Original Article

Artificial Intelligence for Radiotherapy Auto-Contouring: Current Use, Perceptions of and Barriers to Implementation

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Abstract

Aims: Artificial intelligence has the potential to transform the radiotherapy workflow, resulting in improved quality, safety, accuracy and timeliness of radiotherapy delivery. Several commercially available artificial intelligence-based auto-contouring tools have emerged in recent years. Their clinical deployment raises important considerations for clinical oncologists, including quality assurance and validation, education, training and job planning. Despite this, there is little in the literature capturing the views of clinical oncologists with respect to these factors.

Materials and Methods: The Royal College of Radiologists realises the transformational impact artificial intelligence is set to have on our specialty and has appointed the Artificial Intelligence for Clinical Oncology working group. The aim of this work was to survey clinical oncologists with regards to perceptions, current use of and barriers to using artificial intelligence-based auto-contouring for radiotherapy. Here we share our findings with the wider clinical and radiation oncology communities. We hope to use these insights in developing support, guidance and educational resources for the deployment of auto-contouring for clinical use, to help develop the case for wider access to artificial intelligence-based auto-contouring across the UK and to share practice from early-adopters.

Results: In total, 78% of clinical oncologists surveyed felt that artificial intelligence would have a positive impact on radiotherapy. Attitudes to risk were more varied, but 49% felt that artificial intelligence will decrease risk for patients. There is a marked appetite for urgent guidance, education and training on the safe use of such tools in clinical practice. Furthermore, there is a concern that the adoption and implementation of such tools is not equitable, which risks exacerbating existing inequalities across the country.

Conclusion: Careful coordination is required to ensure that all radiotherapy departments, and the patients they serve, may enjoy the benefits of artificial intelligence in radiotherapy. Professional organisations, such as the Royal College of Radiologists, have a key role to play in delivering this.

Introduction

Radiotherapy is a major treatment modality for cancer, utilised with either curative or palliative intent in over 50% of all cases [1–3]. Recent decades have seen the introduction of more complex, technologically advanced radiotherapy aimed at improving survival and reducing toxicity [1,2,4,5]. Despite these advances, several time-consuming manual steps that directly impact on treatment quality remain embedded within the radiotherapy workflow [1,6]. The introduction of more complex radiotherapy, increasing cancer incidence and, more acutely, a pandemic-related backlog in some countries, have contributed to service

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delivery pressures facing health systems. Clinical oncology workforce shortages, as described in the Royal College of Radiologists' (RCR) recent clinical oncology UK workforce census report [1,7] only serve to exacerbate such pressures.

Artificial intelligence, the use of complex computer algorithms that perform tasks normally requiring human intelligence, continues to impact several areas of health care, from drug discovery to service delivery [8,9]. Within clinical oncology, artificial intelligence may have the potential to transform several segments of the radiotherapy workflow, resulting in improved quality, standardisation, safety, accuracy and timeliness of radiotherapy delivery [1,6,10]. As the body representing clinical oncologists, the RCR realises the transformational impact artificial intelligence is set to have on our specialty and has appointed the Artificial Intelligence for Clinical Oncology (AICO) working group. Members of this group have clinical and research interests across various aspects of artificial intelligence and digital health technology, including imaging, treatment planning, data collection/analysis and artificial intelligence modelling to support and advance the RCR's artificial intelligence agenda.

At present, manual contouring of organs at risk (OARs), primary tumour and involved nodal regions is perhaps the most laborious, but crucial, component of the clinical oncologist's role. Errors in this process can lead to underdosing of the tumour or increased toxicity, with resultant effects on survival and quality of life. Atlas-based contouring tools are limited by availability and accuracy and still require significant manual input [1,11–14]. Advances in artificial intelligence domains, such as machine learning and computer vision, have led to the development of methods for accurate and efficient auto-contouring [15]. Indeed, in a survey of medical physicists, auto-contouring was felt to be one of the most popular artificial intelligence supported applications [16]. In a survey of therapeutic radiographers, responses ranked auto-contouring second only to treatment planning as the area of radiography where artificial intelligence would have the most value [17].

