Does stereotactic body radiation therapy with image guidance technology improve treatment outcomes in intra-pulmonary metastasis patients? A randomized controlled study

Xiaofang Zhang
Cancer Hospital of China Medical University: Liaoning Cancer Institute and Hospital
Yingqiu Song
Cancer Hospital of China Medical University: Liaoning Cancer Institute and Hospital
Chenyu Wang
Cancer Hospital of China Medical University: Liaoning Cancer Institute and Hospital
Peng Zhao
Cancer Hospital of China Medical University: Liaoning Cancer Institute and Hospital
Bo Huang
Cancer Hospital of China Medical University: Liaoning Cancer Institute and Hospital
Lei He
Cancer Hospital of China Medical University: Liaoning Cancer Institute and Hospital
Tianlu Wang (wangtianlu126@126.com)
Cancer Hospital of China Medical University: Liaoning Cancer Institute and Hospital
https://orcid.org/0000-0002-9732-3441

Research Article

Keywords: Intra-pulmonary metastasis, Stereotactic body radiation therapy, Image guidance radiotherapy, Conventional fractionated radiotherapy

Posted Date: May 5th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1004143/v1

Abstract

Background

Stereotactic body radiation therapy (SBRT) with image guidance technology aims to improve treatment outcomes in cancer patients. Image guidance radiotherapy (IGRT) is used with SBRT to deliver tumor ablation therapy in 3–5 fractions. This precise radiotherapy delivery method can be applied to various tumor types, and preliminary evidence suggests that it is efficient, accurate, and cost-effective. We present the protocol for a trial aimed at assessing the safety and efficacy profile of SBRT with image guidance technology for the first time. In so doing, the trial seeks to compare the outcomes of patients treated with this method with those of patients treated with conventional fractionated radiotherapy (CFRT).

Methods

This will be a randomized, controlled, prospective study with 102 lung cancer patients undergoing palliative treatment for intra-pulmonary metastasis. The trial will be based at the Liaoning Cancer Hospital Medical Center (a tertiary medical center). Using the random number table method, a random number sequence is generated, and the 102 patients are randomized (1:1) to the experiment group (SBRT with IGRT group) or the control group (CFRT group). The primary outcome is progression-free survival. The secondary outcomes include tumor response measures, overall survival, quality of life scores, and Acute and chronic adverse reactions, recorded over a 2-year follow-up period. After the final patient completes the follow-up study, Statistical Product and Service Solutions (SPSS) software is used for scientific and rigorous data analysis. This is version 1.0 of protocol on October 31, 2020. The recruitment process for this clinical trial commenced on February 1, 2021, and will end on January 31, 2023.

Discussion

The study will provide high-quality clinical evidence to support the efficacy and safety of IGRT/SBRT versus CFRT in the treatment of patients with intrapulmonary metastases from lung cancer and has not yet been reported.

Trial registration

This trial is registered with the Chinese Clinical Trial Registry (ChiCTR1900027548) (17 November, 2019). (URL: https://www.docin.com/p-917667939.html)

Background

Stereotactic body radiation therapy (SBRT), also known as stereotactic ablative radiation therapy, is a technique that involves imaging guidance to help deliver large doses of radiation to target tumors, using fewer fractions than traditional radiation therapy. However, lung tumors tend to be mobile, which makes delivering high-precision treatment challenging. Failure to fully account for the uncertainty caused by

patient movement can lead to target loss and inaccurate dose coverage.[1–4] SBRT includes the delivery of high-dose radiation in several fractions and has a sharp dose gradient, which results in precise dose delivery to each treatment target. Use of an image guidance technology helps prevent such errors, improving the accuracy of radiotherapy delivery. During radiotherapy, movements associated with respiration,[5] changes in tumor size and shape or patient physique, and the therapist's positioning habits can introduce treatment positioning errors and affect the accuracy of intensity modulated radiation therapy.[6–8] The use of image-guided radiotherapy (IGRT) can help control the positioning error.[9–10] In general, IGRT is essential for successful SBRT.[11–12] IGRT/SBRT is associated with high levels of precision, accurate dose delivery to the target area, reduced risk of missing the target area, and increased likelihood of achieving desirable treatment outcomes, including improved survival and lower toxicity rates.[13–16]

