EVALUATION OF HIGH-DOSE RATE (HDR) RADIOBIOLOGIC DOSE-EQUIVALENT WEB TOOL FOR CERVICAL CANCER

HAZIQ ASYRAAF BIN SHAFIZAN

UNIVERSITI SAINS MALAYSIA

2024

EVALUATION OF HIGH-DOSE RATE (HDR) RADIOBIOLOGIC DOSE-EQUIVALENT WEB TOOL FOR CERVICAL CANCER

by

HAZIQ ASYRAAF BIN SHAFIZAN

Thesis submitted in fulfilment of the requirements for the degree of Medical Radiation

JULY 2024

CERTIFICATE

This is to certify that the dissertation titled 'Evaluation of High-dose Rate (HDR) Radiobiologic Dose-equivalent Web Tool for Cervical Cancer,' submitted for the Degree of Bachelor of Health Science (Hons) (Medical Radiation), is a genuine record of the research work conducted by Haziq Asyraaf bin Shafizan, 153836, during the period from October 2023 to July 2024, under my supervision. I have reviewed this dissertation and, in my opinion, it meets the acceptable standards of scholarly presentation and is fully adequate in both scope and quality to be submitted in partial fulfilment of the requirements for the Degree of Bachelor of Health Science (Hons) (Medical Radiation). The research work and data collection are the property of Universiti Sains Malaysia.

Signature of Supervisor

_____

Medical Radiation
School of Health Sciences
Universiti Sains Malaysia

Date:_____

Signature of Co-Supervisor

_____

Medical Radiation
School of Health Sciences
Universiti Sains Malaysia

Date:_____

DECLARATION PAGE

I hereby declare that this dissertation is the product of my own research, except where otherwise indicated. I also confirm that it has not been previously or concurrently submitted, in whole or in part, for any other degree at Universiti Sains Malaysia or any other institutions. I acknowledge that the research work and data collection are the property of Universiti Sains Malaysia.

\

_____

Haziq Asyraaf bin Shafizan

_____

ACKNOWLEDGEMENT

To begin the thesis presentation, the highest of gratitude is expressed to The Almighty Allah SWT for giving me the time, health, and opportunity in furthering my study in medical radiation program, I believe in His plans and is confident His plan is never wrong and is the best for me, His servant. A special thank you to my main supervisor, Dr. Mohd. Zahri bin Abdul Aziz for guiding and supporting me throughout conducting this project. Without his guidance, this project is unachievable and impossible to accomplish. My co-supervisors, Dr Ahmad Lutfi Yusoff and Dr. Gokula Appalanaido also with the help of my field supervisors, and Encik Reduan bin Abdullah with Cik Arifah Nazirah binti Abdullah also deserve the utmost of gratitude due to their contributions in completing the project. During conducting the project, I am also deeply grateful and would like to express my gratitude to Dr. Mohammad Khairul Azhar bin Abdul Razab and Dr. Jayapramila A/P Jayamani who commonly motivate me and gave words of wisdom in life. I would also like to give a special dedication to my pillars of strength Sarifah Binti Omar, my grandmother, Zuraiti Binti Othman, my mother, Shamriz bin Jaafar, my uncle and my brother, Harith Danial bin Shafizan. I would also like to express my gratitude to Nor Aliah Syahirah Binti Mohd. Hadzir who always gave me her unwavering support in accomplishing this project. Furthermore, this project is also devoted to people suffering or have suffered from cervical cancer or any type of cancer especially in the world.

TABLE OF CONTENTS

Contents

LIST OF TABLES

Page

LIST OF FIGURES

LIST OF ABBREVIATIONS

AI-Artificial-intelligence

BED-biologically effective dose

EQD2-Equivalent dose in 2 Gy fraction

Gy-Gray

HPV- Human papillomavirus

RT-Radiation therapy

PAP- Papanicolaou

PENILAIAN ALAT WEB EKUIVALEN DOS RADIOBIOLOGI BERKADAR DOS LATAR BELAKANG YANG TINGGI (HDR) UNTUK KANSER SERVIKS

ABSTRAK

Setelah fasa ketepatan dan ketepatan masa berjaya, langkah seterusnya ialah penilaian menyeluruh terhadap aplikasi web berbanding templat Microsoft Excel. Ujian dengan data klinikal memastikan kekukuhan. Dokumentasi dan latihan untuk ahli fizik perubatan adalah penting. Pelaksanaan akan bermula dengan kumpulan perintis, diikuti oleh pelaksanaan skala penuh. Penilaian nilai BED dan EQD2 menunjukkan sisihan yang minimum, menunjukkan kebolehbandingan yang tinggi. Untuk tisu sasaran, sisihan BED ialah 0.048% dan EQD2 ialah 0.008%. Pundi kencing menunjukkan sisihan BED sebanyak 0.055% dan EQD2 sebanyak 0.073%. Rektum mempunyai sisihan BED sebanyak 0.014% dan EQD2 sebanyak 0.029%. Untuk sigmoid, sisihan BED ialah 0.035% dan EQD2 ialah 0.142%. Semua sisihan adalah dalam had toleransi kurang daripada 3%. Aplikasi web melengkapkan rawatan penuh dalam 138.69 saat, berbanding 202.67 saat untuk Excel, dengan TER sebanyak 1.46. Untuk pesakit tambahan pertama, aplikasi web mengambil masa 96.84 saat, manakala Excel mengambil masa 107.11 saat, memberikan TER sebanyak 1.11. Untuk pesakit tambahan kedua, aplikasi web mengambil masa 94.77 saat berbanding 78.66 saat untuk Excel, dengan TER sebanyak 0.83. Walaupun terdapat pengecualian sesekali, aplikasi web secara umumnya lebih cekap masa dan boleh dipercayai.

EVALUATION OF HIGH-DOSE RATE (HDR) RADIOBIOLOGIC DOSE-EQUIVALENT WEB TOOL FOR CERVICAL CANCER

ABSTRACT

Following successful precision and timing accuracy phases, the next step is a comprehensive evaluation of the web application versus the Microsoft Excel template. Testing with clinical data ensures robustness. Documentation and training for medical physicists are essential. Implementation will start with a pilot group, followed by full-scale deployment. Evaluation of BED and EQD2 values reveals minimal deviations, indicating high comparability. For target tissue, BED deviation is 0.048% and EQD2 is 0.008%. The bladder shows a BED deviation of 0.055% and EQD2 of 0.073%. The rectum has a BED deviation of 0.014% and EQD2 of 0.029%. For the sigmoid, the BED deviation is 0.035% and EQD2 is 0.142%. All deviations are within the 3% tolerance limit. The web application completes the full treatment in 138.69 seconds, compared to 202.67 seconds for Excel, with a TER of 1.46. For the first additional patient, the web application takes 96.84 seconds, while Excel takes 107.11 seconds, giving a TER of 1.11. For the second additional patient, the web application takes 94.77 seconds versus 78.66 seconds for Excel, with a TER of 0.83. Despite occasional exceptions, the web application is generally more time-efficient and reliable.

CHAPTER 1
INTRODUCTION

1.1 What is BED?

BED is a convenient concept in RT which helps understand different impacts of radiation based on both total doses and how it is divided into fractions. BED enables doctors to differentiate and plan radiation treatments more efficient by taking into consideration not only the radiation amount but also how it is delivered over time.

The calculation of BED is denoted by equation 2:

$$BED = nd\ (1 + \frac{d}{\alpha/\beta})$$

Equation 1 formula for calculating BED

where n is the fraction, d is dose given per fraction and α/β is part of linear-quadratic model to predict response of cells to radiation.

BED is crucial in making sure treatment effectively targets tumors and protects normal tissues (Joiner & van der Kogel, 2009).

1.2 What is EQD2?

Equivalent dose in 2 Gy fractions, is a crucial concept in RT that enables doctors differentiate treatment plans easily. Total dose and dose given in each session are heavily affect the radiation's effects. By achieving the conventional RT of 2 Gy per fraction, comparing effectiveness of different regimes are easier.

