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Quality Assessment of Commercial Contouring Software based on Convolutional Neural Networks for Cervical Cancer: Implications for Clinical Practice

Avaliação da Qualidade de Software Comercial de Contorno Baseado em Redes Neurais Convolucionais para Câncer do Colo Uterino: Implicações para a Prática Clínica

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Abstract

The treatment planning for radiotherapy, particularly the delineation of pelvic structures, is a complex and time-consuming task, demanding considerable expertise from physicians. The development of automation tools for these procedures could potentially reduce the workload and improve treatment planning efficiency. The goal of this study is to evaluate the efficacy of the AutoContour software, a commercial auto-segmentation tool utilizing convolutional neural networks, in delineating organs at risk during cervical cancer radiotherapy. We evaluated the performance of the AutoContour software on fifteen pelvic CT scans from cervical cancer patients previously treated at our institution. This study compared the automatically generated structures with those manually delineated by two experienced radiation oncologists. The comparison employed the Dice Similarity Coefficient (DSC) to assess the quality of structures, and we also measured the time savings achieved by using the auto-segmentation tool. The study found that most of the structures delineated by the AutoContour software closely matched those contoured by the radiation oncologists, with DSC values greater than 0.80, indicating high similarity. However, the bowel bag showed lower similarity, which could be attributed to interobserver variability among the physicians themselves. The use of AutoContour resulted in a reduction of up to 25.86 minutes in the time required per patient for structure delineation, demonstrating substantial efficiency gains without compromising the quality of the contours. The AutoContour software streamlines the delineation process in cervical cancer radiotherapy planning, maintaining high-quality output with minimal need for adjustments. These results suggest that the integration of this auto-segmentation tool could considerably decrease the specialized workload, enhancing the overall efficiency of clinical workflows in radiation oncology departments. This automation not only saves time but also reduces the potential for human error, promising more consistent and reliable treatment planning.

Keywords: Convolutional Neural Networks, Automatic delineation, Treatment Planning, Radiation Therapy, Uterine Cervix Cancer.

Resumo

O planejamento radioterápico, particularmente o delineamento das estruturas pélvicas, é uma tarefa complexa e demorada, exigindo expertise dos radio-oncologistas. O desenvolvimento de ferramentas de automação para esses procedimentos pode potencialmente reduzir a carga de trabalho e melhorar a eficiência do planejamento de tratamento. O objetivo deste estudo foi avaliar a eficácia do software AutoContour, uma ferramenta comercial de auto-segmentação que utiliza redes neurais convolucionais, no delineamento de órgãos de risco em câncer do colo do útero. Avaliamos o desempenho do software AutoContour em quinze tomografias pélvicas de pacientes com câncer do colo do útero previamente tratados em nossa instituição. Este estudo comparou as estruturas geradas automaticamente com aquelas delineadas manualmente por dois radio-oncologistas experientes. A comparação utilizou o Coeficiente de Similaridade de Dice (DSC) para avaliar a qualidade das estruturas; também avaliamos a economia de tempo produzida pelo seu uso. O estudo constatou que a maioria das estruturas delineadas pelo software apresentou boa concordância com as estruturas contornadas pelos radio-oncologistas, com valores de DSC superiores a 0,80, indicando alta similaridade. No entanto, o saco intestinal apresentou menor similaridade, o que pode ser atribuído à variabilidade interobservadores. O uso do AutoContour resultou em uma redução de até 25,86 minutos no tempo necessário por paciente para a segmentação das estruturas, demonstrando ganhos substanciais de eficiência sem comprometer a qualidade. O software AutoContour simplifica o processo de delineamento no planejamento da radioterapia para câncer do colo do útero, mantendo resultados de qualidade com mínima necessidade de ajustes. Esses resultados sugerem que a integração dessa ferramenta de auto-segmentação pode reduzir consideravelmente a carga de trabalho especializado, aumentando a eficiência geral dos fluxos de trabalho clínicos nos departamentos de radioterapia. Essa automação não apenas economiza tempo, mas também reduz o potencial de erro humano, podendo promover delineamento de estruturas em risco mais consistente e padronizado.