The analgesic effect of SBRT has been shown to be better than that of CFRT in patients undergoing repeat radiation therapy and in those whose primary tumor is refractory to radiation.[17–18] Some previous reports of phase II studies have shown that SBRT and surgery can prolong PFS in this patient group compared with maintenance therapy alone.[19–20] A large retrospective study published by Zhong et al. has shown clinical benefits of SBRT over CFRT in patients with advanced pancreatic cancer. In this study, which included a total of 8,450 patients with stage cT2-4/N0-1/M0 disease registered in the National Cancer Database (2004–2013), SBRT was associated with longer survival than CFRT. In subsequent tendency score matching analysis, which included 988 patients (494 patients per group), the average 2-year survival rate in the SBRT group was significantly higher than that in the CFRT group.[21] In addition to non-small-cell lung cancer (NSCLC), SBRT is increasingly being used to treat other primary tumors and oligometastatic disease.[22–23] However, findings from randomized controlled studies on SBRT and CFRT for early-stage NSCLC have not shown differences in overall survival (OS) or progression-free survival (PFS), and further research is required to elucidate any differences between these approaches.[24] Therefore, to ensure the efficacy and safety of the IGRT/SBRT compared to those of CFRT in intra-pulmonary metastasis patients, the applicant designed the clinical trial. In future, we will improve the treatment plan for patients with intrapulmonary metastases from lung cancer based on the results of this clinical trial. This clinical trial is expected to further improve the efficacy of radiotherapy for patients and improve the quality of life and survival.

Methods And Design

Design

This is a randomized, controlled, prospective study with 102 lung cancer patients undergoing palliative treatment for intra-pulmonary metastasis. The trial will be based at the Liaoning Cancer Hospital Medical Center (a tertiary medical center). Using the random number table method, a random number sequence is generated, and the 102 patients are randomized (1:1) to the experiment group (SBRT with IGRT group) or the control group (CFRT group). This study will not use a blinding process for the trial participants, because the treatment process enable a clear differentiation between the experimental group and the

control group. The primary outcome is progression-free survival. The secondary outcomes include tumor response measures, overall survival, quality of life scores, and Acute and chronic adverse reactions, recorded over a 2-year follow-up period. After the final patient completes the follow-up study, Statistical Product and Service Solutions (SPSS) software is used for scientific and rigorous data analysis.

The trial sponsors are the Shenyang Major Scientific Research Projects (No. 191124090) and Cancer Research Program of National Cancer Center (NCC2017A08). This is version 1.0 of protocol on October 31, 2020. The recruitment process for this clinical trial commenced on February 1, 2021, and will end on January 31, 2023.

Patient and Public Involvement

The public is not involved in the design of this study. The results of the study will be presented at a conference or academic journal, and the public will not be involved in the dissemination plan of the study findings during this process.

Study Participants

The patient's treating physician obtains the patient's consent and explains the trial to those patients who meet the inclusion criteria. The computer will automatically generate the allocation sequence using the random number table method. Team investigators will recruit participants and assign them to the intervention. The order in which assignments will be implemented is a sequential number sequence, opaque, sealed, and not known in advance by the investigator who contacts the participant prior to assigning the intervention.

The study population included 102 lung cancer patients diagnosed with intra-pulmonary metastasis. The inclusion and exclusion criteria are listed in Table 1.