The calculation of EQD2 is denoted by the equation 1:

$$EQD2 = \frac{BED}{1 + (\frac{2}{\alpha/\beta})}$$

Equation 2 formula for calculating EQD2

where BED is the biologically effective dose calculated and α/β is part of linear-quadratic model to predict response of cells to radiation.

Comparing treatments that use different fractionation schedules, such as hypo-fractionated (few large dose) or hyper-fractionated (smaller dose) makes the EQD2 calculation crucial and essential. This ensures that the biological effect on tissues is equivalent, making it easier to evaluate and optimise treatment plans (Joiner & van der Kogel, 2009).

1.3 How BED and EQD2 is related

BED and EQD2 in 2 Gy fractions are closely related in RT, providing valuable insights in treatment effectiveness. EQD2 standardizes radiation doses to common 2 Gy per fraction meanwhile BED measures biological impact of radiation considering total doses and doses per fraction (Joiner & van der Kogel, 2009).

An equivalent dose is basically a modified version of BED which is calculated by adjusting BED to reflect EQD2 delivered in 2 Gy fractions. This adjustment ensures that EQD2 accurately represents the biological effects of radiation doses in a standardised manner, aiding in treatment comparisons and optimisation (Joiner & van der Kogel, 2009).

1.4 What is cancer?

Cancer is a complex disease characterised by the uncontrolled growth and spread of abnormal cells in the body (American Cancer Society, n.d.). These cells can invade nearby

tissues and organs, disrupting their normal function. Cancer can arise from virtually any type of cell in the body and can occur in any organ or tissue. It is often caused by genetic mutations or alterations in cellular DNA that disrupt the normal mechanisms controlling cell growth, division, and death. The hallmark of cancer is its ability to metastasise, meaning that cancer cells can break away from the primary tumour and travel through the bloodstream or lymphatic system to other parts of the body, where they forms a new tumour. This process can lead to the spread of cancer throughout the body, making it more difficult to treat. Cancer encompasses a diverse group of diseases, each with its own unique characteristics, behaviours, and treatment approaches. It is a major cause of morbidity and mortality worldwide, accounting for millions of deaths annually. Despite its complexity, significant progress has been made in understanding and treating cancer in recent decades, leading to improved outcomes for many patients. Treatment options for cancer may include surgery, radiation therapy, chemotherapy, targeted therapy, immunotherapy, or a combination of these approaches, is depending on the type and stage of the disease.

1.5 Cervical cancer

Cervical cancer emerges from abnormal cell growth in the cervix, the lower segment of the uterus (American Cancer Society, n.d.). It typically results from persistent infection with specific types of HPV, a sexually transmitted virus. Although most HPV infections clear up on their own, some can evolve into cervical cancer.

The progression of cervical cancer tends to be gradual, often without evident symptoms in its early stages. However, as the disease advances, symptoms such as irregular vaginal bleeding, pelvic discomfort, and pain during intercourse may arise.

Effective screening methods, such as PAP tests and HPV tests, play a crucial role in detecting cervical cancer in early stage when treatment is most successful. Treatment options for cervical cancer typically encompass surgery, radiation therapy, chemotherapy, or a combination thereof, tailored to patient’s needs.

Preventive measures include HPV vaccination, recommended primarily for adolescents and young adults to diminish cervical cancer risk (American Cancer Society, n.d.).

1.6 Statistic of cervical cancer in Malaysia

The Star, 2024 highlights the alarming statistics on cervical cancer in Malaysia. According to the Global Cancer Observatory (GCO), cervical cancer is the fourth most common cancer affecting women in Malaysia, with 1,740 cases in 2020, of which 991 or 57% succumbed to the disease. The GCO also estimated that over 12 million women in Malaysia aged 15 and above are at risk of developing cervical cancer. Additionally, the HPV Information Centre reported that it is the second most frequent cancer among Malaysian women between the ages of 15 and 44. Globally, cervical cancer is the fourth most common cancer in women, with an estimated 604,000 new cases diagnosed in 2020. The World Health Organisation (WHO) recommends HPV vaccination at the age of nine to 14 to prevent HPV infection, cervical cancer, and other HPV-related cancers.

1.7 Risk factors

Cervical cancer risk factors include parameters like receiving certain types of HPV, not receiving vaccination against HPV, having sex early or with multiple partners, smoking, weak immune systems, family history of cervical cancer, and other related factors. These factors make it more likely for someone to get cervical cancer, so it's important to get vaccinated, get regular check-ups, and try to stay healthy (American Cancer Society, n.d.).

1.8 The importance of EQD2 & BED calculation

The computation of EQD2 and BED holds significant importance in radiation therapy for several key reasons. Firstly, EQD2 and BED offer a standardised method to compare various radiation treatment plans, considering both the total radiation dose administered and the dose per fraction (Joiner & van der Kogel, 2009). This enables clinicians to evaluate the relative biological efficacy of different treatment schedules and tailor therapy strategies to optimise tumor control while minimising harm to surrounding healthy tissues. Moreover, EQD2 and BED calculations aid in predicting and comprehending the long-term consequences of radiation exposure, guiding decisions on treatment duration, dose escalation, and fractionation schemes. By integrating the biological effects of radiation, EQD2 and BED computations enhance the accuracy and effectiveness of radiation therapy, ultimately leading to improved patient outcomes and reduced risks of treatment-related complications.

Manual miscalculations in EQD2 and BED can indeed jeopardise patient's health. Mistakes in these calculations may result in inaccurate assessments of treatment efficacy and potential harm to patients. For example, underestimating the biological effectiveness of radiation could lead to inadequate tumor control, while overestimating it may result in excessive damage to surrounding healthy tissues. Therefore, it is crucial for radiation oncologists and medical physicists to utilise accurate and validated methods for EQD2 and BED calculations to ensure the safety and effectiveness of the treatment. Additionally, automated software tools and quality assurance procedures can help to minimise the risk of manual errors and enhance the reliability of this calculation in clinical practice.

1.9 Problem statement

Medical physicist are using a Microsoft Excel template that is unable to calculate the BED and EQD2 of target and OAR simultaneously. Therefore, this web-app enables medical physicist to calculate the EQD2 and BED of target and OAR simultaneously with little to no difference and quickly hassle free.

1.10 Objective of study

To assess a web-based tool for high-dose rate (HDR) radiobiologic dose-equivalents specifically for cervical cancer.

1.10.3 Specific objective

To evaluate radiobiologic dose-equivalent web tool for cervical cancer by comparing with manual EQD2 and calculation of Microsoft Excel by ensuring software functions optimally for target and OAR.

1.10.4 Specific objective

To evaluate radiobiologic dose-equivalent web tool for cervical cancer by comparing with manual BED calculation of Microsoft Excel by ensuring software functions optimally for target and OAR.

1.10.5 Specific objective

To evaluate radiobiologic dose-equivalent web tool for cervical cancer by comparing the time to complete a treatment prescription of patient by comparing the Microsoft Excel template and web-app calculation time.

1.11 Web-app evaluation

In contemplating the accuracy of a web application against a Microsoft Excel template for calculating BED and EQD2, a systematic evaluation approach is envisioned. This assessment aims to determine whether the web application can perform comparably to the established Excel template. Key phases of this evaluation include the precision accuracy phase and the timing accuracy phase. The goal is to enhance the workflow efficiency of medical physicists by reducing the redundancy associated with manually adjusting the (α/β) ratio in Excel. Achieving consistency and reliability in dose calculations is crucial, as it ensures precise and accurate clinical applications. The acceptance limit to consider successful evaluation is if the percentage difference (<3%) Refinements and adjustments to the web application will be necessary to meet the stringent standards required for clinical use, ultimately supporting its integration into medical practice. By carefully evaluating both the precision accuracy and timing accuracy of the web application, and making necessary adjustments based on feedback and testing, the goal of replacing the Microsoft Excel template for BED and EQD2 calculations can be achieved, ultimately making the workload of medical physicists more efficient and less error-prone.