In recent years, artificial intelligence-based auto-contouring tools have migrated from the domain of research to commercially available products [1,6,16]. Although such products may represent ideal solutions to the problems described above, their clinical deployment raises several important considerations for clinical oncologists, including quality assurance and validation, education and training and job planning. Despite this, there is little in the literature capturing the views of clinical oncologists with respect to these factors. The aim of this work was to survey UK clinical oncologists with regards to perceptions, current use of and barriers to using artificial intelligence-based auto-contouring for radiotherapy, to share our findings with the wider clinical and radiation oncology communities and to use these insights in developing support, guidance and educational resources for the deployment of auto-contouring for clinical use, to help develop the case for wider access to artificial intelligence-based auto-contouring across the UK and to share practice from early-adopters.

Materials and Methods

Survey questions were developed by AICO and consisted of a mixture of close-ended questions and open-ended statements with options to select. Free-text comments were invited where further information was deemed necessary (Table 1). The RCR's Data, Audits and Surveys team advised on changes to avoid bias. The survey was conducted through the RCR Insights Panel and was sent to trainees, Specialty and Associate Specialist (SAS) doctors and consultants in current employment (not retired) across the UK and oversees within the Faculty of Clinical Oncology. The survey ran from 08:30 6 June to 23:59 12 June 2022. Responders were not incentivised. Free text comments were reviewed by the lead author and grouped into common categories. Responses were analysed with descriptive statistics.

Results

The survey was sent to 236 members of the Faculty of Clinical Oncology that had subscribed to the RCR's Insights Panel. Fifty-one responded, giving a response rate of 22% (≥20% is considered acceptable by the Insights Panel), which is in keeping with other recent Insights Panel surveys (response rate range 21−27%). Forty respondents (78%) were consultants, seven (14%) were trainees and three (6%) were of another grade. Fifty (98%) practiced within the National Health Service or an overseas equivalent, six (12%) in a university or academic setting and five (10%) in the private sector. Forty-four respondents (85%) provided their hospital. These were grouped into regions (Table 2). Response rates for individual questions are presented in Table 1.

Perceived Impact of Artificial Intelligence-Based Auto-Contouring for Clinical Oncologists and Patients

When asked about the impact artificial intelligence will have on radiotherapy practice, 40 respondents (78%) felt that this would be positive. None felt that artificial intelligence would replace their role and only one (2%) felt the impact would be negative. Three (6%) felt the impact would be non-significant and seven (14%) did not know. With respect to risk for patients, 25 respondents (49%) felt that the use of artificial intelligence in radiotherapy would decrease risk and 11 (22%) felt there would be no change in risk to patients. Two (4%) felt that artificial intelligence would increase the risk to patients and 13 (25%) did not know.

Current Use of Artificial Intelligence-Based Auto-Contouring

We asked respondents to identify the percentage of OAR contouring that was carried out by artificial intelligence or various staff within their department (Figure 1). Nineteen respondents (37%) reported that consultants undertook ≥60% of all OAR contouring. Forty-five respondents (96%) reported that trainees undertook ≤40% of all OAR

Table 1
Questions included in the survey, together with answer options where relevant and number of responses to individual questions

Question stem	Options for selection	Number of responses to individual questions (%)
Grade	- Consultant - Trainee - Other	51 (100)
Where do you work? (Possible to select more than one option)	- NHS (or overseas equivalent) - University (/academic setting) - Private sector	51 (100)
Artificial intelligence in radiotherapy will …	- Replace my role - Have a positive impact on my practice (e.g. by reducing workload) - Have no significant impact on my practice - Will have a negative impact on my practice (e.g. by increasing workload) - Don't know	51 (100)
Will the use of artificial intelligence in radiotherapy increase or decrease the risk for patients?	- Increase risk (e.g. due to insufficient clinical expert involvement) - No change in risk - Decrease risk (e.g. due to faster, higher quality or more consistent contours) - Don't know	51 (100)
In your department, approximately what percentage of organ at risk contouring is performed by … (Allocate each option to %. Please ensure values add up to 100%)	- Clinical oncology consultants - Dosimetrists - Specialty trainees - Physicists - Radiographers - Auto-contouring tools	51 (100)
Are you currently using auto-contouring tools in your practice?	- Yes – for routine clinical use - Yes – for selected clinical cases - Yes – for research - No – but our department plans to introduce auto-contouring within the next year - No	50 (98)
For which organs at risk and tumour sites are auto-contouring tools used (in your department)?	- Brain - Head and neck - Thorax - Abdomen - Prostate - Bladder - Other pelvic - Skin - Sarcoma	21 (41)
How much time (if any) does auto-contouring save you in a typical week?	- It makes my contouring take longer - None (it neither speeds up my contouring nor slows it down) - It saves me up to 30 min - It saves me 30 min to 1 h - It saves me over 1 h - Don't know	25 (49)
What do you think are the key priorities/learning points regarding artificial intelligence for the Royal College of Radiologists?	Optional free text	39 (76)
Please share any further comments about artificial intelligence for auto-contouring:	Optional free text	20 (39)
Email:	Optional free text	27 (53)
Hospital:	Optional free text	27 (53)

