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Original paper

Medical physics aspects of Intensity-Modulated Radiotherapy practice in Malaysia

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ABSTRACT

Purpose: Intensity Modulated Radiotherapy (IMRT) has changed the practice of radiotherapy since its implementation in the 1990s. The purpose of this study is to review current practice of IMRT in Malaysia.
Methods: A survey on medical physics aspects of IMRT is conducted on radiotherapy departments across Malaysia to assess the usage, experience and QA in IMRT, which is done for the first time in this country. A set of questionnaires was designed and sent to the physicist in charge for their responses. The questionnaire consisted of four sections; (i) Experience and qualification of medical physicists, (ii) CT simulation techniques (iii) Treatment planning and treatment unit, (iv) IMRT process, delivery and QA procedure.
Results: A total of 26 responses were collected, representing 26 departments out of 33 radiotherapy departments in operation across Malaysia (79% response rate). Results showed that the medical physics aspects of IMRT practice in Malaysia are homogenous, with some variations in certain areas of practices. Thirteen centres (52%) performed measurement-based QA using 2D array detector and analysed using gamma index criteria of 3%, 3 mm with variation confidence range. In relation to the IMRT delivery, 44% of Malaysia's physicist takes more than 8 h to plan a head and neck case compared to the UK study possibly due to the lack of professional training.
Conclusions: This survey provides a picture of medical physics aspects of IMRT in Malaysia where the results/data can be used by radiotherapy departments to benchmark their local policies and practice.

1. Introduction

Cancer is one of the leading causes of death in Malaysia. It is the fourth most common cause of death in this country [1]. Based on the "*GLOBOCAN 2018* estimates of cancer incidence and mortality" produced by the International Agency for Research on Cancer (IARC) [2], 43 837 new cancer cases were diagnosed in Malaysia in the year 2018 at which 47% were males and 53% were females. The top three most common cancers among Malaysian men were lung, colorectal and prostate whereas the three leading cancers among Malaysian women were breast, colorectal and cervix uteri. Radiotherapy plays an important role in the treatment of cancer apart from surgery and chemotherapy. Up to June 2019, Malaysia has a total of 33 operating radiotherapy facilities throughout the country.

Advances in radiotherapy have made it possible to deliver the highly precise radiation beam to cancer patients. Intensity Modulated Radiotherapy (IMRT) is one of the techniques providing a treatment with more conformal radiation to the target volume while minimising the radiation to the surrounding tissues [3]. This reduces the toxic effect of radiotherapy and thus improving quality of life for patients [4,5]. Another form of IMRT that has been introduced is the Volumetric Modulated Arc Therapy (VMAT), where the linear accelerator (linac) rotates around the patient during the delivery of beam in the form of arcs. The VMAT technique has a shorter beam on time compared to conventional IMRT technique. In Malaysia, a number of radiotherapy facility started IMRT in early 2000 s, but majority started IMRT services after the year 2010. At present, most radiotherapy facilities in Malaysia provide IMRT services.

The implementation of IMRT requires several steps including commissioning of the linac and treatment planning system for IMRT

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delivery, producing a treatment plan based on treatment goals and objectives as well as performing the quality assurance (QA). Guidelines for implementation of IMRT have been published in numerous publications such as the American Association of Physicist in Medicine (AAPM) [6,7], the American Society of Therapeutic Radiation Oncology (ASTRO) and American College of Radiology (ACR) [8], European Society of Therapeutic Radiation Oncology (ESTRO) [9], The Nederlandse Commissie voor Stralingsdosimetrie (NCS, Netherlands Commission on Radiation Dosimetry) [10] and Cancer Care Ontario (CCO) [11]. However, there are a lot of variations in the methods and equipment used for commissioning and conducting QA. The quality of IMRT delivery will be jeopardised if proper and stringent QA programme is not implemented. In addition, inadequate professional training of staffs would also lower the quality of IMRT treatment.