1.11.1 Precision accuracy phase

The precision accuracy phase involves several key steps. Initially, data collection and preparation are conducted by identifying all input parameters used in the BED and EQD2 calculations, such as dose per fraction, total dose, alpha/beta ratio, number of fractions, and other relevant clinical parameters. A diverse set of sample data is then prepared to cover a wide range of clinical scenarios, including varying doses, fractionation schedules, and alpha/beta ratios. Next, a calculation comparison is performed, starting with benchmarking where the Microsoft Excel template is used to perform calculations on the sample data sets to obtain the reference BED and EQD2 values. The same data is then input into the web application, and the

output is recorded. Finally, an accuracy assessment is carried out through statistical analysis, comparing the results from the web application with the Excel template using statistical methods to calculate the percentage error. Acceptable tolerance levels for the differences between the web app and Excel template results are established, ideally ensuring that differences are minimal and within clinically acceptable limits.

1.11.2 Timing accuracy phase

The second phase of evaluation is the timing accuracy phase where it assesses the efficiency of the web application in performing calculations compared to the Microsoft Excel template. This phase begins with baseline timing, where the time taken to perform BED and EQD2 calculations using the Excel template is measured across various scenarios, including data entry, formula application, and manual adjustments like changing the alpha/beta ratio. The timing for the web application is then measured, covering the entire process from data input to obtaining the final results. Following this, a comparison is made between the timing data from both the Excel template and the web app, calculating the time saved per calculation and overall efficiency improvements. Finally,The usability of the web app is also evaluated to identify any bottlenecks or areas for potential time savings. Based on this timing data, iterative improvements are made to enhance the app's speed and efficiency.

CHAPTER 2
LITERATURE REVIEW

In this chapter, a summary of preexisting research on web applications and on the project will be showcased. Ranging from what is brachytherapy to why miscalculations are dangerous, it is evident that medical physicist has tried numerous ways to transition from manual calculation to automatic calculation in which will further improve the process by having less mistake due to human limitations and mistakes as compared to automated calculations. Nevertheless, it is wise to acknowledge the human way as it was the way for many years but unfortunately every good thing must come to an end and is in dire need of an upgrade. Nevertheless, it must be noted that earlier studies whole-heartedly agreed that the help of automation can be very beneficial.

2.1 Automated Calculation in RT

Tseng et al., 2024 introduces an automated Monte Carlo (MC) workflow to improve radiation dosimetry studies. This workflow aims to streamline dosimetry analysis and expand MC applications in clinical practices. It performs secondary independent dose calculations and verifications, ensuring accuracy in dosimetric data from treatment planning systems and actual beam measurements. MC simulations offer detailed dosimetric information, particularly useful in special radiotherapy procedures with non-standard setups. The workflow can be adapted to various clinical settings, requiring customization for different equipment configurations to ensure accurate MC simulations.

2.2 Previous studies

2.2.1 Method Obtaining EQD2

Nag, S. and Gupta, N. (2000) A Simple Method of Obtaining Equivalent Doses for Use in HDR Brachytherapy

- Summary: This study proposes a simplified method for calculating equivalent doses in high-dose-rate (HDR) brachytherapy. The approach involves adjusting the total dose based on biological effectiveness, considering differences in dose rate and fractionation between HDR and conventional therapies. This method helps in ensuring accurate dose delivery and improving treatment outcomes in brachytherapy.

2.2.2 The usage of Microsoft Excel

Cheng, G. et al. (2020) Predictive Value of Excel Forms Based on an Automatic Calculation of Dose Equivalent in 2 Gy per Fraction in Adaptive Brachytherapy for Cervical Cancer

- Summary: This paper explores the use of Excel-based forms for predicting dose equivalents in adaptive brachytherapy for cervical cancer. The automated calculations allow for precise adjustment of dose distributions, enhancing treatment planning and execution. The study demonstrates the reliability and effectiveness of these forms in clinical settings.

2.2.3 Variation optimisation techniques

Azahari, A.N. et al. (2022) Variation of Optimisation Techniques for High Dose Rate Brachytherapy in Cervical Cancer Treatment

- Summary: The authors investigate different optimisation techniques for HDR brachytherapy in cervical cancer treatment. The study compares various methods to determine the most effective approach for maximizing tumor control while minimising exposure to healthy tissues. Results indicate significant differences in outcomes based on the optimization technique used, highlighting the importance of method selection in treatment planning.

2.2.4 Validation of automated post-adjustments

Dohlmar, F. et al. (2023) Validation of Automated Post-Adjustments of HDR Prostate Brachytherapy Treatment Plans by Quantitative Measures and Oncologist Observer Study

- Summary: This research validates the use of automated post-adjustments in HDR prostate brachytherapy treatment plans. Quantitative measures and evaluations by oncologists confirm the accuracy and clinical relevance of these automated adjustments, suggesting they can effectively improve treatment precision and outcomes.

2.2.5 Maxicalc

Hanlon, M.D., Smith, R.L. and Franich, R.D. (2022) MaxiCalc: A Tool for Online Dosimetric Evaluation of Source-Tracking Based Treatment Verification in HDR Brachytherapy

Summary: MaxiCalc is introduced as a tool for the online dosimetric evaluation of source-tracking in HDR brachytherapy. The study highlights its capabilities in real-time verification of dose delivery, ensuring accurate treatment execution. The tool enhances the safety and effectiveness of brachytherapy by providing immediate feedback and corrections during treatment.

2.3 What is gynaecological Cancer

Gynaecological cancers arise in different regions of the female reproductive system, like the cervix, ovaries, uterus, vulva, and vagina. These cancers occur when cells within these organs undergo abnormal growth. Symptoms can differ based on the type of cancer but might include irregular vaginal bleeding or discharge, abdominal discomfort, pain during sexual intercourse, itching around the vaginal opening, trouble with urination, and alterations in bowel patterns. Experiencing these symptoms doesn't automatically imply cancer, yet seeking medical advice for assessment and diagnosis is essential (Cancer Society of New Zealand, n.d.).

2.4 The dire effects of miscalculations

Passen & Powell Law Firm, n.d. discusses the misuse of radiation therapy in cancer treatment. It outlines various instances where radiation therapy has been improperly administered, leading to serious harm to patients. Examples include overdoses, incorrect targeting of radiation, and failure to monitor patients during treatment. Passen & Powell Law Firm, n.d. emphasises the severe consequences of such errors, including permanent injury, pain, suffering, and even death. It also highlights the responsibility of healthcare providers to adhere to safety protocols and standards of care in radiation therapy. Overall, (Passen & Powell Law Firm, n.d.) serves as a resource for individuals who have experienced harm due to radiation therapy errors and provides information on seeking legal recourse for damages.

2.5 The importance of EQD2

Abbott et al. (2023) address the limitations of Equivalent Dose in 2 Gy fractions (EQD2) for voxelized dosimetry, proposing the Equivalent Physical Dose (EPD) as a more accurate alternative. The study demonstrates that EQD2 can lead to significant errors in heterogeneous dose distributions and advocates for EPD to enhance the precision of radiotherapy treatment planning (Abbott et al., 2023).

2.6 The importance of BED

BED is a measure that considers the effects of radiation dose and fractionation on tumor control and normal tissue toxicity. (Jones *et al.*, no date) explains that BED can be used to compare the biological effects of different radiation regimens, such as those used in brachytherapy and external beam radiation therapy. By calculating the BED for a given treatment, clinicians can estimate the likelihood of tumor control and the risk of normal tissue complications. (Jones *et al.*, no date) also highlights the importance of considering BED when designing and evaluating radiation therapy protocols. By optimising the BED, clinicians can aim to maximising tumor control while minimising the risk of side effects. Overall, (Jones *et al.*, no date) emphasises the utility of BED as a tool for optimising radiation therapy in clinical oncology and provides a framework for comparing and evaluating different treatment regimens.