Table 2
Respondents by geographical location

Geographical region	Number of respondents (%)
England — East	5 (10)
England — London	6 (12)
England — Midlands	1 (2)
England — North East	4 (8)
England — North West	7 (13)
England — South East	9 (17)
England — South West	6 (12)
Northern Ireland	1 (2)
Scotland	4 (8)
Wales	1 (2)
No place of work given	8 (15)

contouring, with 12 (26%) reporting that trainees did no OAR contouring. Interestingly, two respondents reported that artificial intelligence auto-contouring was used for most OAR contouring in two departments (between 41 and 60% of all cases in one department and 61 and 80% in the other).

Twenty-three respondents (45%) reported that artificial intelligence auto-contouring was being used clinically in their departments. Four (8%) reported it was used only for research and eight (16%) stated that although it was not currently being used, their department plans to introduce it within the next year.

Where artificial intelligence-based auto-contouring was being used, this was predominantly for OAR contouring and most commonly for head and neck, brain, thorax and prostate radiotherapy. Three respondents reported that artificial intelligence auto-contouring was being used for thoracic, prostate and bladder tumour contouring in their departments (Table 3).

Twenty-five respondents replied to the question regarding how much time artificial intelligence auto-contouring saved in a typical week. Sixty per cent (15) reported a time saving, with 8% (two) reporting this to be up to 30 min, 16% (four) between 30 min and 1 h and 36% (nine) reporting this to be over 1 h per week. Six (24%) reported that artificial intelligence made no time saving. None reported that artificial intelligence delayed their contouring.

Key Priorities and Views Regarding Artificial Intelligence for the Royal College of Radiologists

We also asked respondents what they thought the key priorities and learning points regarding artificial
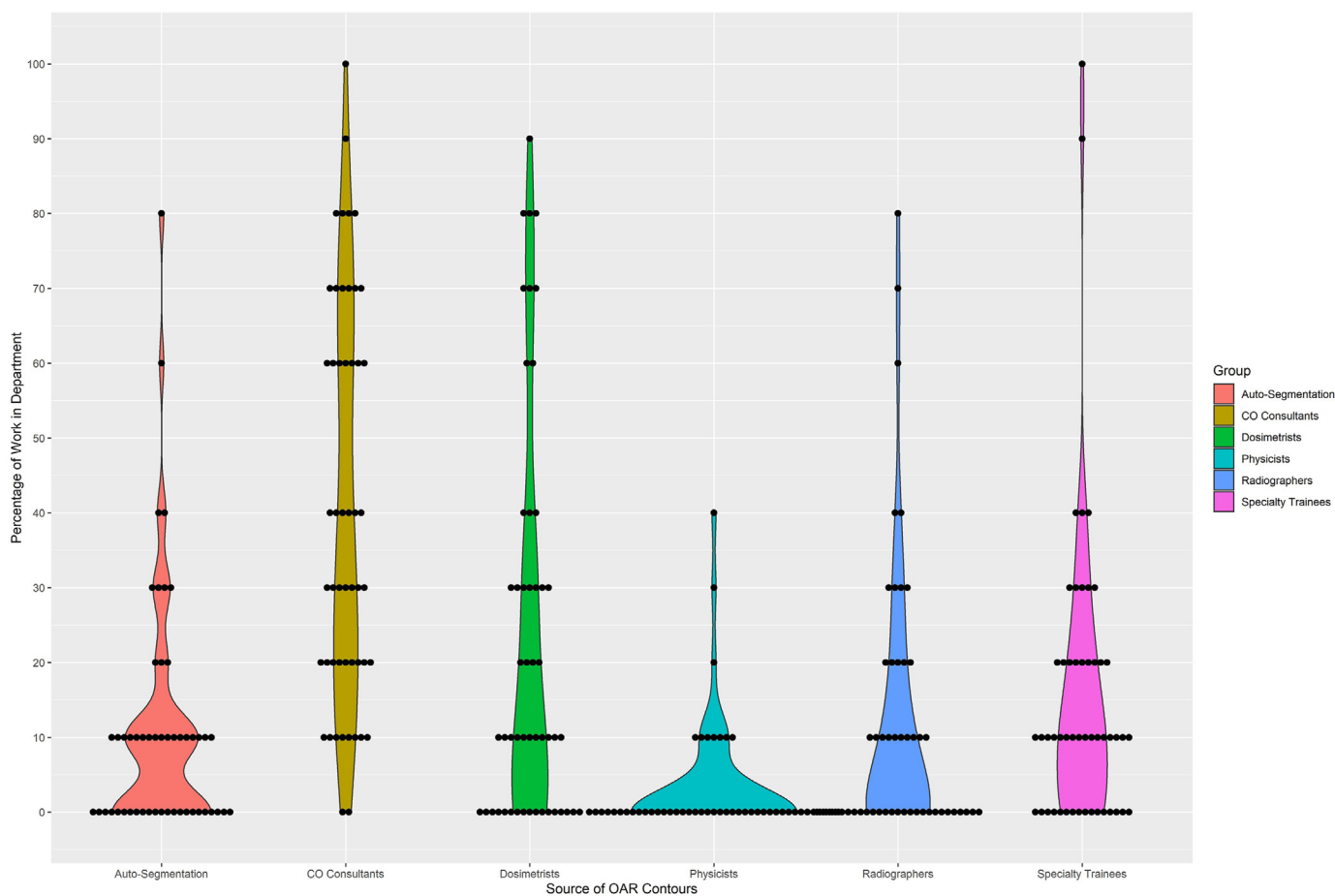
Fig 1. Burden of organ at risk contouring completed by five staff groups and artificial intelligence. The number of responses broken down by person/tool completing the organ at risk work and the percentage of workload.