Table 1 Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
• Age ≥18 years • Lung cancer patients diagnosed with intra-pulmonary metastasis • No serious cardiopulmonary dysfunction • Blood routine test result and liver, kidney and heart function are basically normal • Anticipated survival time of >6 months.	• Presence of a mental disorder or intolerance to radiotherapy treatment • Difficulties in understanding the presented information and in complying with trial requirements and recommendations • Presence of advanced disease along with anemia, weight loss, or cachexia • Presence of complications, including perforation in esophageal cancer or a large amount of effusion in lung cancer • Diagnosis of acute inflammation • History of heart failure • History of severe pulmonary insufficiency

Sample Size

It will be necessary to evaluate whether there is a difference between the two groups. The sample size of the experimental group (SBRT with IGRT group) will be set as n_1 and the sample size of the control group (CFRT group) as n_2, n_1=n_2. The two groups will have the same sample sizes, therefore a single-sided test will be used. The sample size calculation formula will be:

$$n_1 = n_2 = 2\left[\frac{(z_\alpha + z_\beta)\sigma}{\delta}\right]^2$$

Where σ will be the overall standard deviation, estimated to be 1.84, δ will be the difference between the two sets of numerical variables, estimated to be 1, Z_α will be the standard normal value corresponding to the inspection level α, Z_β will be the standard normal value corresponding to β, If σ=1.8 months, δ=1 month, α=0.05, β=0.20, $Z_{\alpha/2}$=$Z_{0.05/2}$=1.96, and Z_β=$Z_{0.20}$=0.842, then by substituting the above formula will give:

$$n_1 = \mathrm{n}_2 = 2\left[\frac{(1.96+0.842)\times 1.8}{1}\right]^2 = 50.9 \approx 51$$

That is, 51 cases will be in the control group and 51 cases in the experimental group, with the total sample size being 102 cases.

Primary Study Outcome

PFS will be the primary study outcome. PFS is defined as the number of months from the start of IGRT/SBRT to the occurrence of the first evidence of disease progression, according to the Response Evaluation Criteria in Solid Tumors.

Secondary Study Outcomes

Tumor response measures

Tumor response measures are progressive disease (PD), stable disease (SD), complete response (CR), and partial response (PR). PD is the sum of the largest diameter of the target lesion increased by≥20% or new lesions appear. SD is the sum of the largest diameter of the target lesion that did not reach PR but increased to PD. CR is the complete disappearance of the tumor after radiotherapy. PR is the sum of the largest diameter of the tumor after radiotherapy and the largest vertical diameter by 50% and no increase in other lesions for a duration of more than 1 month.

Overall survival

Overall survival (OS) is defined as the number of months from the start of radiotherapy to the last follow-up or death, according to the criteria established by the American Joint Committee on Cancer and the International Union for Cancer Control Committee.

Quality of life scores

Quality of life (QoL) is assessed including EORTC QLQ-C30 (version 3) for lung cancer patients with intra-pulmonary metastasis at baseline, 4 weeks, 3 months, 6 months, 12 months and 24 months.

Acute and chronic adverse reactions

Acute and chronic adverse reactions are assessed according to the Radiation Therapy Oncology Group/European Organization for Research and Treatment of Cancer criteria, which define chronic adverse reactions as reactions occurring after radiotherapy lasting more than 90 days.

Study Outline

VARIAN's high-energy line accelerator, an IGRT device, American ADAC treatment planning system, a radiotherapy-specific neck and shoulder positioning rack, a neck and shoulder film made of low-temperature hydrolyzed polymer, and a positioning laser lamp (part of a dedicated external positioning system) are available at our radiotherapy department. In addition, a 3.0-T magnetic resonance imaging (MRI) scanner and a positron emission tomography (PET)/CT scanner are available at the study site. Equipment and technical support details are presented in Table 3.

Table 3 Summary of the available equipment

Device	Device model	Manufacturer	Factory number
3D-TPS	Pinnacle^3	Philips	20028
TPS	Pinnacle Smart Enterprise	Philips	20030126
3D water tank	RFA-300	IBA	20021210
Linear electron accelerator	IX6117	Varian	20151217
Image fusion software	MIM	MIM Software	20151125
Linear electron accelerator	UNIQUE	Varian	20140122
TOMO	Tomotherapy HD	Accuracy	20151125
Medical linear accelerators	Clinac IX	Varian	20151203
CT	SOMATOM	Siemens	20140731

3D-TPS, three-dimensional treatment planning system; 3D water tank, three-dimensional (3D) water tank scanning system; TOMO, tomotherapy system

CT-based tumor localization method

The patient will be placed in a supine position on a radiotherapy-specific body frame and stabilized with the low-temperature hydrolyzed polymer film. The laser will be aimed at the midline of the chest and on both sides of the body, and the corresponding reference points will be marked on the body membrane and surface. Next, the lead particles will be placed for marking. Spiral CT will be performed while the patient is breathing calmly; the chest scan will be continuous in nature, using 2-mm slice thickness, and the data will be transmitted to the ADAC Pinnacle3 TPS workstation. PET/MRI images will be collected at the imaging department in two dimensions; subsequently, MRI or PET images will be fused with CT images using MIM software.