A number of studies have reported the status of IMRT practice in their countries [12–19]. In Malaysia, anecdotal evidence shows that there is a wide variety of tools and methods in implementation as well as delivery of IMRT. This study aims to report the medical physics aspects of current IMRT practice in Malaysia. Specifically, it will highlight the background and experiences of medical physicists involved in IMRT, tools and equipment used as well as the QA methods employed for pre-treatment verification. This is the first national medical physics survey on IMRT practice in Malaysia and this report summarizes the results and discusses the implications of the findings.

2. Methods

Addresses and contact information of all radiotherapy centres in Malaysia were obtained from the Medical Radiation Surveillance Division, Ministry of Health (MOH) Malaysia. All radiotherapy centres were contacted through the respective chief physicist or physicist in charge to request for their contributions to the study. Upon agreement for participation in the survey, a questionnaire was sent to the chief/senior physicist through email.

A questionnaire was developed and distributed. It contained the following four sections:

a. Medical physics staffing and experience
   i. Years of experience with IMRT
   ii. Number of IMRT cases treated
   iii. Number of physicist(s) and their qualifications
b. CT Simulation techniques
   i. Details of Computed Tomography (CT) simulator
   ii. Scanning orientation and slice thickness
c. Treatment planning and treatment unit
   i. Fusion of MRI or PET-CT for treatment planning
   ii. Model of treatment planning system (TPS)
   iii. Beam energy and arrangement
   iv. Smallest field size for commissioning
   v. Photon dose calculation algorithm and matrix size
   vi. Details of equipment used for IMRT
d. IMRT process, delivery and QA procedure
   i. Type of IMRT delivery technique
   ii. Time to produce a clinically acceptable IMRT plan
   iii. Patient-specific QA method, analysis and passing criteria
   iv. Time to perform patient-specific QA
   v. Availability of independent monitor unit calculation

To standardise answers for the survey, some questions were asked based on IMRT for head and neck treatment as this is a popular site for IMRT in this country. More than 50% of the cases treated with IMRT in majority of the centres was head and neck cases. In addition to the questionnaire, participants were invited to provide as many free form comments which deemed useful in the context of the survey. The original time frame for answering the questions was two weeks; however, responses given after a longer period were accepted. The questionnaire was sent to all centres between December 2018 and September 2019.

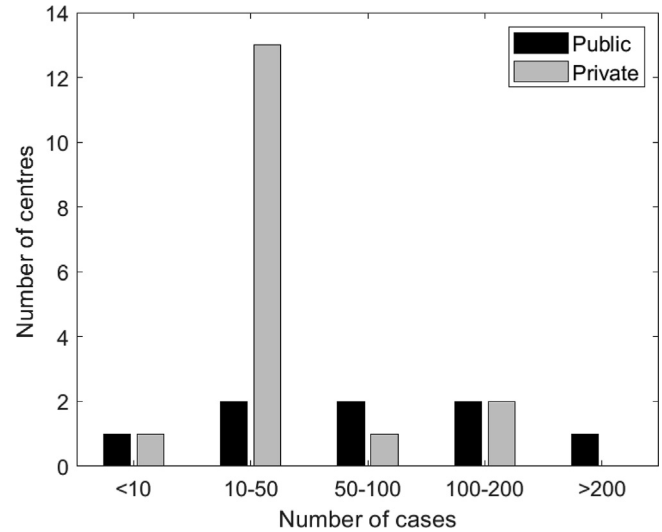

Fig. 1. Number of IMRT head and neck cases treated for the past 12 months (August 2018 to July 2019). Total responses for public and private centres were 8 and 17, respectively. There are one public and one private centre treated less than 10 cases for the past 12 months (August 2018 to July 2019).

3. Results

From the list provided by MOH, there are in total 33 radiotherapy centres in Malaysia at the time of this survey, which comprises nine public or university hospitals and 24 private centres. Answers were received from 26 centres, accounting for 79% response rate. Responding centres comprised of eight public or university hospitals and 18 private centres. However, one centre is excluded from the analysis as it does not provide IMRT service.

3.1. Medical physics staffing and experience

The experiences of centre in IMRT were assessed based on the number of head and neck cancer patients treated using IMRT as well as the duration in terms of number of years since the implementation of IMRT technique.