Table 3
Respondents were asked for which organ at risk and tumour sites artificial intelligence-based auto-segmentation tools were used in their department

	Number of respondents by tumour site (%)								
	Brain	Head and neck	Thorax	Abdomen	Prostate	Bladder	Other pelvic	Skin	Sarcoma
Organ at risk	12 (57)	14 (67)	12 (57)	10 (48)	12 (57)	10 (48)	9 (43)	7 (33)	7 (33)
Tumour	0	0	1 (5)	0	1 (5)	1 (5)	0	0	0

intelligence should be for the RCR and to share any other comments on their views or experience with artificial intelligence for auto-contouring. These were distilled into five categories.

(i)   Validation and quality assurance

Respondents expressed the need for robust quality assurance and validation of auto-contouring tools, ensuring that appropriate safety checks are available for artificial intelligence-generated contours. One comment suggested the 'ability to check [clinical target volume] contours versus 'gold-standard' adaptive measures'. Another suggested reviews of learning, audit of outcomes and evaluation of the impact of processes within their department would be helpful.

(ii)   Education, training and guidance

Others highlighted the requirement for guidance to be provided to clinical oncologists, especially if they are expected to take clinical responsibility for artificial intelligence solutions. Published guidance should include advice on the use and regulation of auto-contouring and awareness of the pitfalls and limitations associated with auto-contouring. Respondents also wanted guidance on 'the balance between reliance on [artificial intelligence] and the on-going need for professional clinical judgement'. One respondent commented that it is 'important to have [an] adequate learning dataset and be aware of limitations' and for clinical oncologists to 'use [artificial intelligence] as a tool but do not over rely on it'. Another commented on a 'real risk of complacency by the user' and that 'guidance needs to be in place to check the radiotherapy volumes are directed to patient history and that mistakes do not happen'.

A range of comments highlighted appetite for formal training on how to use artificial intelligence tools. There are a variety of training needs, from some respondents looking for basic training, 'I don't know anything about it — so [the RCR] need [s] to educate us all!', 'I have little experience in using [artificial intelligence] auto-contouring tools; formal training will be helpful', to more practical applications, 'More teaching on how to incorporate it in clinical practice, in practical terms' and 'Every clinical oncologist and radiologist should embrace [artificial intelligence] but also be equipped to understand how to use it optimally in clinical practice'.