CHATPTER 3

MATERIAL AND METHODOLOGY

3.1 Materials

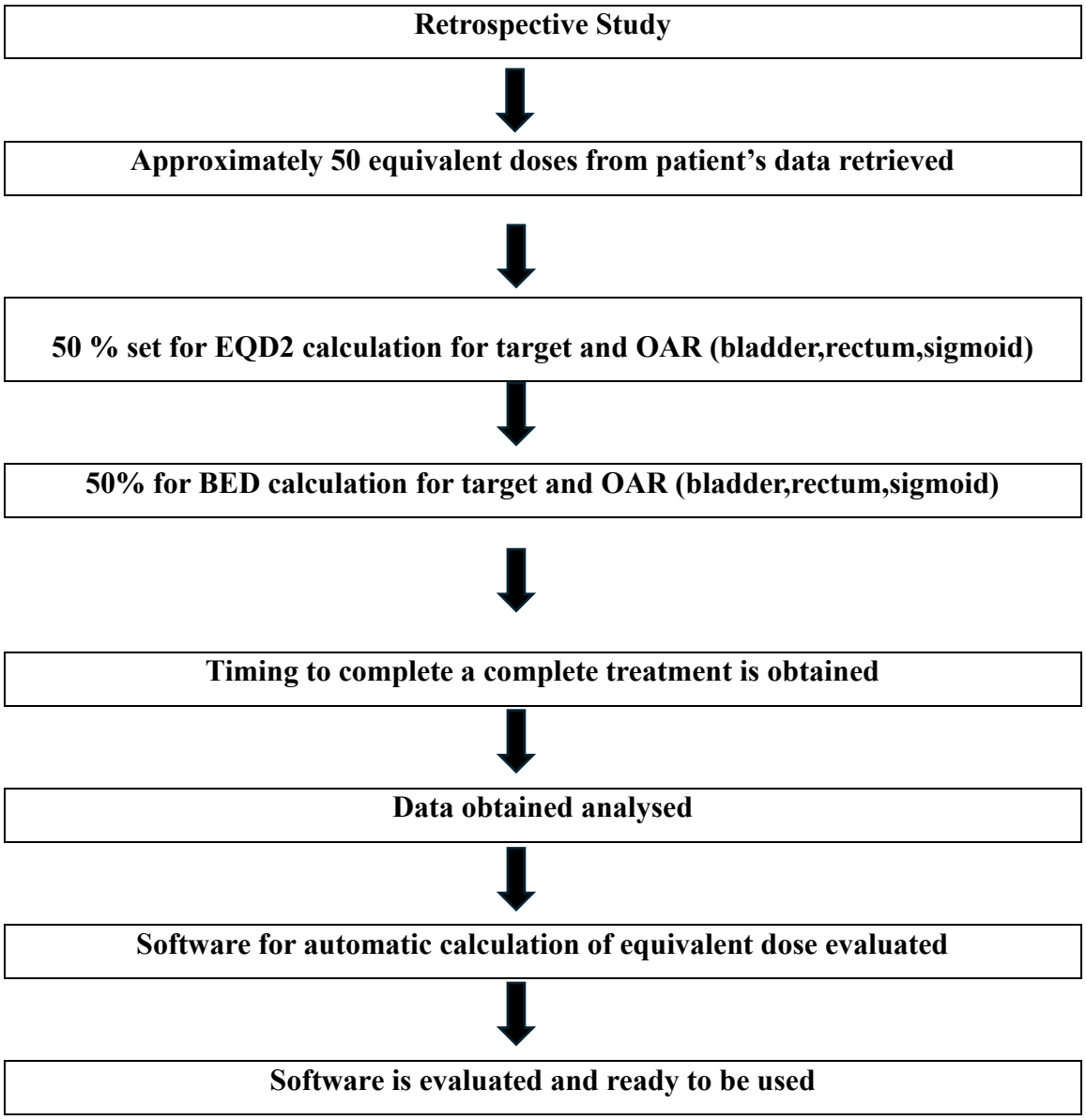
The evaluation of the High-Dose Rate (HDR) radiobiologic dose-equivalent web tool for cervical cancer involved a meticulously developed web-app using Google Apps Script. This web-app was designed to streamline and enhance the accuracy and efficiency of calculating Biologically Effective Dose (BED) and Equivalent Dose in 2 Gy fractions (EQD2), which are critical for effective radiation therapy planning. The Google Apps Script framework was chosen for its robust capabilities in automating complex calculations, integrating seamlessly with Google Sheets for data management, and providing a user-friendly interface for medical physicists. The development process included extensive coding to ensure precise algorithm implementation for BED and EQD2 calculations, accommodating different α/β ratios for various tissues, including target tissues and organs at risk (OAR). Rigorous testing phases were conducted to validate the app's performance, ensuring minimal deviations in dose calculations compared to the traditional Microsoft Excel templates. The web-app's functionality was further enhanced by incorporating features such as automated error-checking, real-time calculation updates, and comprehensive data logging for future reference. By leveraging the capabilities of Google Apps Script, the web-app provides a reliable, efficient, and user-friendly tool for medical physicists, significantly reducing calculation time and minimizing the risk of human error, ultimately improving the quality of patient care in cervical cancer treatment.

3.2 Study design

This is a retrospective study to evaluate a web-apps tool in calculating EQD2 and BED for cervical cancer for tumour and OAR. 50 patients' data with cervical cancer were obtained based on inclusion and exclusion criteria. The web-app software evaluation is divided into two which are the precision accuracy phase and timing accuracy phase.

3.3 Study flow chart

Figure 1 Study flowchart



3.4 Sample size calculation

Cochran's formula (1997) is used to determine sample size for this research with 95% within 0.5 true value confidence level.

$$N = \left(\frac{Z}{\Delta}\right)^2 p(1-p)$$

Equation 3 Cochran's formula

Where N = sample size

Z = value representing desired confidence level

Δ = precision or true value

P = anticipated dataset proportion

Confidence level corresponds to Z-score. 95% constant value is 1.96. True value is assumed 0.05. Estimated dataset proportion p = 0.966

$$N = \left(\frac{1.96}{0.05}\right)^2 0.966(1 - 0.966)$$

$$N = 50.4$$

$$N \approx 50$$

Approximately 50 patients' data are needed for this project.

3.5 Subject criteria

The data from patient that successfully underwent gynaecological cancer treatment at PPUSMB

3.5.1 Inclusion criteria

The patients' data used are asked for permission to get consent and patients that have done both the treatment of EBRT and brachytherapy at PPUSMB

3.5.2 Exclusion criteria

The patients who are still undergoing treatment for gynaecological cancer at PPUSMB and palliative patients suffering from gynaecological cancer

3.6 Data Collection

The data collection was conducted at PPUSMB. The equivalent dose data was retrieved from PPUSMB and filtered from 2020-2024 meaning equivalent dose from these cases are still considered new.

3.7 Data method assessment

The data collected was systematically analysed by first organising it into a comparative table, which allowed for a clear and structured presentation of the results from both the web-based tool and the Microsoft Excel template. This table was subsequently transformed into a visual figure to provide a more intuitive and immediate representation of any significant differences between the two methods. To further ensure the accuracy and reliability of the results, the percentage deviation of the data was calculated. This calculation was crucial for verifying that the deviations between the web-based tool and the Excel template remained within an acceptable tolerance limit, specifically less than 3%. By maintaining deviations within this threshold, it was ensured that the web-based tool's performance was consistent with established benchmarks, thereby validating its effectiveness for clinical use in calculating radiobiologic dose-equivalents for cervical cancer treatment.

3.8 Data evaluation

To ensure the feasibility of this evaluation, the process will be structured into two distinct phases: the accuracy evaluation phase and the timing evaluation phase. The accuracy evaluation phase will focus on verifying that the measurements and calculations are precise, while the timing evaluation phase will assess the promptness and efficiency of the procedure. For the evaluation to be deemed successful and to be considered comparable to the Microsoft Excel template, it is essential that both phases achieve a deviation of less than 3%. This stringent criterion ensures that the results are both accurate and timely, meeting the required standards for reliable and effective assessment.

3.9 Data analysis

In evaluating the accuracy of a web application against a Microsoft Excel template for calculating BED and EQD2 values, it is crucial to compare results from both phases—precision accuracy and timing accuracy—tediously and meticulously to ensure utmost precision.

