools for treatment planning and oncologic imaging. Most health professionals could afford bandwidth for real-time video-based synchronous learning, which involves intense interaction between trainees and trainers. The study shows an improved competence in tumor target delineation and contouring for LMIC staffs and trainees using web-based platforms to surmount the space-time or cost barriers to collaborative training. It also opens a door of opportunity for trainees and residents in the United States and Europe to participate in impactful peer-to-peer education and twinning programs with LMIC oncologists and radiologists.

Despite the small cohort of participants in this study, the potential impact of remote learning should not be underestimated. Our results are promising and should serve as a motivation to scale internet-based contouring resources for the global health terrain.

## Conclusion

The global spread of computer and internet networks coupled with the development of multimedia platforms able to integrate any radiological imaging technique can provide valuable support for training in radiology and radiation oncology. Web-based interactive contouring atlases enable

remote interactive learning on contouring activities. With adequate internet access, these tools are useful for training oncologists, radiologists, and other medical staff in developing countries. They can enable international collaboration, simulations, and self-directed learning.

## Conflict of interest

The authors report no conflict of interest.

## Acknowledgments

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**Appendix 1. ProKnow Survey Questions.**

<u>**INSTRUCTIONS**</u>
Questions in Section 1 and 2 are to be answered before the class, then Section 2 and 3 after the class.

<u>SECTION 1</u>
1.  What is your profession?
        A.        Medical Doctor
        B.        Medical Physicists
        C.        Therapy Radiographer
        D.        Dosimetrist

2.  What is your current level of education?
        A.        Medical or Undergraduate Physics student
        B.        Resident Doctor or Post Graduate Trainee
        D.        Attending or Consultant
        E.        Others

3)  Mention the resource (text, or atlas) you use to contour cases: _____

4)  Who contours normal structures on most of your treatment plans?
        A.        Residents
        B.        Dosimetrist
        C.        Attendings
        D.        Auto-contoured
        E.        Other

<u>SECTION 2</u>

For the following statements, please put the level of agreement or disagreement.

1)  I am confident in my ability to list normal structures in an anatomic atlas for Parotid tumor site.
        A.        Strongly disagree
        B.        Disagree
        C.        Neither agree nor disagree
        D.        Agree
        E.        Strongly agree

2)  I am confident in my ability to list normal structures on a CT scan for Parotid tumor site.
        A.        Strongly disagree
        B.        Disagree
        C.        Neither agree nor disagree
        D.        Agree
        E.        Strongly agree

3)  I am confident in my ability to contour Parotid tumor site
        A.        Strongly disagree
        B.        Disagree
        C.        Neither agree nor disagree
        D.        Agree
        E.        Strongly agree

4) I am confident in my ability to evaluate a DVH for Parotid Tumor site
     A.       Strongly disagree
     B.       Disagree
     C.       Neither agree nor disagree
     D.       Agree
     E.       Strongly agree

7) I am confident in my ability to evaluate a treatment plan for Parotid cancer
     A.       Strongly disagree
     B.       Disagree
     C.       Neither agree nor disagree
     D.       Agree
     E.       Strongly agree

8) I am confident in my ability to evaluate PORT film for Parotid tumor
     A.       Strongly disagree
     B.       Disagree
     C.       Neither agree nor disagree
     D.       Agree
     E.       Strongly agree

9) I am confident in my ability to evaluate cone-beam CT (CBCT) for Parotid tumor
     A.       Strongly disagree
     B.       Disagree
     C.       Neither agree nor disagree
     D.       Agree
     E.       Strongly agree

SECTION 3

10) Please list any sites you would like more experience contouring.

| QUESTIONS | ANSWERS | | | | |
|---|---|---|---|---|---|
| Rate your internet connectivity while utilizing the ProKnow tool | Impossible | Severely Limited | Limited | OK | Great |
| How affordable was your internet connection? | Very Expensive | Expensive | Affordable | Cheap | Very Cheap |
| How will you rate the class overall? 5 is the highest and best rating | 1 | 2 | 3 | 4 | 5 |
| ProKnow is helpful for your professional learning | Strongly disagree | Disagree | Neither disagree or agree | Agree | Strongly agree |
| ProKnow is easy to use | Strongly disagree | Disagree | Neither disagree or agree | Agree | Strongly agree |
| I am likely to recommend ProKnow for learning in my institution of learning | Strongly disagree | Disagree | Neither disagree or agree | Agree | Strongly agree |