Radiotherapy target area outline

The chief physician of the radiotherapy department and an experienced diagnostic imaging physician will be tasked with combining imaging data to outline the radiotherapy target area on the CT fusion image. Planning target volume (PTV) is based on the gross tumor volume (GTV) considering factors such as positioning errors/positional movement between simulation and treatment. Overall, 105% of the prescribed dose must be delivered within the PTV, and the dose gradient outside the target area should show a rapid drop.[25]

Treatment plan

Eligible patients will receive IGRT/SBRT. The motion of the target area will be evaluated by a CT scan acquired in 10 respiratory phases, using a 4D-CT scanner.[26-27] When the range of tumor movement exceeds 1.5 cm, abdominal compression/accelerator gating and ABC methods will be used to reduce organ movement. Based on the IGRT method, the VARIAN high-energy linear accelerator will be used to deliver radiotherapy to the target areas using a 6–10 MV photon beam; the dose of radiation will be personalized as follows:

1.peripheral tumors smaller than 2 cm and located within 1 cm from the chest wall will receive a DT of 25–34 Gy/1F,

2.peripheral tumors farther than 1 cm from the chest wall will receive a DT of 45–60 Gy/3F,

3.central or peripheral tumors that are 4-5 cm in size and are located within 1 cm from the chest wall will receive a DT of 48–50 Gy/4F,

4.other tumors located within 1 cm from the chest wall will receive a DT of 50–55 Gy/5F, and central tumors will receive a DT of 60–70 Gy/8–10F.[28]

Radiotherapy will be performed once per day over a continuous period of 5 days; subsequently, treatment effects will be assessed.

Post-radiotherapy follow-up

Patients will be reviewed at months 1, 3 and 6 after radiotherapy to assess the efficacy and whether there is recurrence. Six months to two years after treatment, the review will be conducted every six months. The examinations will include CT scan of the lungs, routine blood tests, and liver and kidney function tests. In addition, we perform the QoL assessment at each review of the patient. The effect of IGRT/SBRT radiotherapy is evaluated according to the primary and secondary evaluation criteria established by the committee. The follow-up period for PFS is 2 years. The outline of the study is shown in Figure 1.

Data analysis

After the last patient completes the follow-up study, the committee will assess the occurrence of primary and secondary endpoints. Data will be organized and analyzed using SPSS 25.0 software, and $P<0.05$ will be considered a statistically significant difference in all statistical tests. Survival time will be defined as the time from the date of diagnosis of lung metastases from lung cancer to the date of death or the date of the most recent follow-up visit. Overall survival and progression-free survival will be calculated using the Kaplan-Meier method; Hazard Ratios (HR) and their 95% confidence intervals (Confidence Intervals, CI) will be calculated using the Cox regression method, and Chi-square tests will be used to analyze the differences between the different variables in patients who died and survived. Quality of life for two years will be scored with the FACT-G. The Chi-square test will be used in combination with propensity matching analysis to minimize differences due to smoking, gender, weight loss, geographic factors, economic status, education level, and to avoid baseline effects to the greatest extent possible.

Discussion

Evidence from previous studies has suggested that the use of SBRT for early-stage NSCLC and advanced pancreatic cancer can improve patient prognosis. SBRT is associated with a precise treatment plan and delivery, both of which overcome the limitations of previously used methods.[29] The use of IGRT/SBRT helps achieve accurate dose estimates for the target area, thereby improving the rate of treatment delivery to the target lesion. In addition, this increases the likelihood of treatment success, while protecting surrounding tissues and organs and reducing the risk of complications. With this method, radiotherapy is delivered at relatively high doses in few fractions, resulting in tumor damage with a more efficient schedule; this approach is associated with improved tumor control, which is associated with improved patient survival.

