Published in final edited form as:
Cancer. 2010 August 15; 116(16): 3953–3960. doi:10.1002/cncr.25129.

A SURVEY OF IMAGE-GUIDED RADIATION THERAPY USE IN THE UNITED STATES

Daniel R. Simpson, B.S., **Joshua D. Lawson, M.D.**, **Sameer K. Nath, B.A.**, **Brent S. Rose, B.S.**, **Arno J. Mundt, M.D.**, and **Loren K. Mell, M.D.**
Department of Radiation Oncology, Center for Advanced Radiotherapy Technologies, University of California San Diego, La Jolla, CA

Abstract

BACKGROUND—Image-guided radiation therapy (IGRT) is a novel array of in-room imaging modalities that are utilized for tumor localization and patient set-up in radiation oncology. The prevalence of IGRT use among U.S. radiation oncologists is unknown.

METHODS—A random sample of 1600 radiation oncologists was surveyed by internet, email and fax regarding frequency of IGRT use, clinical applications, and future plans for use. The definition of IGRT included imaging technologies used for set-up verification or tumor localization during treatment.

RESULTS—Of 1089 evaluable respondents, 393 responses (36.1%) were received. The proportion of radiation oncologists using IGRT was 93.5%. When the use of MV portal imaging was excluded from the definition of IGRT, the proportion using IGRT was 82.3%. The majority used IGRT rarely (in <25% of their patients) (28.9%) or infrequently (25–50% of their patients) (33.1%). The percentage using ultrasound, video, megavoltage (MV) planar, kilovoltage (kV) planar, and volumetric technologies were 22.3%, 3.2%, 62.7%, 57.7% and 58.8%, respectively. Among IGRT users, the most common disease sites treated were genitourinary (91.1%), head and neck (74.2%), central nervous system (71.9%), and lung (66.9%). 59.1% of IGRT users planned to increase use, while 71.4% of non-users planned to adopt IGRT in the future.

CONCLUSIONS—IGRT is widely used among radiation oncologists. Based on prospective plans of responders, its use is expected to increase. Further research is required to determine the safety, cost-efficacy, and optimal applications of these technologies.

Keywords

image-guided radiation therapy (IGRT); in-room; set-up; survey; radiation oncology

INTRODUCTION

Image-guided radiation therapy (IGRT) consists of an array of imaging technologies designed to improve target localization and patient set-up. In recent years, new in-room technologies have provided the opportunity for unprecedented accuracy in radiation therapy (RT) delivery. The concomitant expanding use of intensity modulated RT (IMRT) 1 and

Corresponding author, Loren K. Mell, M.D., Co-director, Center for Advanced Radiotherapy Technologies, UCSD Department of Radiation Oncology, University of California, San Diego, 3855 Health Sciences Dr., MC0843, La Jolla, CA 92093-0843, Tel: 858-822-5129 / Fax: 858-822-6078 / lmell@ucsd.edu.

Conflicts of Interest Notification: None

To be presented at the 51st Annual Meeting of the American Society of Radiation Oncology (ASTRO), Chicago, IL, November, 2009

hypofractionated stereotactic techniques 2 has required improved accuracy, providing a strong impetus to adopt IGRT.

Numerous IGRT technologies have been applied to treat cancer over the last half century. Early technologies to improve patient set-up included kilovoltage (kV) planar x-ray-based 3 and video-based systems 4–6. Subsequently, megavoltage (MV) planar imaging technologies were developed, notably electronic portal imaging devices (EPID) 7, 8. Various types of floor-mounted 9–12 or gantry mounted 13–16 kV planar imaging technologies have also been implemented over the years. Ultrasound 17–24 and EPID with implanted radio-opaque (fiducial) markers 25–33 were relatively early developments to improve target localization. Recently, in-room volumetric imaging systems, such as MV computed tomography (CT) 34, 35 and MV 36–38 or kV 16, 39–43 cone-beam computed tomography (CBCT) have been introduced, providing greater soft tissue definition and improved target localization. Collectively, these IGRT technologies provide the potential to escalate target doses while decreasing normal tissue doses, thereby improving the therapeutic ratio of RT.