Fig. 1 shows the number of treated head and neck cases using IMRT for the past 12 months (August 2018 to July 2019). It can be observed that over half of the centres (both public and private) had treated less than 50 head and neck cases for the past 12 months (August 2018 to July 2019). There was only one public centre that treated more than 200 cases within 1 year. Fig. 2 shows the number of all head and neck cases treated since the commencement of IMRT technique in the responding centres. More than 50% of the centres had treated more than 100 cases since commencing IMRT services.

Fig. 3 shows experiences of the responding centres based on the number of years of implementing IMRT technique. Most public centres (7/8) in Malaysia have experiences of less than 5 years on using IMRT techniques while most private centres have experience of more than 5 years. In terms of the experience of physicist, three categories have been categorised namely, (i) senior physicist (greater than5 years working experience), (ii) physicist (3 to 5 years working experience) and (iii) junior (less than2 years working experience). There are 65% senior physicists working in radiotherapy departments in Malaysia, with 23% physicists and 12% junior physicists. Most physicists are involved in both IMRT planning and quality assurance (QA) while in few centres, senior physicists are not involved in planning and QA. All centres have at least one senior physicist in their department. Fig. 4 shows the academic qualifications of physicists at which 79% physicists

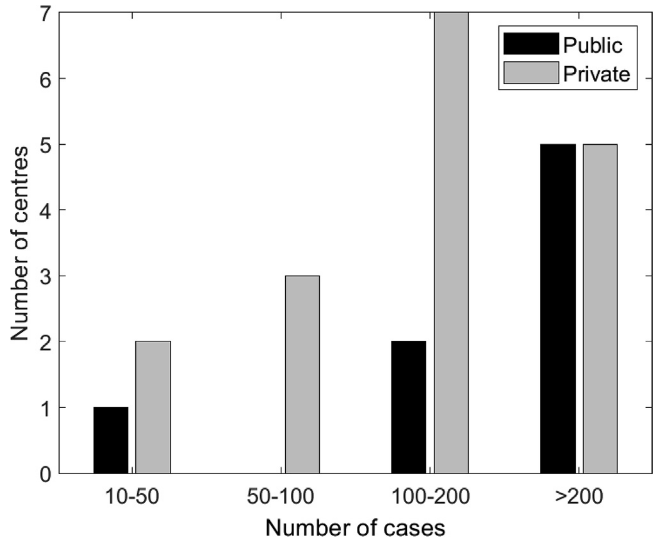

Fig. 2. Cumulative number of head and neck cases treated with IMRT since the implementation of the techniques for the participating centres. Five public and five private centres have treated more than 200 cases since they started using IMRT to treat their head and neck cancer patient.

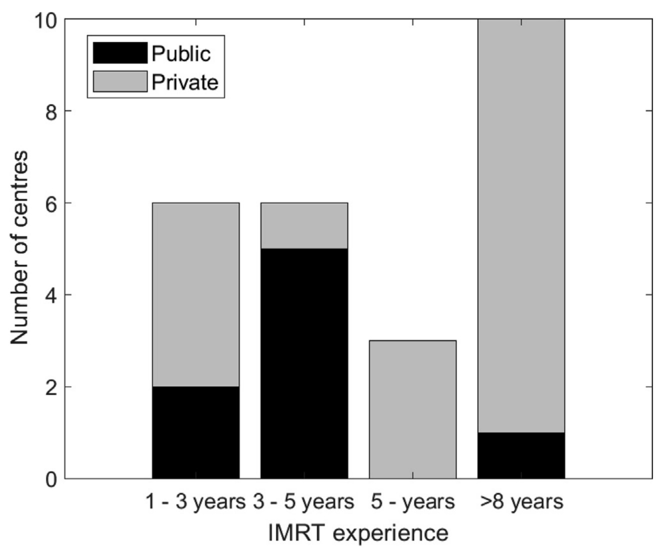

Fig. 3. IMRT/VMAT experience from responding centres. All three centres that used both IMRT and VMAT techniques have the experience of 3 to 5 years.