Palavras-chave*: Redes Neurais Convolucionais, Auto-segmentação, Planejamento de Tratamento, Radioterapia, Câncer de Colo do Útero.*

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1. Introduction

Cervical cancer accounts for approximately 7% of all malignant neoplasms among women in Brazil, with an anticipated 17,000 new cases during the 2023-2025 period as projected by the Instituto Nacional de Câncer (1). This disease is predominantly observed in nations with low to medium Human Development Index levels, including Brazil (2). According to World Health Organization data, over 85% of patients affected by this type of cancer are young individuals with low educational levels from the poorest regions of the world. When identified early and treated, it presents a high cure rate (3). Commonly, treatment integrates radiation therapy with chemotherapy, markedly improving survival rates and disease management (4,5).

In the realm of gynecological cancer treatment, a comprehensive survey from the United Kingdom highlights the intricate and time-intensive nature of contouring for radical radiotherapy. Radiation oncologists reportedly dedicate about 120 minutes solely to contouring structures, emphasizing the complexity inherent in this crucial phase of treatment planning (6).

In response to these challenges, there is a growing focus on strategies that streamline routines, thereby alleviating the burden on Radiation Oncologists and medical physicists engaged in repetitive tasks such as organ contouring and treatment planning. Such innovations are particularly vital in high volume centers that require rapid treatment planning to effectively treat all patients. Recent trends in research underscore a substantial increase in studies exploring automation in radiotherapy, which not only conserves time for specialists but also enhances task quality, consistency, and uniformity. This automation can reduce professional variability and enables swift planning (7–12).

The Brazilian healthcare landscape, characterized by substantial infrastructural and human resource challenges as outlined in a 2018 Ministry of Health census (13), further underscores the necessity for efficient workflows. The Brazilian Society of Radiation Therapy has identified critical shortages in both treatment technology and skilled professionals across the nation’s radiation therapy centers (14). Hospitals serving the public health system (SUS) stand to benefit immensely from the deployment of workflow optimization tools, aimed at bolstering the efficiency of radio-oncology teams. This study seeks to assess the efficacy of the auto-segmentation tool AutoContour (Radformation, Inc., New York, NY) and its impact on the workload of specialist medical teams.

2. Material and methods

Fifteen Computed Tomography (CT) scans of patients receiving pelvic radiotherapy for cervical cancer treatment were randomly chosen for analysis (*n=15*). The research was conducted using anonymized data. The CT scans were acquired utilizing a Siemens Somatom model tomograph, featuring six channels with patients positioned supine and their arms elevated. The acquisition was conducted with slices of 2.5 mm thickness. To enhance patient comfort and ensure the reproducibility of the treatment, supports for the head, knees, and ankles were utilized.

2.1. The AutoContour Software

The software employed for contouring organs at risk was AutoContour, version 2.4.6, developed by Radformation. This software employs an algorithm based on Convolutional Neural Networks (CNNs), known for their proficiency in detecting image patterns and deriving anatomical structures from them. CNNs are designed to discern relevant image patterns within a training dataset; upon encountering new images, they automatically identify and label voxels that match the characteristics of the targeted organs at risk (8).

According to Radformation, the model training was conducted using 6,928 series of tomographic images obtained from two distinct centers in the United States, some of which, depending on the anatomical site, were acquired with patients in the treatment position. The structures were processed, when necessary, to comply with the major contouring guidelines.

AutoContour is integrated into the Eclipse treatment planning system (Varian Medical Systems, Palo Alto, CA), and is accessed through a plugin. Within the AutoContour interface, users have the capability to designate the anatomical site, customize the selection of structures for delineation, set contouring guidelines, preview the generated volumes, and ultimately, validate the structures prior to exporting them into the planning system.

2.2. Structures Delineation

Two experienced radiation oncologists were instructed to delineate, in all CT scans, the organs at risk typically contoured in the routine for cervical cancer treatments in the Eclipse planning system, version 15.1. The contours of the rectum, bladder, kidneys, bowels (bowel bag), and femoral heads were delineated based on the RTOG Guidelines (15). Subsequently, one technologist was instructed to perform auto-contouring of the organs at risk in the same planning CT in the planning system. The structures generated by the tool were reviewed and validated by the radiation oncologists.

Figure 1 illustrates a flowchart delineating the tasks and the respective professionals involved in each study arm.