Although there is considerable interest in IGRT technologies, little is known about their use in the radiation oncology community. It is unclear how many radiation oncologists currently use these technologies, which technologies are used and to what extent, and how they are being applied. To answer these questions, we conducted a nationwide survey of practicing radiation oncologists.

MATERIALS AND METHODS

Sample

We randomly selected 1600 out of approximately 5000 radiation oncologists listed in the 2008 American Society for Radiation Oncology (ASTRO) directory. All physicians designated as *active* and *allied* members were included. Emeritus professors and radiation oncologists practicing outside of the United States were excluded. The survey was sent in three forms: as an email attachment, as a link to an online survey, and via fax. We attempted to contact each physician using the listed email address or fax number. If neither were valid, we searched for updated contact information in the 2009 ASTRO on-line directory. If no information could be found or if the fax or e-mail information were invalid, the physician was designated as uncontactable and excluded from further analysis. Those who had retired were also excluded. Physicians who returned the survey blank were counted as non-respondents.

Survey

A 10-question survey was designed to collect demographic information and address the use of IGRT technologies in patients undergoing RT (Table 1). This survey was conducted between February 1 and March 31, 2009 as part of a larger, comprehensive survey on IGRT, including the use of advanced imaging modalities to augment target delineation. The results of other aspects of the IGRT survey are the subject of a separate report.

Survey responses were considered evaluable if the survey was at least partially completed. For the purposes of this survey, we defined IGRT as the use of any of the following imaging modalities: ultrasound, video, planar, and volumetric imaging performed in the treatment room to aid in patient set-up or tumor localization. Each of the four categories included home-grown and multiple commercial systems (Table 2). Accompanying the survey was a cover letter outlining the goals of the project and confidential nature of the results obtained. In particular, it was stressed that the findings were to be used for academic purposes only and that company-specific data would not be disclosed or presented.

In addition to inquiring about practice type (academic vs. private practice) and size of practice group, physicians were asked about the type(s) of IGRT technologies used, the year they had adopted them, percentage of patients in their practice they currently treat with IGRT, disease sites treated, and future plans for IGRT use. Nonusers were asked whether or not they intended to adopt IGRT technologies in the future.

Statistical Analysis

Survey results are presented as a percentage of evaluable responses. Differences in proportions between various groups were analyzed using the chi-square and Fisher's exact test. The Holm step-down method was used to adjust the p values for multiple comparisons 44.

RESULTS

Of 1600 randomly selected physicians, 1089 physicians (68.1%) were contactable (Figure 1). From these, we received a total of 393 responses (36.1%). Of the 393 respondents, 7 were retired and 1 returned the survey blank, thus a total of 385 responses were evaluable.

Responses were received from physicians in 45 states (Table 3). One-hundred thirty-three responses were from academic physicians (34.5%), and 252 responses were from private practice physicians (65.5%). Three respondents returned the survey with incomplete demographic information.

Of 385 evaluable respondents, 360 respondents (93.5%; 95% confidence interval, 91.0–96.0%) reported having used IGRT technologies in their practices. When the use of MV portal imaging was excluded from the definition of IGRT, the proportion using IGRT was 82.3%. The majority reported using such technologies rarely (in <25% of their patients) (28.9%) or infrequently (25–50% of their patients) (33.1%). The percentages of physicians who reported using IGRT frequently (51–75% of their patients) or routinely (>75% of their patients) were 18.7% and 19.3%, respectively.

The most commonly used IGRT modalities were MV planar (62.7%), volumetric (58.8%) and kV planar imaging (57.7%). The percentage of respondents using at least one or more of these technologies was 89.4%. Ultrasound and video technologies were used by 22.3% and 3.2% of physicians, respectively.