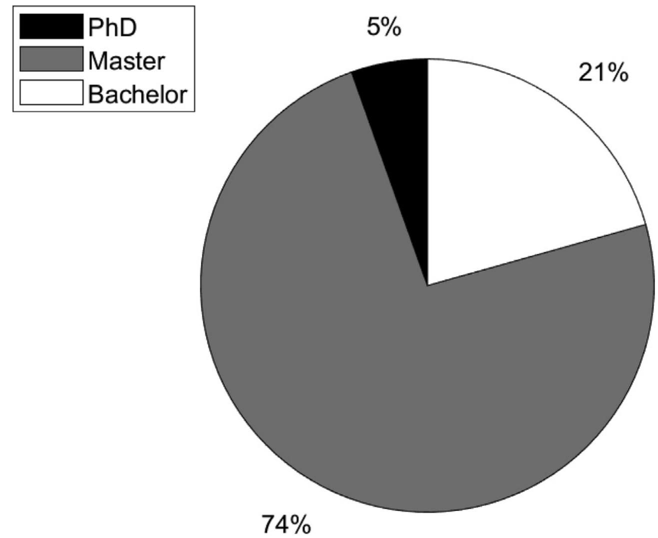

Fig. 4. Academic qualification of medical physicists in all participating centres.

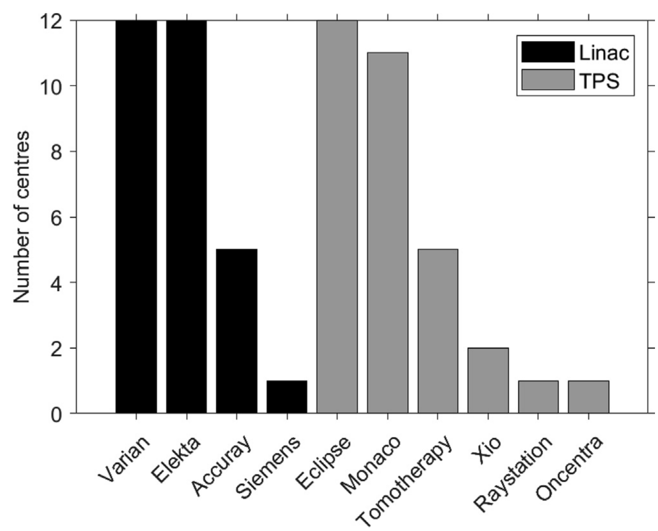

Fig. 5. Number of linacs and treatment planning systems in the responding centre.

from the responding centres have at least Master's degree qualification. It is also noted that every centre has at least one physicist with a master's degree.

3.2. CT Simulation, treatment planning and treatment unit

Data gathered in every centre show variation on the use of CT simulators. There are 14 using CT simulator from Siemens, nine centres are using CT simulator from Toshiba Medical System and two are using Philips Brilliance Big Bore. From the survey, the most common answers for head and neck cases are 3 mm for CT slice thickness. Five of the centres are using 2 mm for CT slice thickness.

64% (16/25) centres routinely performed image fusion of magnetic resonance imaging (MRI) images with CT images to assist with planning of head and neck cases. 48% (12/25) centres indicate the use of positron emission tomography (PET)-CT fusion when planning for the head and neck cases. Six different treatment planning system (TPSs) are used by the radiotherapy centres in Malaysia for generating treatment plans as shown in Fig. 5. Eclipse (n = 12), (Varian Medical Systems Inc., Palo Alto, CA, USA) and Monaco (n = 11) (Elekta AB, Stockholm, Sweden) are the most commonly used TPS for generating IMRT plans in this survey. Most of the centres used only one type of TPS, with the exception of two centres where two different TPSs are used and two centres with three different TPSs are used for generating clinical IMRT plans. Twelve centres used 2 × 2 cm fields as the smallest field collected during commissioning and four centres used 1 × 1 cm as the smallest field size during commissioning. The dose grids used are 2.5 mm and 3 mm for Eclipse and Monaco users respectively. Besides, all Tomotherapy centres (3/25) and one Radixact centre are using 1.95 mm grid size for dose calculation. All centres use 6 MV energy when treating head and neck cancer patients. Most centres use 7 to 9-field technique or 2-arc technique (if use VMAT) when planning IMRT for head and neck cases. All Eclipse users use analytical anisotropic algorithm (AAA) algorithm for photon dose calculation except for one centre that uses Acuros XB algorithm while all Monaco users use Monte Carlo-based algorithm.