2.3. Evaluated Parameters

To assess the quality of the delineated structures, the Dice Similarity Coefficient (DSC) was employed. This coefficient is a quantitative metric widely used in computer vision to evaluate graphic similarity (10). Simplistically, the DSC is derived from Equation (1), where A and B represent two volumes. This metric quantifies the similarity between two structures, providing a numerical index that ranges from 0, indicating no similarity, to 1, indicating complete congruence.

$$DSC = \frac{2\,|A \cap B|}{|A| + |B|} \quad (1)$$

Additionally, the time required for specialists to delineate the structures, from initiation to completion, was recorded for each patient. The duration of the physician review and validation of the structures generated by the AutoContour software was also documented. Furthermore, the time spent by the technologist in generating these structures was carefully tracked. The hardware employed in this study was an Intel Xeon Silver 4110, 2.1 GHz (16 CPUs), 32 GB of RAM, x64 system, Windows 10 Enterprise, Nvidia P600.

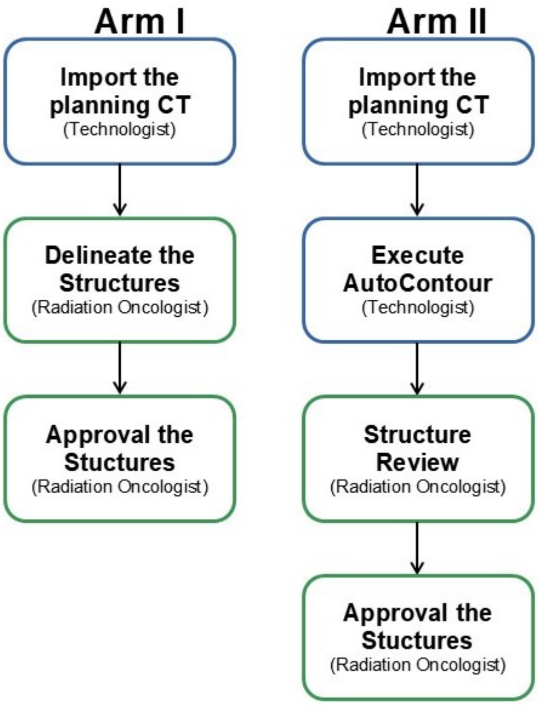

Figure 1. Study design illustration: In Arm I, structural delineation is manually performed by the Radiation Oncologist; in Arm II, the auto-segmentation tool is operated by the technician, followed by evaluation and approval of the generated structures by the specialist physician.

2.3. Statistical Analysis

A descriptive analysis of the evaluated parameters was conducted. A comparative analysis of the Dice Similarity Coefficients associated with the volumes delineated by individual physicians compared to those generated by the auto-contouring tool, as well as between the radiation oncologists, was performed. Furthermore, the time and DSCs obtained were compared using either the Student's t-test (16) or the Mann-Whitney U test (17), as appropriate, with a significance level set at 0.05. Prior to these tests, the normality of the distributions was assessed with the Shapiro-Wilk test (18). All analyses were conducted using IBM SPSS software, version 21 (IBM Corporation, New York, USA).

3. Results and Discussions

The Figure 2 illustrates the distribution of DSCs concerning the comparison between the volumes delineated by each radiation oncologist (RO) and AutoContour, as well as between the volumes delineated by each professional for every assessed organ at risk in this study.

Concerning the similarity between the automatically generated and radiation oncologist delineated structures, the results unveiled a minimum median value of 0.56 (interquartile range = 0.18) for the Bowel Bag structure and a maximum median value of 0.96 (interquartile range = 0.02) for the Right and Left Femur structures. According to Liu et al., a DSC above 0.80 generally indicates high similarity, between 0.70 and 0.80 moderate similarity, and DSC values below 0.70 indicate low similarity (10). Thus, based on the obtained median DSC values and this classification, 04 structures exhibited high similarity, 02 structures showed moderate similarity, and only 01 structure demonstrated low similarity.