IGRT was applied in all disease sites, most commonly genitourinary (GU) (91.1%), head and neck (74.2%), and the central nervous system (CNS) (71.9%) (Table 4). Volumetric-based technologies were the most commonly used modalities in lung (59.3%), head and neck (56.9%), gastrointestinal (56.9%), and GU (55.3%) tumors, while kV planar-based technologies were the most commonly used in CNS tumors (62.6%). Ultrasound (with the exception of GU tumors) and video were less commonly used in all sites (Figure 2).

A similar proportion of academic and private practice radiation oncologists used IGRT overall (94.7% and 94.8%, $p = 0.78$). As shown in Figure 3, there was no difference observed in the proportion of academic and private practice physicians using video, ultrasound, or MV planar modalities. However, academic physicians were more likely to use volumetric techniques (75.2% vs. 50.8%, $p < 0.001$) and kV planar techniques (72.2% vs. 50.0%, $p < 0.001$) than private practice physicians. In addition, academic physicians were more likely to use IGRT frequently or routinely (>50% of their patients) in their practice, compared to private practice physicians (47.5% vs. 31.8%, $p<0.01$).

Results were also compared based on geography, years of experience, size of practice, and specialization. The percentages of radiation oncologists using IGRT in the East, South, Midwest, and West were 92.6%, 93.1%, 94.4%, 97.4%, respectively (p=0.56). No difference was seen in utilization by years in practice; the percentages of users with 1–10, 11–20, and > 20 years in practice were 96.1%, 93.9% and 96.5% (p = 0.38), respectively. However, a difference in the type of IGRT used was seen, with physicians with ≤ 10 years in practice less likely to use MV planar-based technologies than those with > 10 years in practice (50.0% vs 65.0%, p=0.02). The percentages of respondents in practices with 1, 2–10, and >10 physicians who reported using IGRT were similar (90.7%, 94.8%, and 97.2%, respectively, p=0.31) Overall, utilization was similar for specialists and non-specialists. However, specialists were more likely to use them frequently or routinely (in >50% of their patients) compared to non-specialists (47.1% vs. 19.1%, p<0.001).

Figure 4 illustrates the cumulative adoption of each IGRT modality, based on reported years of adoption and cessation. Ultrasound and MV planar-based systems were adopted earliest. The majority of respondents using ultrasound (54.5%) reported having adopted it by 2001. However, the percentage of respondents adopting ultrasound peaked in 2006, then declined. The majority of respondents using MV planar technologies (53.4%) reported having implemented them by 2004. Adoption of kV planar-based modalities followed, with the majority of users (54.3%) having adopted them by 2006. Volumetric-based imaging modalities were implemented more recently, with the majority of users (67.1%) having adopted them by 2007. Of responders using IGRT, 40.6% planned to maintain their current level of use, while 59.1% planned to increase use. Among rare or infrequent users (≤ 50% of their patients), 65.8% planned to increase their use, while 47.0% of frequent or routine users (> 50% of their patients) users planned to increase use. One current user planned to decrease use. Among non-users, 71.4% planned to adopt IGRT technologies in the future.

DISCUSSION

Our aim in this study was to assess the utilization of IGRT technologies among radiation oncologists in the United States. We found that the great majority of practicing radiation oncology physicians currently use IGRT, with more than 90% of respondents using at least one form of IGRT in their practice. However, the majority of users implemented IGRT in less than 50% of their patients.

Although no overall difference in IGRT use existed between academic and private practice physicians, academic physicians tended to use IGRT in a larger proportion of their patients. Moreover, we found that certain modalities, notably kV planar and volumetric imaging, were used more commonly among academic physicians. The reason underlying such differences is uncertain, but may be due to different levels of access to these technologies, greater use by specialists, or use of volumetric-based imaging for research trials at academic centers.