3.3. IMRT process, delivery and QA procedure

40% centres (10/25) treated their patients using VMAT technique

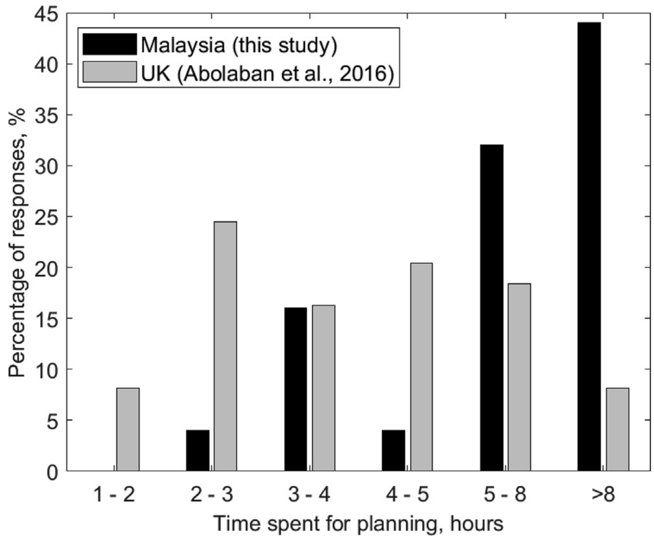

Fig. 6. Length of time taken to plan (including pseudo structure creation by physicist, optimisation and calculation) head and neck IMRT/VMAT plan.

only, while 36% (9/25) centres use IMRT only. 24% (6/25) centres use both IMRT and VMAT techniques for treating head and neck patients. Most centres (76%) delivered IMRT treatment using the dynamic MLC (DMLC) approach while two centres using the static MLC (SMLC) technique and one centre using both SMLC and DMLC techniques. For three centres with Tomotherapy treatment units and one centre with Radixact treatment unit, the binary MLCs are used to deliver VMAT (helical) technique for their patients.

The time spent to complete one acceptable head and neck treatment plan is shown in Fig. 6, with comparison made with a published study from the UK [16]. Treatment planning time includes pseudo structure delineation by physicist as well as optimisation and calculation of plan. 44% of centres in Malaysia spend more than 8 h to complete one head and neck plan compared with the UK study with only 8.2% centres. This shows that physicists in Malaysia take a longer time for planning head and neck cases.

Fig. 7 illustrates the comparison of time spent to carry out IMRT/VMAT patient-specific QA between this study and the UK survey [16]. The time spent on IMRT/VMAT patient-specific QA in Malaysia corresponds well with the UK study, with most centres spend less than 1 h for one plan. All respondents stated that patient-specific QA are performed whenever the treatment machine is available, both during and after working hours.

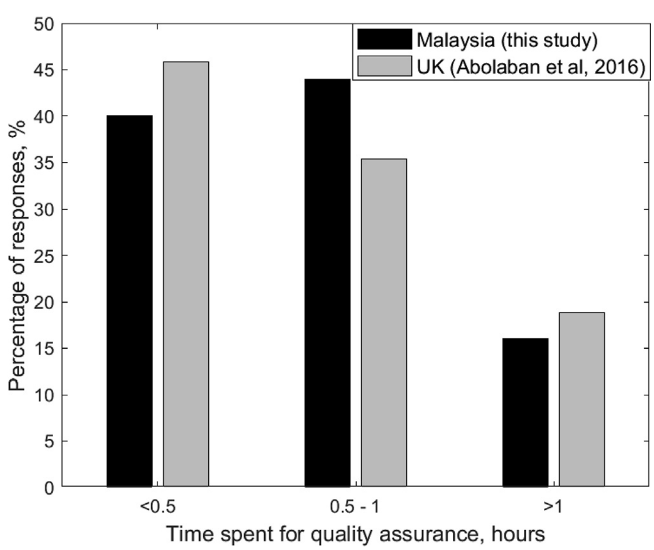

Fig. 7. Length of time taken to carry out IMRT/VMAT patient-specific QA.

Table 1
Patient-specific QA methods conducted by the respondents.