During the precision accuracy phase, extensive statistical analysis is conducted to verify that the output of the web application aligns closely with that of the Excel template. The focus

is on ensuring that the web application consistently produces reliable and accurate dose calculations. Any discrepancies found are carefully examined and corrected to maintain high standards of accuracy.

In the timing accuracy phase, the efficiency of the web application is scrutinized to confirm that it matches or exceeds the performance of the Excel template in terms of speed and user experience. This involves measuring the time taken for calculations, data entry, and overall user interaction with the web application.

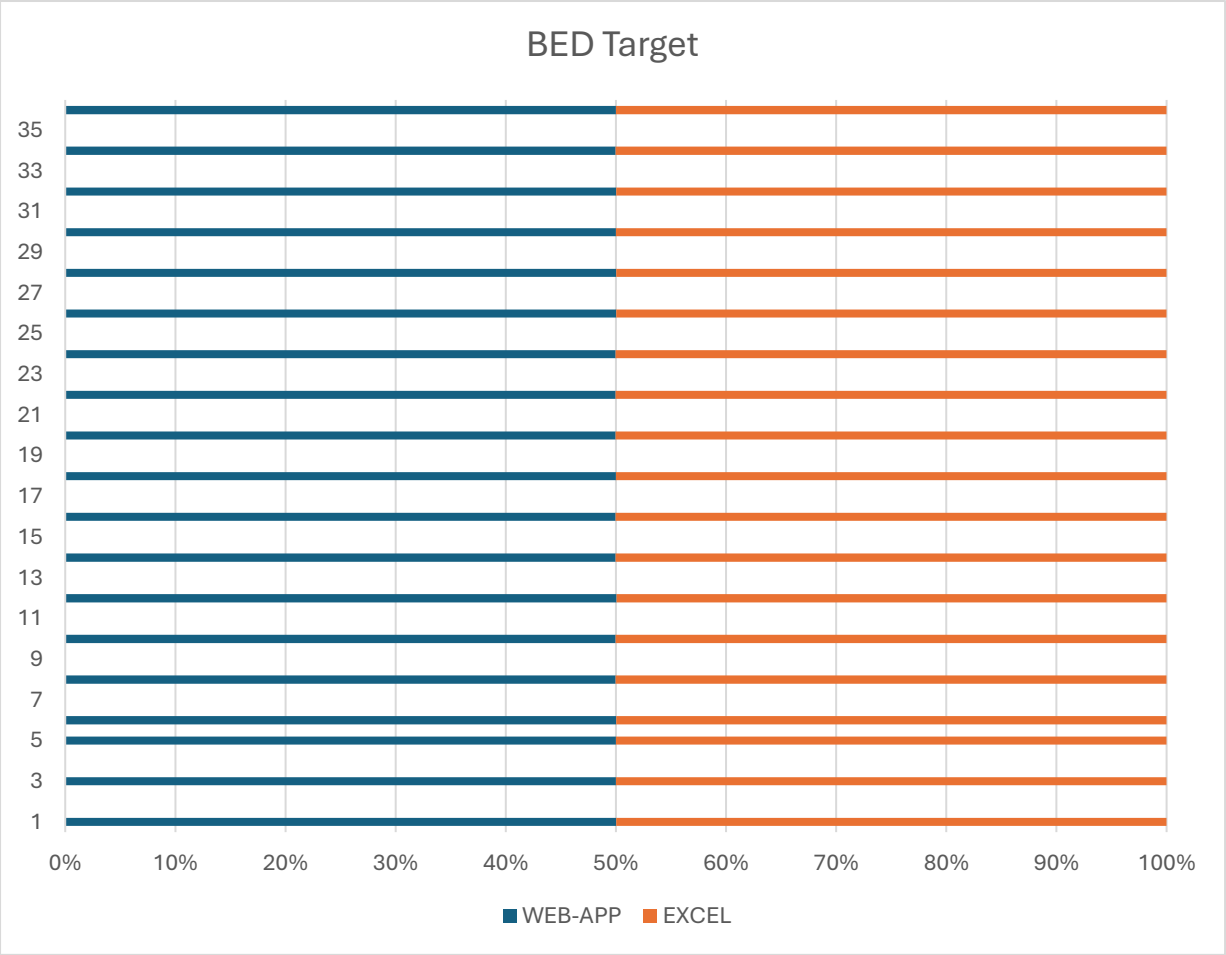
Through these thorough comparisons and adjustments, the web application is refined to meet the stringent standards required for clinical use. These refinements will ensure that the web application can reliably replace the Microsoft Excel template, ultimately supporting its integration into medical practice and making the workload of medical physicists more efficient and less prone to errors.