A number of responses expressed concern regarding the impact of artificial intelligence on retaining our own radiotherapy planning skills and on training future oncologists, 'we need to be careful that when left to do the things that [artificial intelligence] can't do, we haven't lost expertise because of doing much less than previously', 'we need to be careful to ensure that SpRs continue to know the basics of OAR (and GTV etc) contouring - consultants of the future must know how to contour otherwise we won't be able to deal with issues with auto-contouring' and 'robust training should be created to ensure trainees retain skill in interpretation of cross-sectional anatomy'.

(iii)   Understanding the impact on clinical oncologists

Most comments received related to how artificial intelligence would impact on the clinical oncologist's work. These were overwhelmingly positive, with a view that artificial intelligence would save time.

- 'It does need reviewing and editing but still saves time'
- 'Having trialled systems, [artificial intelligence] for OARs is definitely the future in terms of consistency and reducing contouring times'
- 'Purely from efficiency, [artificial intelligence] will improve overall work time, especially regarding OARs'
- 'Aids workflow efficiency especially if limited planning time'
- 'Improved efficiency in planning and delivery of radiotherapy'

Other responses were more sceptical, highlighting the need to ensure that artificial intelligence 'actually reduces workload and doesn't just add extra checking' or that it 'does not create delays or more work'. Comments included, 'I suspect, as with many changes, this will have both good and bad, hence me not being remotely sure about whether things will get better or worse overall'.

Two comments speculated on how the clinical oncologist's role might change with the introduction of artificial intelligence, 'freeing up time for clinical oncologists to develop new skills and activities' and 'the role of clinical oncologist will be to edit artificial intelligence generated volumes'.

Key priorities for the RCR in this category were felt to be 'to best understand the direct/indirect, positive/negative consequences of the impact on clinicians (e.g. job planning) and where necessary make recommendations about mitigation'. For the use of artificial intelligence in clinical oncology in general, one respondent felt priorities should be '1. Peer review tools and consensus on cases, 2. OAR outlining, 3. Pathway streamlining (for example scheduling chemoradiotherapy)'.

Beyond auto-contouring, respondents speculated on how artificial intelligence might improve clinical oncology in the future, 'we should be looking at opportunities for a 10—15-year time horizon: plan data combined with patient reported outcome measures and disease outcome data fed-back into datasets to help clinical decision making: e.g. would this patient be better served by protons vs photons or radiotherapy vs no radiotherapy? Machine vendors are already looking at these potential solutions and we should partner with them', 'linking artificial intelligence to clinical outcomes and normal tissue complication probability would fully realise benefits of [artificial intelligence]' and 'artificial intelligence will also allow for effective radiomic data to be collected to better understand/audit [radio-therapy] volumes and plans by correlating to outcomes in patients'.

(iv)   Patient engagement

Two comments related to the responsibility of the RCR and clinical oncologists to reassure patients that artificial intelligence -based auto-contouring is safe and effective and to make clear where the clinical responsibility for artificial intelligence auto-contouring lies, 'patients should know who is in control of the auto-contouring'.

(v)   Rolling out clinical artificial intelligence tools for radiotherapy

Additional comments related to the introduction of clinical artificial intelligence tools for radiotherapy and the perceived role the RCR might play in this. Several respondents commented on the need for widespread equitable access to artificial intelligence technology for all departments across the country. Respondents felt that a national approach, possibly coordinated by the RCR, would be helpful to achieve proper implementation and verification, 'validation takes time and implementation could be sped up if it was done collaboratively/nationally (e.g. with the support of the RCR). We have never done this at scale before and have missed opportunities, e.g. for machine commissioning to be done by regional teams to allow local physics teams to continue clinical work'. It was also felt that as 'investment and funding availability is crucial', the RCR should 'lobby the government for a separate pot [of money] for clinical radiotherapy improvement rather than the single which will mostly fund radiology'. Also, that, 'the RCR needs to push and stimulate departments into using auto-contouring software. With the current workforce shortage and levels of burnout, anything that can help reduce contouring time needs to be trialled and implemented as a matter of priority'.

Discussion

This report provides useful insight on views of consultant and non-consultant grade clinical oncologists across a wide geography towards the perceptions, current use of and barriers towards artificial intelligence-based auto-contouring in radiotherapy. The results will be valuable in developing further support, guidance and educational resources for the deployment of clinical artificial intelligence tools, to help develop the case for wider access to artificial intelligence-based auto-contouring and to identify early-adopters who may be able to share learning with the wider clinical and radiation oncology communities.