We noted that among the various IGRT modalities, MV planar and ultrasound modalities were adopted earliest, followed later by kV planar and volumetric modalities. Utilization of ultrasound appears to be decreasing, likely due to decreasing use in favor of alternative technologies. This may be in part due to studies comparing ultrasound to other technologies, which have found planar imaging with implanted seeds and volumetric modalities to provide superior accuracy in terms of set-up and tumor localization [45–47]. We also observed that physicians with fewer years in practice tended to use MV-planar modalities less commonly, possibly signifying a decline in their use in the future. Overall, however, based on future plans of both users and non-users, IGRT utilization is expected to increase. Notably, even

physicians who reported using IGRT in the majority of patients planned to increase utilization within their practices.

This is the first study to assess the overall utilization of in-room IGRT in the radiation oncology community. We randomly sampled a large cohort of radiation oncologists representative of physicians with a wide range of characteristics. However, despite diligent attempts to collect responses from the sample, non-response and recall bias are potential limitations of this study. It is possible that IGRT non-users or users of specific technologies were less likely to respond, which would lead to biased estimates of the true prevalence of IGRT utilization. The survey was also brief and could not address questions concerning reasons for IGRT adoption. In order to address some of these limitations, we intend to conduct a follow-up survey in 2011.

Our study's findings indicate a need for further research to assess the efficacy and safety of IGRT utilization 48. IGRT technologies come with added cost, time, and, in the case of some imaging modalities, dose delivered to patients during treatment 49⁻51. The majority of literature published on these technologies reports on dosimetric consequences and set-up accuracy, but there is limited data regarding clinical outcomes, such as disease recurrence and treatment toxicity. Given the widespread and apparently increasing use of IGRT, prospective studies on clinical outcomes are needed to assess its clinical impact, safety, and cost-efficacy.

Acknowledgments

Supported by NIH T32 grant RR023254

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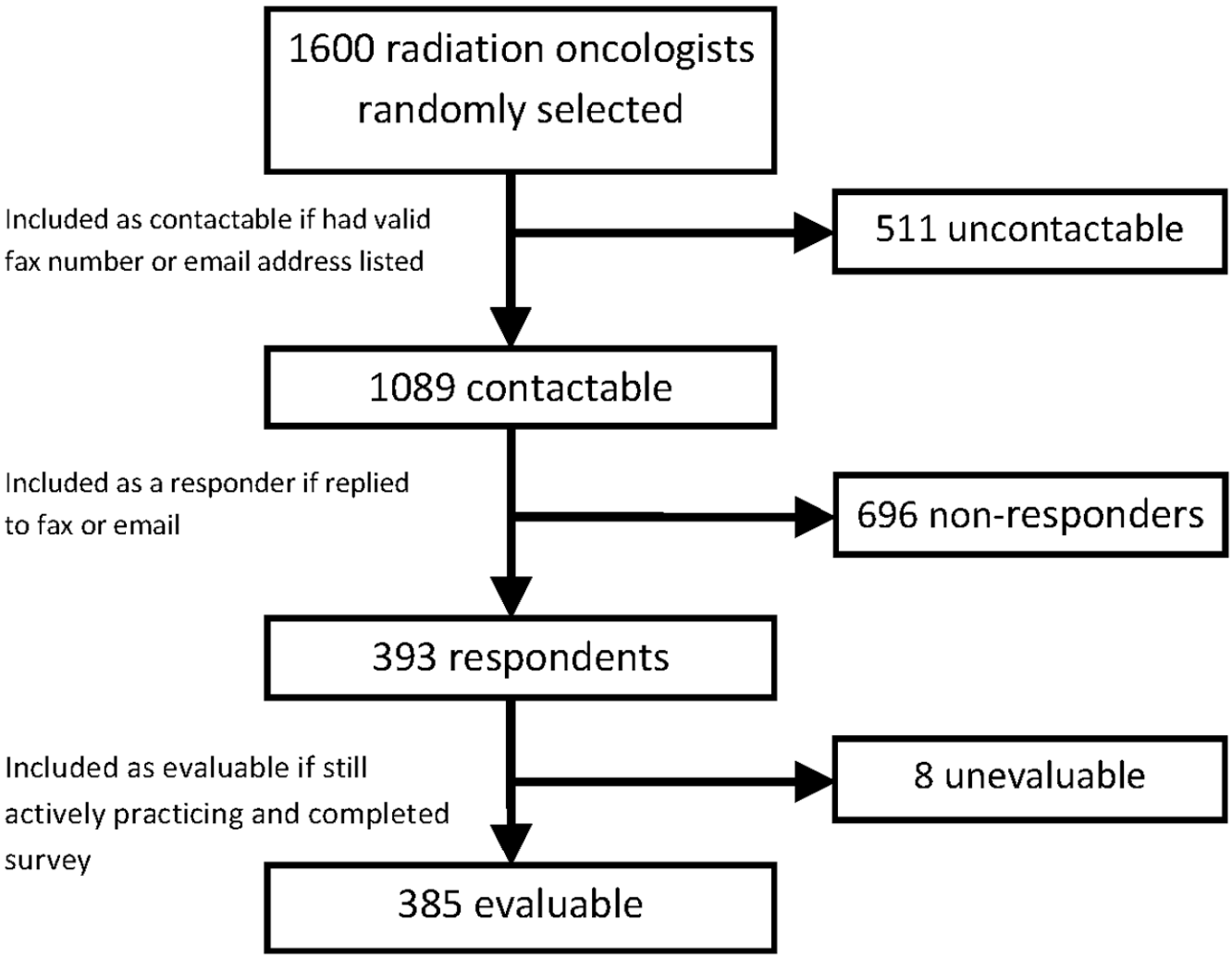