CHAPTER 4

RESULTS

4.1 The difference between web-app and Microsoft Excel template for BED target

Figure 2 Graph representing BED target for web-app and Microsoft Excel template



4.2 The difference between web-app and Microsoft Excel template for BED OAR

Figure 3 Graph representing BED bladder for web-app and Microsoft Excel template

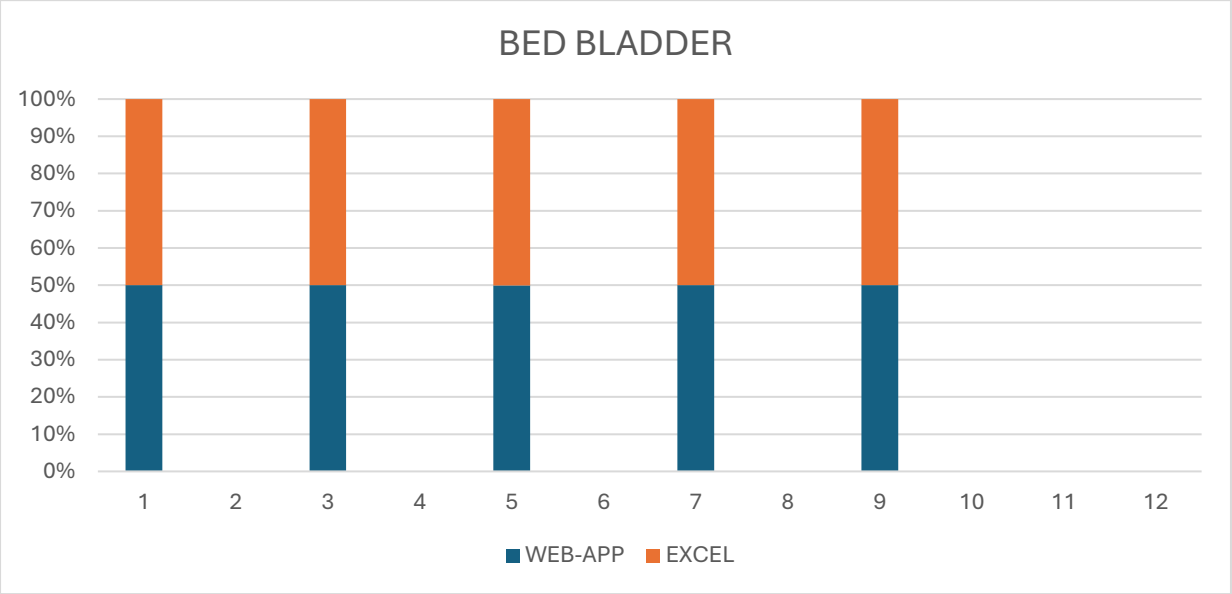


Figure 4 Graph representing BED rectum for web-app and Microsoft Excel template

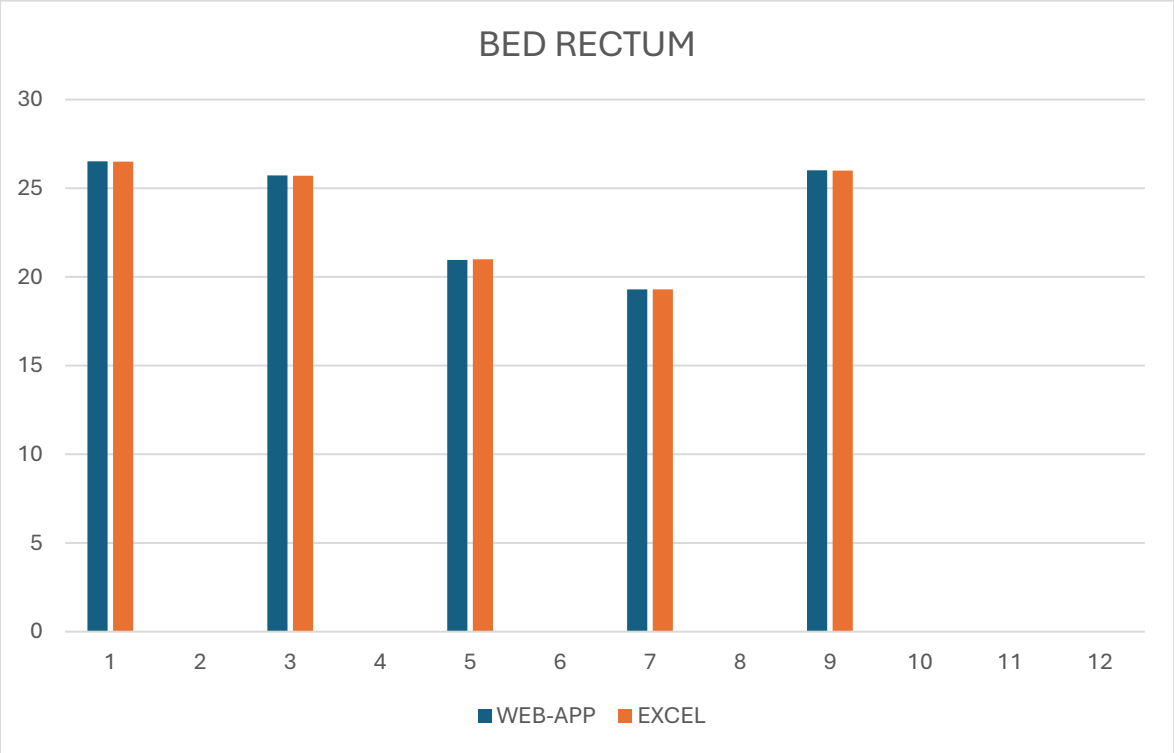
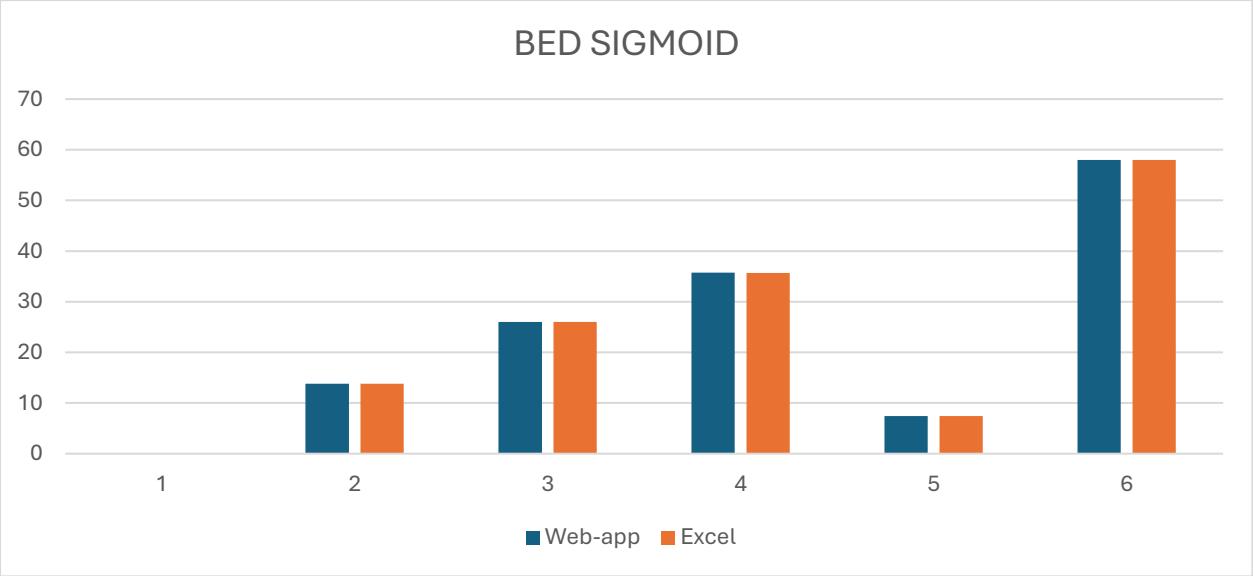
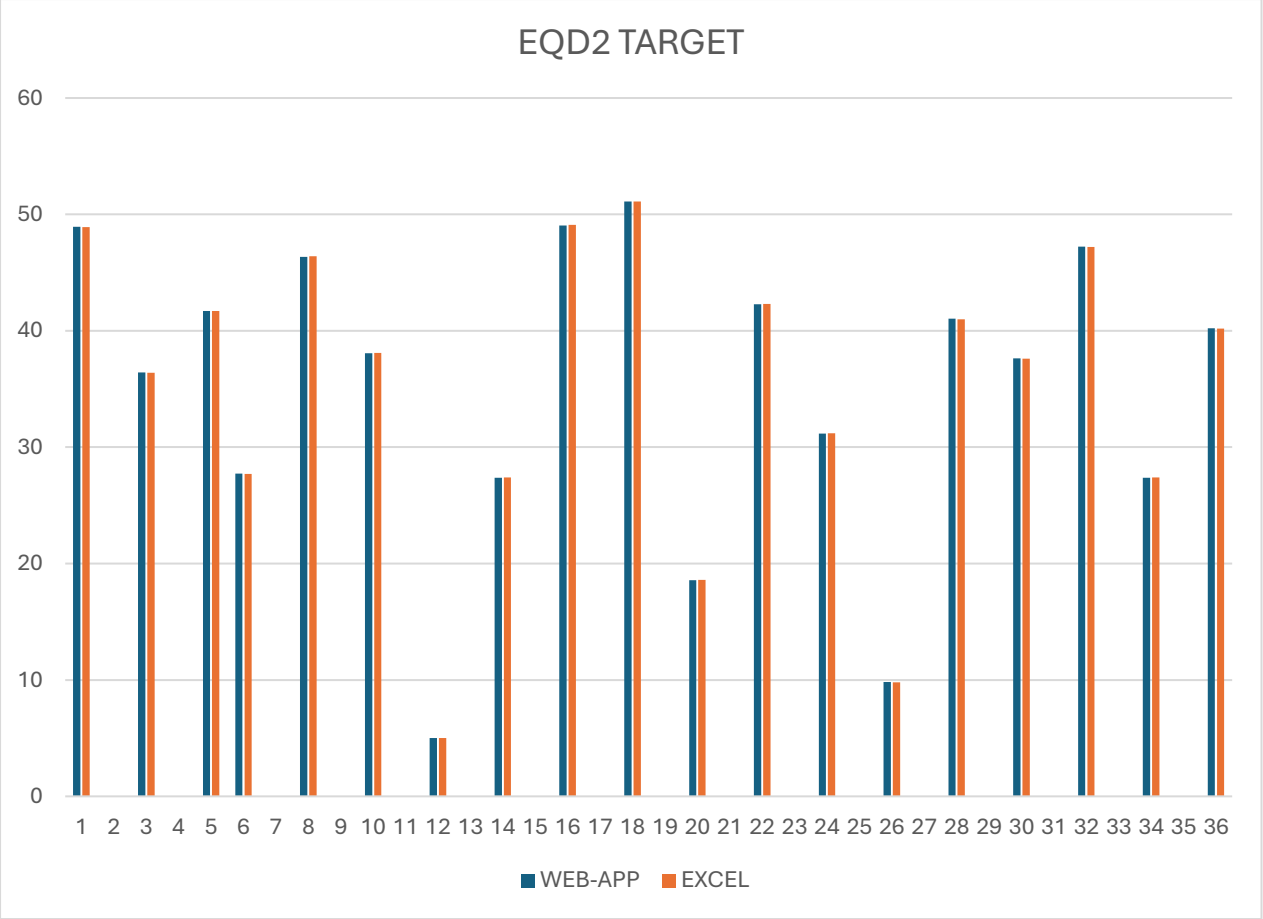