The only structure that exhibited a median DSC below 0.7 was the Bowel Bag, which was observed in only one of the Radiation Oncologists. However, upon comparing the contours between the two Radiation Oncologists, the DSC for this structure remained below 0.7 and the statistical test showed no statistical difference ($p = 0.62$) between the analyzed data, indicating differences between the physicians in the delineation of the bowel bag. Upon closer examination, it was observed that one of the Radiation Oncologists delineated this structure only a few slices beyond the upper limit of the target volume, consistent with typical clinical practice, while the auto-contouring and the other Radiation Oncologist delineated the entire Bowel Bag. Exclusion of this structure from the analysis of cases with a DSC above 0.8 resulted in an increase to 83% in the proportion of structures displaying high similarity. Despite variations in the DSC scores, both radiation oncologists agreed that the contours of the delineated bowel bags generated by the tool were considered satisfactory for use in clinical practice.

Two cases were identified where the DSC for the bladder approached zero. In one instance, this discrepancy was observed in only one of the Radiation Oncologists, whereas in the other, it was noted in both. Upon assessment, both ROs agreed that in the first scenario, the artificial intelligence accurately outlined the structure's contour, while the RO misaligned the structure within the CT scan. Conversely, in the second case, the AI included the tumor volume as part of the bladder volume. It is noteworthy that in both instances, the disease was at an advanced stage, and the Radiation Oncologists themselves encountered difficulty in identifying the structures, as exemplified by the first case in which high discrepancy was observed.

The quality of manual contouring is heavily dependent on the expertise of the clinician and is susceptible to errors, given its tendency to exhibit considerable inter-operator variability, owing to its inherently subjective nature (19–21). This aspect renders it one of the principal sources of uncertainty in radiation therapy (21). Hence, it is anticipated that there will be variability in the delineation of structures among the radiation oncologists in our team.