Figure 1.
Survey Flow Chart

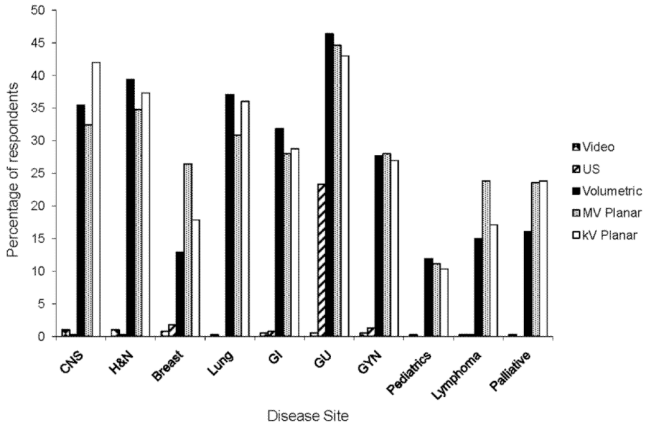

Figure 2.

Utilization of individual image-guided radiation therapy modalities, by disease site. MV, megavoltage; kV, kilovoltage; CNS, central nervous system; H&N, head and neck; GI, gastrointestinal; GU, genitourinary; GYN, gynecology.

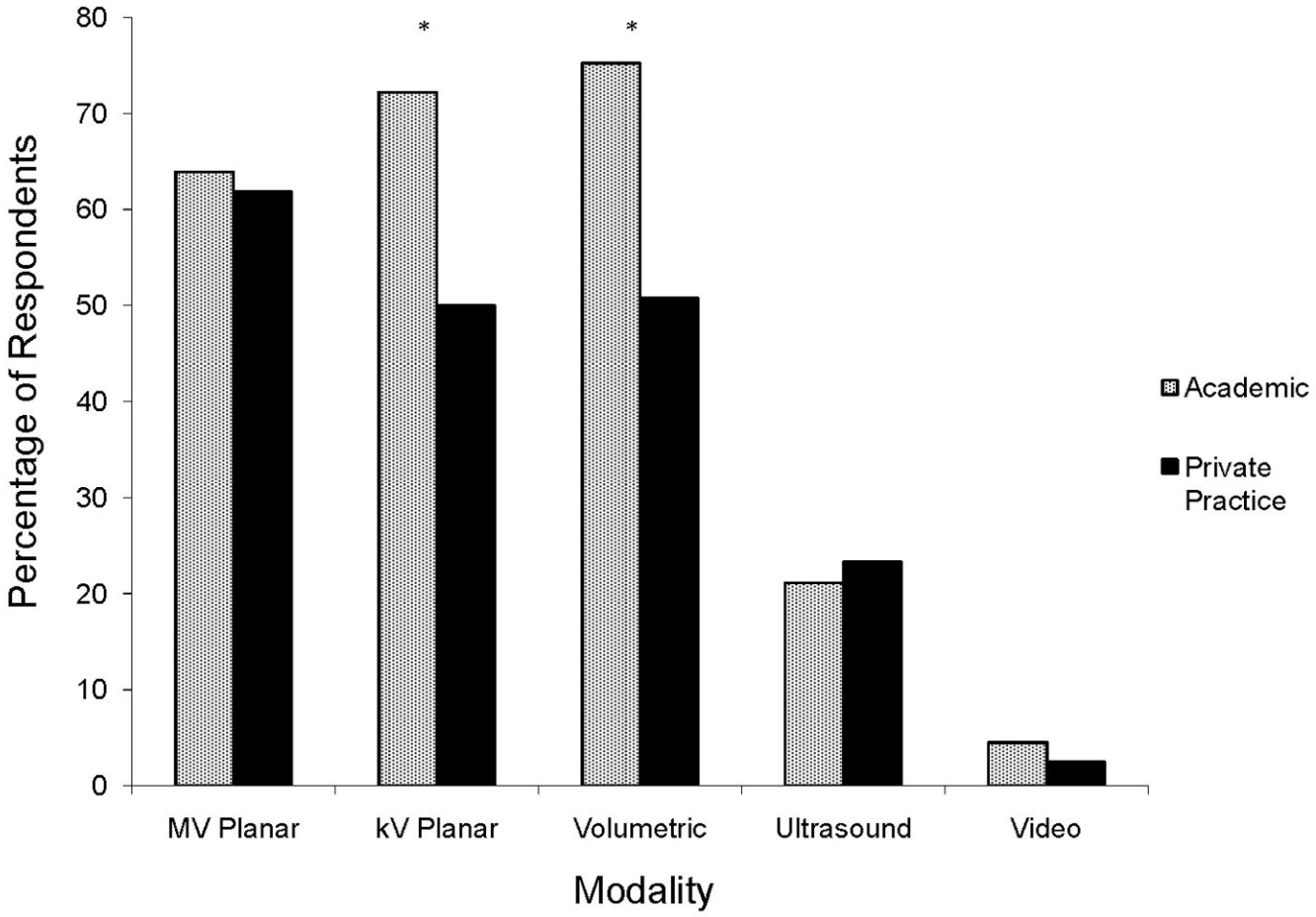

Figure 3.
Percentage of academic versus private practice physicians using image-guided radiation therapy technologies. MV, megavoltage; kV, kilovoltage. *p<0.05.