Figure 5 Graph representing BED sigmoid for web-app and Microsoft Excel template



4.3 The difference between web-app and Microsoft Excel template for EQD2 target

Figure 6 Graph representing EQD2 target for web-app and Microsoft Excel template



4.4 The difference between web-app and Microsoft Excel template for EQD2 OAR

Figure 7 Graph representing EQD2 bladder for web-app and Microsoft Excel template

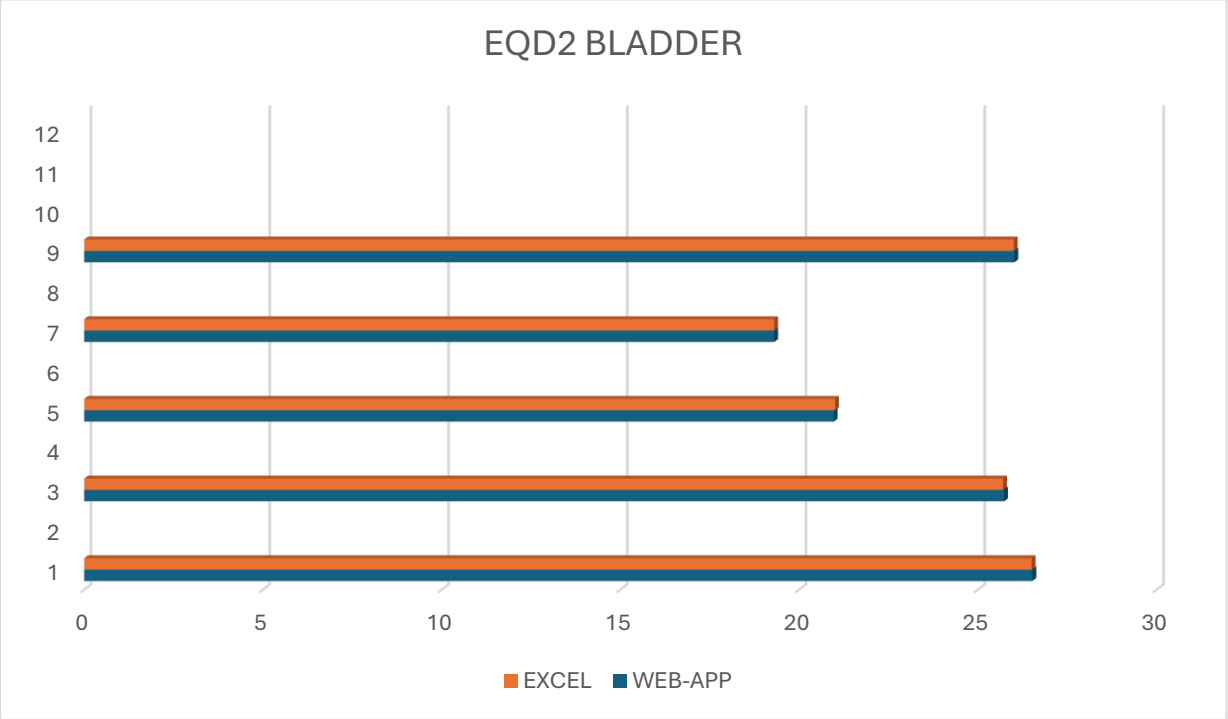


Figure 8 Graph representing EQD2 rectum for web-app and Microsoft Excel template

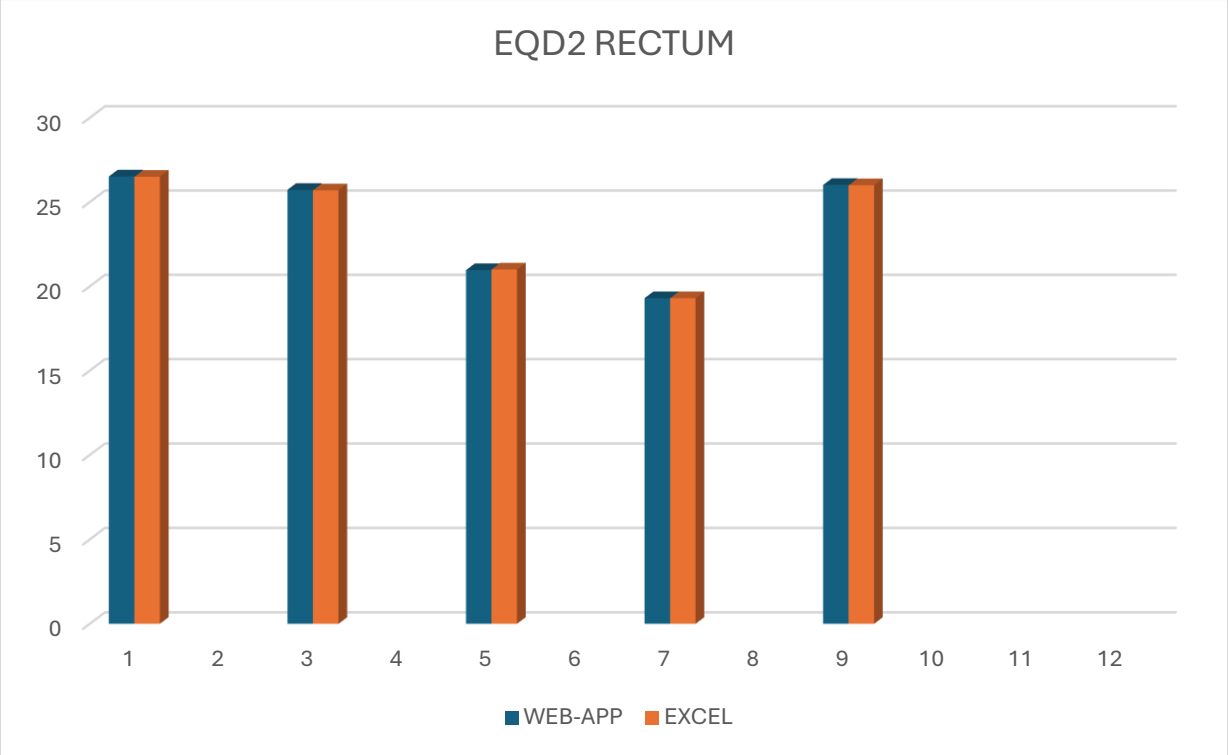
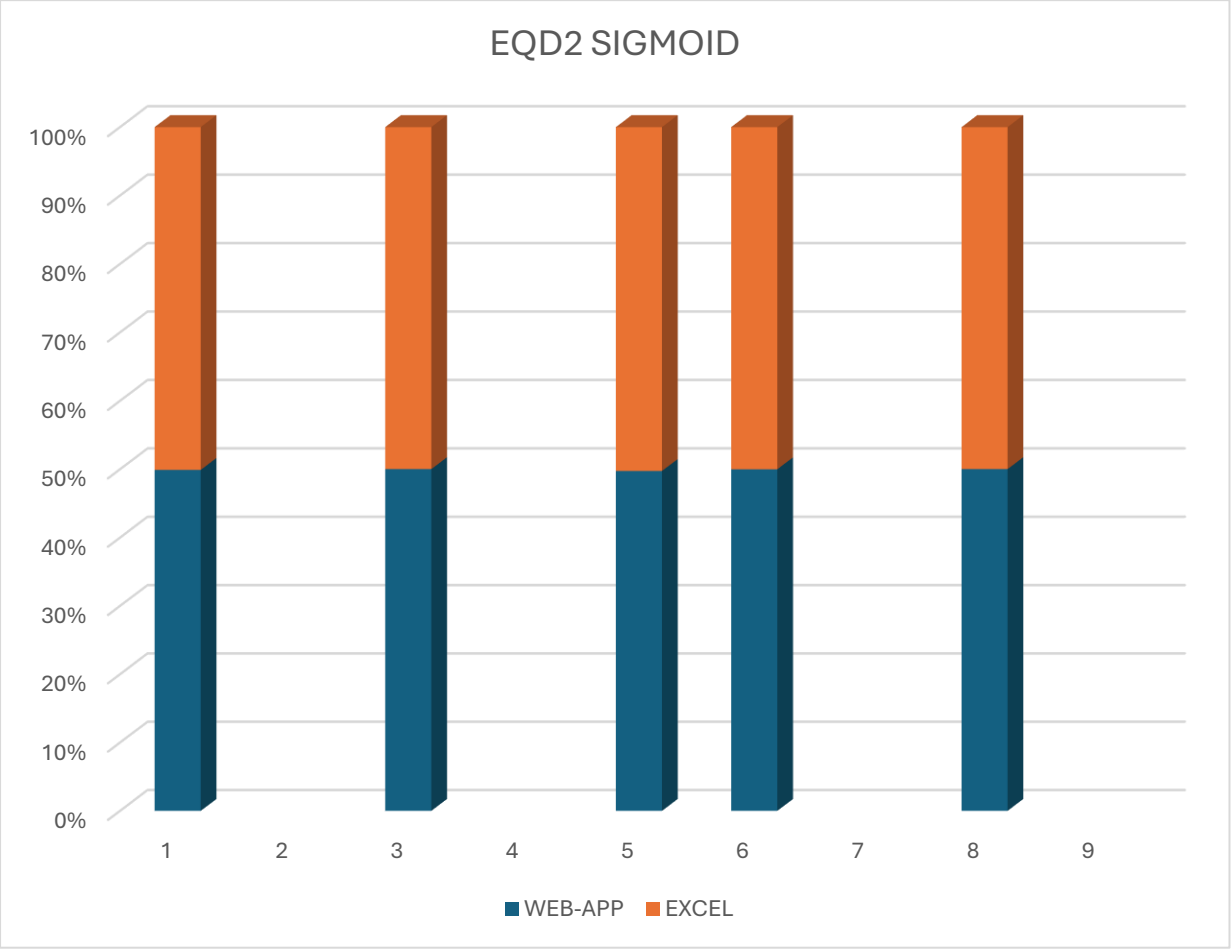