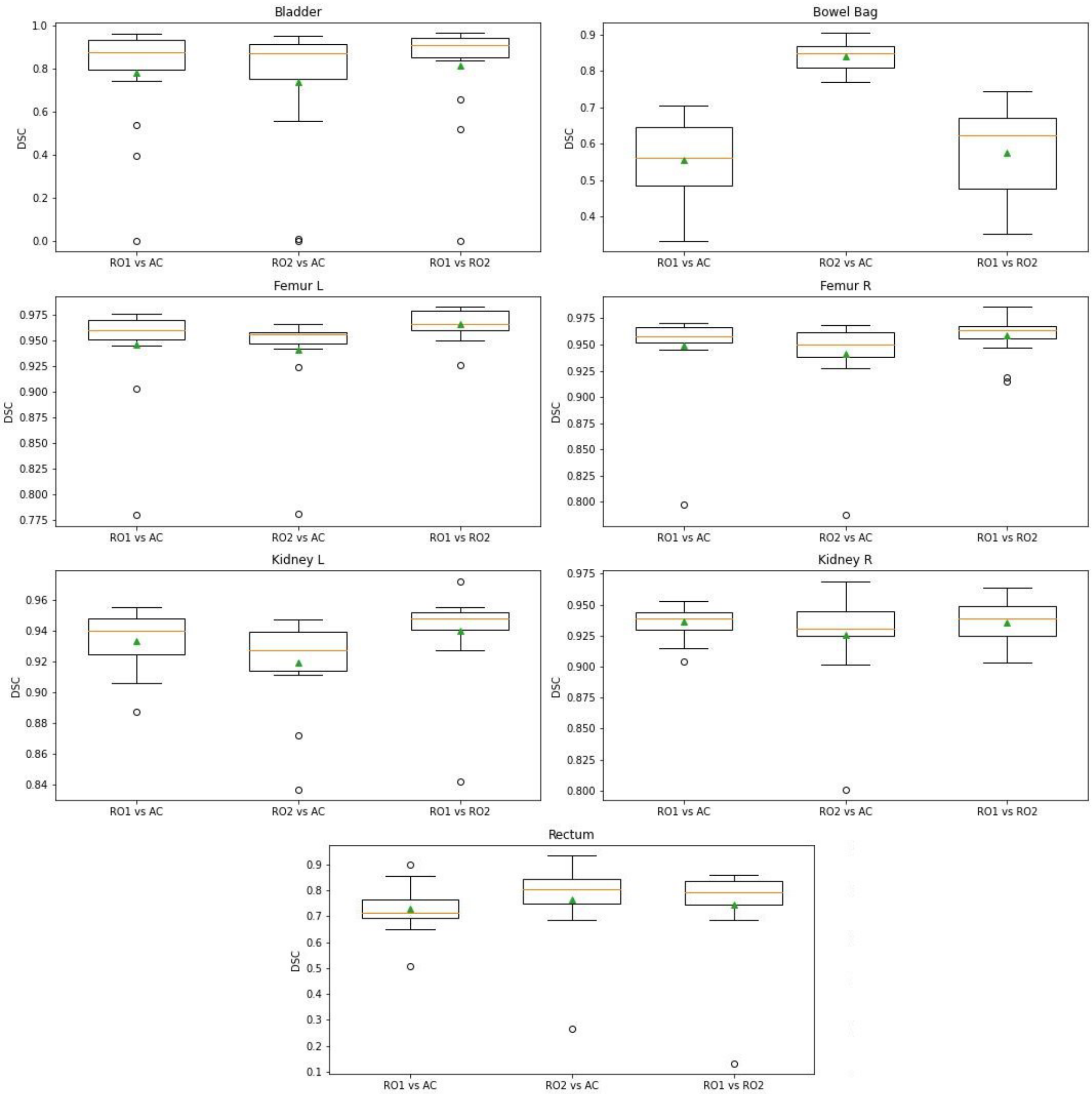

Figure 2. Boxplot distributions of the DSCs relative to the comparison between the volumes delineated by each radiation oncologist (RO) and AutoContour (RO1 vs AC e RO2 vs AC), and between the volumes delineated by each professional (RO1 vs RO2).

The contours manually generated by the physicians and those generated using AutoContour for abdominal and pelvic slices are shown in Figure 3.

Table 1 presents a comparative analysis of the average delineation times for radiation oncologists versus those delineated by AutoContour. Additionally, the table details the time expended in generating the auto-contours. The software-related time is defined as the aggregate of the duration spent by the technologist in creating the structures using the tool and the time utilized by the radiation oncologist for evaluating and validating these structures (review process). The review time listed in the table reflects the average duration required by both radiation oncologists to approve the structures.

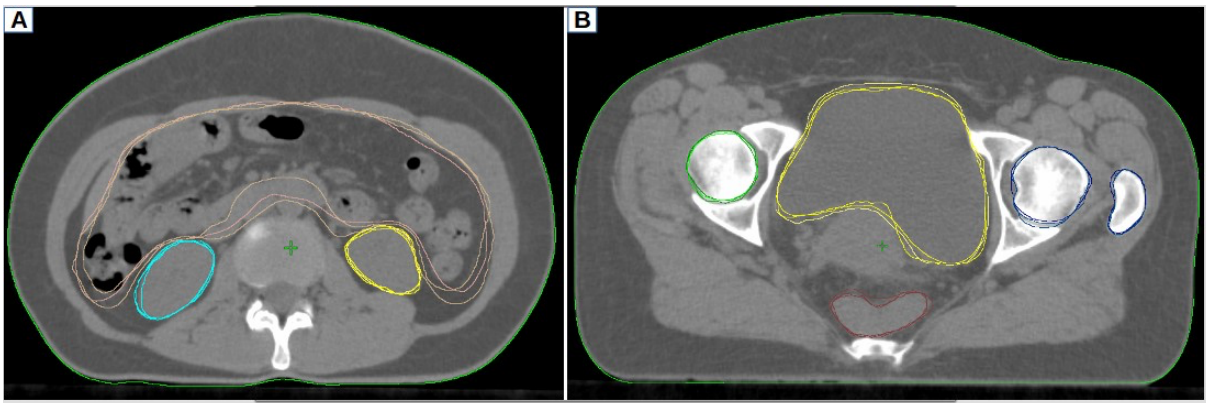

Figure 3. Contours for (A) abdominal and (B) pelvic organs created by radiation oncologists and AutoContour.

The average time required for contouring by radiation oncologists was recorded at 31.45 minutes. With the implementation of the auto-contouring tool, this total time was reduced to 8.24 minutes ($p < 0, 01$), yielding an average time saving of 23.21 minutes. Specifically focusing on the time expended by the specialist physicians, the reduction in their workload is even more pronounced, amounting to approximately 25.86 minutes per session. It is worth mentioning that some structures generated by the tool required minor adjustments.

Table 1. Comparison of the mean time, in minutes, used in the delineation of structures.