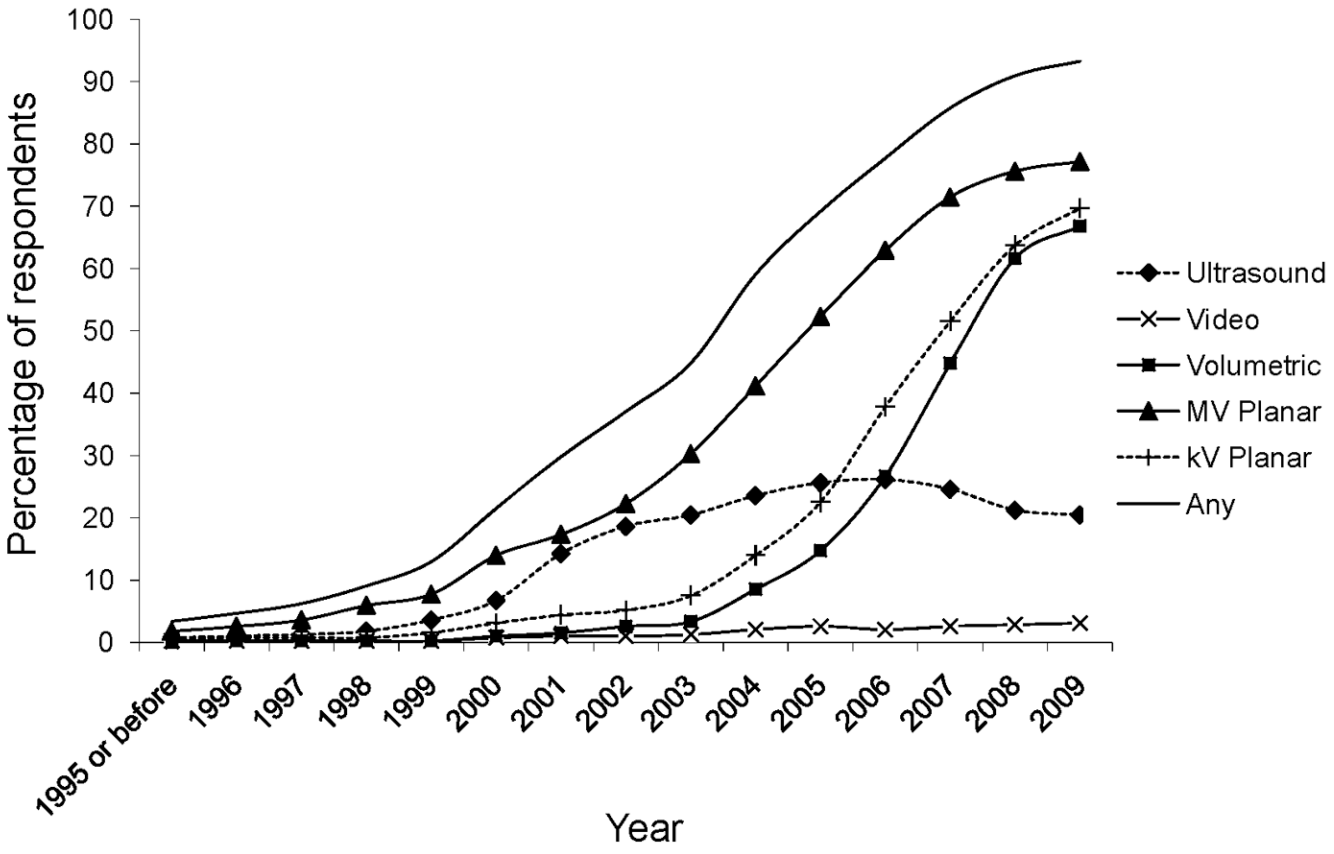

Figure 4.
Cumulative adoption of image-guided radiation therapy (IGRT) technologies. The total percentage of respondents adopting or discontinuing IGRT utilization is plotted by year. MV: megavoltage, kV: kilovoltage.

Table 1

Image-guided radiation therapy survey

1. Type of center at which you practice?			
_____Academic _____Private Practice			
2. Total number of radiation oncologists in your practice? _____			
3. What is your gender?			
_____Male _____Female			
4. What year did you graduate from residency? _____			
5. Do you limit your practice predominantly to select disease sites? If so, which sites? (If you don't limit your practice to select sites, skip to the next question)			
_____CNS _____Breast _____Lung _____GU/Prostate			
_____Other (please specify): _____			
6. Which of the following <u>in-room IGRT technologies</u> have you used for patient setup and/or tumor localization? For each technology you have used, please specify when you adopted it (including experience in residency, if any) and whether you currently still use it. If you have never used a specific technology, leave the corresponding answer space(s) blank.			
Technology	Year Adopted	Currently Use? (Yes/No)	If NO, what year did you stop?
Ultrasound			
Video			
EPID without implanted fiducial markers			
EPID with implanted fiducial markers			
On-Board Kilovoltage Imaging without implanted fiducial markers			
On-Board Kilovoltage Imaging with implanted fiducial markers			
Novalis			
Cyberknife			
Tomotherapy			
CBCT (MV or kV)			
CT-on-Rails			
If you do <u>not</u> CURRENTLY use any of the in-room IGRT technologies listed in question 6, skip to question 10			

7. Mark the disease site(s) with an "x" in which you CURRENTLY use any of the following in-room IGRT technologies. (If you don't use a specific technology in a particular disease site, leave the corresponding answer space(s) blank).