Prior studies have reported on the views of 213 medical physicists across Europe [16], 77 therapeutic radiographers from the UK [17] and a multidisciplinary group including 15 radiation oncologists from New Zealand [18]. However, these have focused on the impact of artificial intelligence on radiation oncology in general rather than artificial intelligence-based auto-contouring and we have been unable to find prior studies reporting specifically on the views of clinical/radiation oncologists. Our findings contribute to the literature and compliment prior work by identifying areas of synergy where our different specialties may work together to deliver the safe clinical deployment of artificial intelligence.

Artificial intelligence is no longer 'on the horizon'. Forty-five per cent of respondents were already using artificial intelligence-based auto-contouring tools for clinical work. Although this was mainly for OAR contouring, respondents reported using artificial intelligence for tumour contours in prostate, thorax and bladder. This is further reflected by the study of European medical physicists, where 37% reported using artificial intelligence in clinical practice, predominantly for contouring and treatment planning [16]. This highlights the urgent need for clear validation and quality assurance measures, as well as guidance, education and training on the safe use of artificial intelligence, its limitations and how to navigate pitfalls. This is further reflected in the free-text comments in response to key priorities for the RCR with regards to artificial intelligence in radiotherapy. Furthermore, although artificial intelligence has entered the radiotherapy arena, this does not appear to be universal, with disparate experience levels across centres. The drivers for this are not well understood and are likely to be multifactorial, e.g. due to resourcing, staffing and complacency. There is a danger for this to exacerbate health inequalities, for example with centres affected by these barriers being the last to adopt artificial intelligence and therefore the last to reap potential efficiency and other benefits. Careful planning is required to ensure widespread equitable access to artificial intelligence technology for all departments within health systems nationally.

Overall attitudes of respondents were largely in favour of artificial intelligence-based auto-contouring, with 78% reporting it would have a positive impact on their practice, for example by reducing time spent contouring and freeing up more time for other activities. These views are in keeping with those of medical physicists, therapeutic radiographers and radiation oncologists [16–18]. Opinions around risk for patients was more varied, however. Forty-nine per cent felt that auto-contouring would decrease risk due to faster, higher quality or more consistent contours. There seems to be some potential for auto-contouring to save time, with 60% of respondents saying it saves anywhere from 30 min to over 1 h per week. This has also been reported by Lustberg *et al.* [19]. Although artificial intelligence has been proposed as a solution to workforce shortages and burnout, it is crucial to note its limitations within this context. Developers and commissioners must ensure that tools do save time rather than increasing workload due to excess review of artificial intelligence-generated volumes. There is a danger of exacerbating burnout if the time saved by artificial intelligence is only allocated towards more complex case management or higher case volume, rather than patient-facing time, professional development or teaching.

The survey was only sent to members of the RCR's Faculty of Clinical Oncology who were currently in-practice and subscribed to the Insights Panel, rather than all members. However, (non)subscription to the Insights Panel is probably indicates (dis)inclination to respond to surveys from the RCR. There is also potential for responder bias, as those who feel strongly about artificial intelligence may be more likely to respond. The response rate was considered acceptable by the RCR and is in keeping with that of previous Insights Panel surveys. Furthermore, responses were from a wide range across the UK (and possibly beyond) and from both consultant and non-consultant grades, therefore capturing diverse views. Importantly, 14% of respondents were trainees, who are most likely to be impacted by the introduction of artificial intelligence during their careers. It is vital that training and educational materials incorporate the needs of this cohort.

Conclusion

In conclusion, this report highlights four important factors. First, artificial intelligence-based auto-contouring is in current clinical use and is expected to be adopted by more departments within the next year. Second, there currently exists no clear consensus on validation and quality assurance. Third, there is a marked appetite for urgent guidance, education and training on the safe use of such tools in clinical practice. Finally, there is a concern that the adoption and implementation of such tools is not equitable, which risks exacerbating existing inequalities across the country. Careful coordination is required to ensure that all radiotherapy departments, and the patients they serve, may enjoy the benefits of artificial intelligence in radiotherapy. Professional organisations such as the RCR have a key role to play in delivering this.

Author Contributions

SH and AT are the guarantors of integrity of the entire study. All authors were responsible for study concepts and design. SH carried out the literature research and experimental studies/data analysis. SH and KZ carried out the statistical analyses. SH prepared the manuscript. All authors edited the manuscript.

Conflicts of Interest

Acknowledgements

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