	Time (min)				
	RO 1	RO 2	AutoContour	Mean Evaluation by RO's	AutoContour + RO Review
Mean	14.51	48.40	2.65	5.59	8.24
SD	±1.73	±9.87	±0.72	±1.55	±1.48
Median	13.87	48.37	2.68	4.77	8.10

RO = Radiation Oncologist; AC = AutoContour; SD = Standard Deviation.

Source: The author (2025).

When assessing the time saved, a study investigating five distinct commercial auto-segmentation tools across four anatomical sites (breast, head and neck, prostate, and lung) noted considerable time savings compared to manual contouring, with AutoContour achieving a mean saving of 36.6 minutes. Furthermore, the quality of structures generated by all evaluated tools, including AutoContour, was deemed very good, with a mean DSC of 0.86 for all structures evaluated (22). A notable reduction was also observed in a study evaluating auto-segmentation of organs at risk in the abdominal region based on U-Net, from 22.60 minutes to 7.10 minutes (23). These findings are consistent with our results, demonstrating that AutoContour facilitated a reduction in overall time by at least 23.21 minutes for delineating organs at risk in pelvic radiotherapy planning tasks and potentially saving approximately 82% of skilled labor time dedicated to the task. Additionally, for most structures, as shown in Figure 2, the DSC remained above 0.80 in most cases.

Numerous studies have documented the use of Convolutional Neural Networks for automated segmentation across various cancer sites, including the prostate, abdomen, thorax, head and neck, and esophagus (8,24–27). The prospect of employing a unified interface capable of delineating organs at risk across diverse anatomical sites in just a few clicks presents a remarkable advantage for clinical practice.

Brouwer et al. (19) emphasize that one potential approach to achieve more consistent contours is the utilization of automatic segmentation. However, the authors discuss the imperative of meticulous validation of such software's. In a dosimetric study comparing the effects on dosimetry across three different sets of structures, including manually contoured and two automatic segmentation tools, one of which was AutoContour, the authors found that auto-segmented contours could be used directly to generate plans without compromising plan quality. Nevertheless, they noted that minor yet consistent differences in contouring preferences may lead to subtle variations in planning outcomes (28).

Baroudi et al. (29), in questioning what would be clinically acceptable concerning auto-segmentation and auto-planning, pointed out that the clinical acceptability of the results from the use of automation tools depends on the appropriate evaluation by metrics based on three pillars: quantitative comparison, qualitative review by experts, and clinical impact. With this concern in mind, the present study aimed to conduct a comprehensive appraisal of the AutoContour software. This evaluation encompassed not only the assessment of efficiency gains in clinical practice but also the comparison of contour quality to manual delineation.

As previously discussed, the use of automated tools has the potential to enhance efficiency, decrease staff workload, and standardize the quality of the automated task (9). The reduction in the time required to generate contours of organs at risk for cervical cancer may potentially have implications for clinical practice. Furthermore, our observations suggest that this efficiency gain is accompanied by high-quality contour generation, without compromising the delineation process's quality.

In addition to alleviating the workload of specialist physicians, as observed in the study, the auto-segmentation tool was capable of detecting errors in the delineated volumes. Thus, akin to medical physics teams encouraged to conduct independent review calculations, AutoContour holds promise as a verification tool, particularly in radiotherapy services with a lone radiation oncologist. It is noteworthy that DSC values for each structure can be obtained directly within the tool.

Overall, the auto-segmentation tool assessed in this study exhibited good performance, with a substantial portion of automatically delineated structures displaying remarkable similarity, as indicated by the high Dice similarity coefficient values. Additionally, when evaluating the time required for contour generation, employing AutoContour led to a remarkable 74% reduction in the time spent. In the study methodology, the direct application of the evaluated tool was executed by the technician to minimize the reliance on specialized labor. Nevertheless, this task could feasibly be undertaken by the radiation oncologist without affecting the time saved.

4. Conclusion

The automatic contouring tool assessed in this study demonstrated commendable performance overall, with the majority of Dice similarity coefficient indices exceeding 0.8, indicating high similarity. Moreover, the structures automatically generated exhibited a low need for modifications during a medical review. Therefore, AutoContour has demonstrated itself as a valuable tool for automated segmentation in cases of cervical cancer, with the potential to markedly diminish the specialized workload during this planning phase.

Conflicts of Interest

The authors declare that they have received a complimentary software license from Radformation Inc (New York, USA) for the development of this work and XXX have received travel support from Radformation.

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