Technology	CNS	H/N	Breast	Lung	GI	GU	Gyn	Ped	Lym	Pall	Other (specify):
Ultrasound											
Video											
EPID without implanted fiducial markers											
EPID with implanted fiducial markers											
On-Board kV Imaging without fiducial markers											
On-Board kV Imaging with implanted fiducial Markers											
Novalis											
Cyberknife											
Tomotherapy											
CBCT (MV or kV)											
CT-on-Rails											

8. Approximately what percentage of your current patients are treated using any of the in-room IGRT technologies specified in question 7?

_____None ____<25% _____25–50% _____51–75% _____>75%

9. Which of the in-room IGRT technologies listed in question 7 do you most commonly use currently? _____

10. What are your future plans for in-room IGRT technologies?

_____Do not plan to adopt _____Maintain current use _____Start using / Increase use
Stop using / Decrease use

IGRT: image-guided radiation therapy; CNS: central nervous system; H/N: head and neck; GI: gastrointestinal; GU: genitourinary; Gyn: gynecological; Ped: pediatric; Lym: lymphoma; Pal: palliative; EPID: electronic portal imaging device; kV: kilovoltage, MV: megavoltage, CT: computed tomography, CBCT: cone-beam computed tomography.

Table 2

In-room image-guided radiation therapy technologies

Category	Product
Ultrasound	B-mode acquisition and targeting (BAT) system
	I-Beam
	SonArray
	Restitu/Clarity system
Video	AlignRT
	Sentinel
Planar (MV) (EPID)	iView
	Beamview
	PortalVision
Planar (kV)	Cyberknife
	Novalis
	Elekta XVI
	OBI
	TomoTherapy
Volumetric (MV)	MVision
Volumetric (kV)	Elekta XVI
	OBI
CT-on-rails	Primatom
	EXaCT

MV: megavoltage, kV: kilovoltage, OBI: On-board-imaging, CBCT: cone-beam computed tomography

Table 3

Characteristics of respondents

Number of Physicians	385
Sex, n (%)	
Male	287 (74.5)
Female	97 (25.2)
Unknown	1 (0.3)
Geographic location [a], n (%)	
Midwest	112 (29.1)
South	104 (27.0)
East	88 (22.9)
West	79 (20.5)
Unknown	2 (0.5)
Practice type, n (%)	
Academic	133 (34.5)
Private	252 (65.5)
Specialist [b], n (%)	107 (27.7)
Years in practice, median (range)	16 (1–44)
Number of physicians per practice, median (range)	5 (1–55)

[a] EAST: CT, DC, DE, MA, MD,ME,NH, NJ, NY, PA, RI, VT, WV; SOUTH: AL, AR, FL, GA, LA,MS, NC, SC, TN, TX, VA; MIDWEST: IA, IL, IN, KS, KY, MI, MN, MO, ND, NE, OH, OK, SD, WI; WEST: AK, AZ, CA, CO, HI, ID, MT, NM, NV, OR, UT, WA, WY.

[b] Specialty categories: central nervous system, breast, lung, prostate, other.

Table 4

Proportions of radiation oncologists using in-room image-guided radiation therapy to treat various disease sites.

Disease Site	Number of users (% of all users)
Genitourinary	328 (91.1)
Head and Neck	267 (74.2)
Central Nervous System	259 (71.9)
Lung	241 (66.9)
Gastrointestinal	216 (60.0)
Gynecologic	209 (58.1)
Palliative	164 (45.5)
Breast	160 (44.4)
Lymphoma	144 (40.0)
Pediatrics	86 (23.9)