QA Process	Responses (n = 25)
Measure Every IMRT Plan	25
Other Process	
Absolute Point Dose	
Yes	14
No	11
Planar Dose	
Yes	24
No	1
Independent Mu Calculation (Software-based)	
Yes	1
No	24
Other QA related to IMRT/VMAT	
Yes	10
No	15

The responses regarding patient-specific QA equipment and methods are summarised in Table 1. All centres measure every IMRT/VMAT plan before starting treatment. 96% (24/25) of the centres perform planar dose measurement for their measurement-based QA while 56% (14/25) of the centres carry out additional point dose measurement. One centre performs only point dose measurement. There is only one centre performed software-based patient QA which is the monitor unit (MU) check as an independent tool, in addition to the planar and point dose measurements. 40% (10/25) of the centres also perform QA tests relating to IMRT/VMAT routinely such as MLC pattern check, picket fence, abutment test, tongue and groove and MLC gap test

The detector systems used by the responding centres for planar dose measurement is as shown in Table 2. The most common measurement devices used for planar dose verification were 2D-ARRAY seven29 (9/25) (PTW, Freiburg, Germany). Two centres are using EBT3 film to measure planar dose.

Table 3 shows that a composite of all fields is more common than field-by-field measurements (65% versus 35%) for planar dose measurements. 26% centres reported multiple measurement methods, including both field-by-field and composite methods for the same detector device. Most of the respondents performed QA with actual treatment angle (68%) compared to fixed gantry angle at 0° (32%). Three centres performed using both methods at actual treatment angles and fixed gantry angle at 0°. All the responding centres analyse their measurement-based QA using the gamma index analysis (GIA) [20] with a 3%, 3 mm criteria. However, the confidence range (points with gamma index less than 1) varied. Most centres use 95% passing rate of the detector points.

4. Discussion

Radiotherapy using IMRT technique is relatively new in Malaysia and this is the first report on medical physics aspects of IMRT in

Table 2
Measurement devices used by the participating centres for planar dose measurement.

Measurement Device	No of Centre
PTW Octavius 729	9
Sun Nuclear MapCHECK2	2
EPID	6
Sun Nuclear 3D ArcCHECK	3
EBT 3 film	2
IBA Matrixx Evolution	2
Scandidos Delta[4] phantom	1

Table 3
Patient-specific QA procedures by gantry angle and beam analysis method.

Patient-specific QA methods	No of Centre
Gantry angle*	
Gantry 0	9
Actual gantry angle	19
Beam analysis method**	
Composite all fields	22
Field-by-field	12

*3 centres were using both methods at actual gantry angle and gantry 0.
**9 centres were using both methods.

Malaysia. Half of the centres implemented the technique for less than 5 years. Ten centres have been treating their patient for more than 8 years. Most private centres indicated that they had started using IMRT more than 8 years ago while public centres had started using IMRT 3 to 5 years ago (around 2012 to 2017). There were 26 centres, accounting for 79% of the centres in Malaysia, participating in this survey. The survey results are therefore felt to be representative of national practice.

The implementation and delivery of IMRT are complex and time-consuming compared to 2D or 3D conformal radiotherapy [3,21]. In this survey, the average time spent by physicists in Malaysia for planning an IMRT head and neck case and performing patient specific QA were compared with a study in the UK [16]. Malaysian physicists spent a longer time compared to those in the UK for IMRT planning. The rate of centres spent more than 8 h to complete one head and neck plan was approximately 50% while this proportion in UK is only 8%. The reasons indicated by Malaysian physicists were limited number of dose calculation license and lack of training. Lack of staffing was also one of the reasons given by the respondents. The time spent on QA, however, is in good agreement with the UK study. Other than adequate professional training of the staffs, upgrades of TPS which have included implementation of more advanced algorithms as well as increasing computing power could be one of the solutions for reducing the time needed to plan.