Figure 9 Graph representing EQD2 sigmoid for web-app and Microsoft Excel template



4.4 The accuracy when using Microsoft Excel template and web-app

The evaluation of BED and EQD2 values for different tissues using the web application and the Microsoft Excel template shows that both methods provide comparable results, with only minor differences in the values produced as stated in Figure 2,Figure 3, Figure 4, Figure 5, Figure 6, Figure 7, Figure 8 and Figure 9. For the target tissue, both the web application and Excel template yielded nearly identical BED and EQD2 values, indicating that either tool can be reliably used for these calculations.

For the bladder, the results from both methods were also very similar, demonstrating the web application's ability to accurately replicate the established calculations of the Excel template. The consistency between the two methods suggests that the web application is a viable alternative for calculating radiobiologic dose-equivalents for organs at risk (OAR), such as the bladder.

In evaluating the rectum, the web application again showed results that closely matched those from the Excel template. This further supports the reliability and accuracy of the web application for calculating BED and EQD2 values for different tissues, reinforcing its potential for clinical use.

For the sigmoid, the web application provided results that were nearly the same as those from the Excel template, confirming that the web application can accurately perform these calculations across various tissues.

Overall, the web application demonstrates consistent performance and accuracy comparable to the Microsoft Excel template. This consistency indicates that the web application can effectively streamline the calculation process, offering a reliable and efficient alternative to traditional methods.

4.5 Time needed to complete calculations when using web-app and Microsoft excel template

The web application demonstrates superior performance compared to the traditional Microsoft Excel template. The web application completes the calculation for a full treatment in 2:18.69, whereas the Excel template takes 3:22.67.

This enhanced performance of the web application is attributed to its ability to calculate EQD2 and BED for both the target and organs at risk (OAR) simultaneously. This simultaneous calculation streamlines the process, significantly reducing the time required. On the other hand, the Microsoft Excel template encounters slight inefficiencies. Specifically, it necessitates manually interchanging the alpha/beta ratio for the target and OAR, and it is incapable of performing simultaneous calculations for the target and all OARs; each calculation must be performed individually.

Although there was a recorded time of 2:11.92 for the Excel template, this was an anomaly due to incomplete information, such as the omission of patient names, patient IDs, and the neglect of noting BED and EQD2 for both the target and OARs. When all necessary information is accounted for, the web application proves to be more efficient and reliable, meeting the stringent standards required for clinical use and supporting its integration into medical practice.

Additional tests with data from two more patients further validate these findings. For the first patient, the web application took 1:36.84, while the Excel template took 1:47.11. For the second patient, the web application took 1:34.77, compared to 1:18.66 for the Excel template. Despite the Excel template occasionally performing faster, the overall efficiency and reliability of the web application make it the preferred tool for clinical use.

This visual approach highlighted any discrepancies or alignments between the two methods, allowing for a more sophisticated analysis. The similarity in standard deviations suggests that while the web application performs well and is comparable to the Excel template, a few minor adjustments are needed to ensure it meets the stringent standards required for clinical use.

4.6 Standard deviation values

For the target, the BED value from the web application is 15.74064, and from the Microsoft Excel template, it is 15.73315. The EQD2 value from the web application is 13.1172, and from the Microsoft Excel template, it is 13.11614.

For the bladder, the BED value from the web application is 24.87106, and from the Microsoft Excel template, it is 24.85735. The EQD2 value from the web application is 14.92264, and from the Microsoft Excel template, it is 14.93354.

For the rectum, the BED value from the web application is 8.796138, and from the Microsoft Excel template, it is 8.794866. The EQD2 value from the web application is 5.277683, and from the Microsoft Excel template, it is 5.276141.

For the sigmoid, the BED value from the web application is 19.92495, and from the Microsoft Excel template, it is 19.93193. The EQD2 value from the web application is 11.95497, and from the Microsoft Excel template, it is 11.93805.

4.7 Percentage deviation between web-app and Microsoft Excel template

The formula used to calculate the percentage deviation is:

$$Percentage\ difference\ (\%) = (\frac{(web - app\ value) - (Excel\ value)}{(Excel\ value)})x100\%$$

Formula 4 Percentage deviation of web-app and Microsoft Excel template

The evaluation of BED and EQD2 values using the web application and the Microsoft Excel template reveals minimal percentage deviations across various tissues, indicating high comparability between the two methods. For the target tissue, the BED deviation is 0.048% and the EQD2 deviation is 0.008%. For the bladder, the BED deviation is 0.055% and the EQD2 deviation is 0.073%. The rectum shows a BED deviation of 0.014% and an EQD2 deviation of 0.029%. For the sigmoid, the BED deviation is 0.035% and the EQD2 deviation is 0.142%. All these deviations are well within the tolerance limit of less than 3%, confirming that the web application provides results that are closely aligned with those produced by the Excel template. This demonstrates its reliability and accuracy in calculating radiobiologic dose-equivalents for different tissues.

4.8 Time efficiency ratio

To calculate the time efficiency ratio (TER) of the web application compared to the Microsoft Excel template, we can use the formula:

$$TER = \frac{Time\ taken\ by\ Microsoft\ Excel\ Template}{Time\ taken\ by\ web - app}$$

Formula 5 Equation for Time efficiency ratio

For the full treatment calculation, the web application completes the task in 2:18.69 (138.69 seconds), whereas the Excel template takes 3:22.67 (202.67 seconds), resulting in a TER of 1.46. For the first additional patient, the web application takes 1:36.84 (96.84 seconds), while the Excel template takes 1:47.11 (107.11 seconds), giving a TER of 1.11. For the second additional patient, the web application takes 1:34.77 (94.77 seconds) compared to 1:18.66 (78.66 seconds) for the Excel template, resulting in a TER of 0.83. The TER values indicate that for the full treatment and the first additional patient, the web application is more time-efficient than the Excel template (TER > 1). However, for the second additional patient, the