Patient-specific QA is an indispensable task in IMRT and contributes to the medical physics workload in a radiotherapy department. The centres which have implemented IMRT for more than 8 years, on average, spent more time for patient-specific QA compared to centres with only a few years' experiences. The reason for this is unclear. Based on the survey, all centres perform patient-specific QA for all patients undergoing IMRT and VMAT using measurement-based dose verification method. All centres verify the planar doses or fluence, with a number of centres complement the measurements with point dose verification. This is a good practice that all centres are performing patient specific QA for all patients as the practice is an important part of the successful implementation of IMRT into any clinic. This practice ensures that the machine can deliver the prescribed dose by checking the accuracy of dose calculation, plan transferability and the treatment delivery [19]. It is also recommended as part of IMRT process by the AAPM, the ACR, and the Netherlands Commission on Radiation Dosimetry [6–11]. All centres are using GIA of 3%, 3 mm for evaluating IMRT QA as recommended in the work by Low et al. [20]. The result of GIA is recorded as the percentage of points that achieved $\gamma < 1$. The fail criterion is when the measurement is out of the tolerance. The new guidance published by AAPM Task Group (TG) 218 recommended using GIA of 3%, 2 mm criteria.

The response rate reported by the Australasia study [15] for the most common gamma pass rate of ≥ 95% at criteria of 3%, 3 mm were 64%, 55% and 76% across the Australasia, USA and UK surveys respectively while this study (Malaysia) reported 60% of the respondents are using gamma pass rate of ≥ 95% at criteria of 3%, 3 mm. In all four regions including Malaysia, 2D arrays were the most common QA detectors being used during patient-specific QA. Similar ranges in performing the patient-specific QA at actual gantry angles for both Malaysia and Australia with a response rate of 68% and 72% respectively. Malaysia was more likely to do analysis methods on a composite plan than Australia (65–44%), and 35% response rate from Malaysia and 56% from Australia indicated that using field-by-field analysis methods.

Moving away from measurement-based to non-measurement-based patient-specific QA is often a topic of discussion among practising physicists, including in Malaysia. However, only one centre has started to use the software-based quality assurance and it was not stated in the survey whether the centre had a plan to gradually change the method. The Australasia study reported that 86% of their centres are using software-based measurement compared to only 74% in the UK. One of the disadvantages of measurement-based QA is the uncertainty that may be contributed from setup errors. Instead of identifying the causes of failures, QA are often repeated by measuring at multiple different positions until the results achieve the acceptable tolerances. In addition, measurement-based QA requires some time to use the treatment modality, which can be difficult to get hold of at a busy department.

The main advantage of software-based patient-specific QA (e.g. based on MLC log files or MU independent check/programs) is that it can be done anytime, without having to rely on the availability of treatment machines. Moreover, there is no setup error for software-based QA and DVH comparison and dose comparison can be done for each anatomy sites. However, software-based QA may have some limitations as well. A study by Agnew et al showed that Varian MLC positional errors were caught by a measurement-based QA method due to a loose T-nut and were not detected using trajectory log files [22]. This study shows the importance of increasing linac specific QA as well such as MLC QA. Accurate leaf positioning plays an important role in the effective implementation of IMRT. Thus, it is recommended for all centres to have a comprehensive MLC program for ensuring high standard of IMRT plan delivery and consequently, accurate dose delivery to IMRT patients.

There are some guidelines and guidance that describing the QA procedures and how to evaluate the results by ASTRO) and ACR [8], ESTRO [9], NCS, Netherlands Commission on Radiation Dosimetry [10] and CCO [11]. Despite these documents, the QA procedures still have variation across the country. Technology issues are not the only factor that requires attention in managing the quality of IMRT treatments. The professional training of the medical physicists involved in IMRT treatments should be available [10]. Medical physicists involved in IMRT should have a good knowledge and grasp on every aspect of treatment, from planning to QA to ensure high quality and safe implementation of IMRT services in their institutions.

5. Conclusion

A first survey on medical physics aspects of IMRT practice in Malaysia is presented. The results of this survey provide a useful reference for a radiotherapy centre to benchmark and assess its local policies and practice in the implementation of IMRT services. Patient-specific IMRT QA is implemented in all participated radiotherapy centres and is homogenous, with some variations in certain areas of practices. Most centres adopt internationally recommended guidelines and criteria for QA. The resources can be improved in some centres, particularly on the treatment planning facilities.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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