The study will provide high-quality clinical evidence to support the efficacy and safety of IGRT/SBRT versus CFRT in the treatment of patients with intrapulmonary metastases from lung cancer and has not yet been reported. The main limitation of this study is theinformation bias caused by patient heterogeneity and missed visits, which may affect the usability of the data. The results of this study will

provide evidence for the efficacy and safety profile of this approach and may inform future trials of similar approaches in larger populations. The results of this clinical study will play an important role in improving treatment options for patients with intrapulmonary metastases from lung cancer and in helping frontline physicians plan radiation treatment options for cancer patients.

Trial Status

The recruitment of participants started on 1 Feb 2021 and the trial is expected to continue until 31 Jan 2023.

On submission for publication, version 1.0 of the protocol is being used. 31 Oct 2020.

List Of Abbreviations

SBRT, stereotactic body radiation therapy

IGRT, image guidance radiotherapy

CFRT, conventional fractionated radiotherapy

SPSS, Statistical Product and Service Solutions

NSCLC, non-small-cell lung cancer

OS, overall survival

PFS, progression-free survival

PD, progressive disease

SD, stable disease

CR, complete response

PR, partial response

QoL, quality of life

MRI, magnetic resonance imaging

3D, three-dimensional

PTV, Planning target volume

GTV, gross tumor volume

HR, Hazard Ratios

CI, Confidence Intervals

Declarations

Ethics approval and consent to participate

The ethics approval received by Medical Ethics Committee of Liaoning Cancer Hospital and the number is 2020X0102. Prior to screening, all participants should sign an informed consent form.

Consent for publication

Not applicable.

Availability of data and materials

The data of this study is available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

Funding for a three-year doctorate scholarship period (2020–2023) was received from the Shenyang Major Scientific Research Projects (No.191124090) and the Cancer Research Program of National Cancer Center (NCC2017A08) in order to conduct and analyze data from this ongoing study.

Authors' contributions

All authors participated in the development and the design of the study. Xiaofang Zhang wrote the first version of the manuscript. Yingqiu Song and Chenyu Wang is responsible for the data management and statistical considerations of this project. Peng Zhao work as a therapist in this clinical experiment. Lei He strictly controlled the quality of the patient's radiation treatment process. Bo Huang provides pathological reports to patients in clinical trials. Tianlu Wang critically revised the manuscript. All authors read and approved the final version of the manuscript.

Acknowledgements

We are very grateful to the participants who participated in the study because they spend precious time participating in the study.

Authors' information

[1]Department of Radiotherapy, Cancer Hospital of China Medical University, Shenyang, China; [2]Department of Information Management, Cancer Hospital of China Medical University, Shenyang, China; [3]Department of Pathology, Cancer Hospital of China Medical University, Shenyang, China; [4]Physical Laboratory in Charge, Department of Radiotherapy Department, Cancer Hospital of China Medical University, Shenyang, China.

References

1. Stephans KL, Djemil T, Tendulkar RD, **et al**. **Prediction of chest wall toxicity from lung stereotactic body radiotherapy (SBRT)**. Int J Radiat Oncol Biol Phys 2012;**82**:**974–80**.
2. Timmerman R, McGarry R, Yiannoutsos C, **et al**. **Excessive toxicity when treating central tumors in a phase II study of stereotactic body radiation therapy for medically inoperable early-stage lung cancer**. J Clin Oncol 2006;**24**:**4833–9**.
3. Ong CL, Palma D, Verbakel WF, **et al**. **Treatment of large stage I-II lung tumors using stereotactic body radiotherapy (SBRT): planning considerations and early toxicity**. Radiother Oncol 2010;**97**:**431–6**.
4. Baumann P, Nyman J, Hoyer M, **et al**. **Outcome in a prospective phase II trial of medically inoperable stage I non–small-cell lung cancer patients treated with stereotactic body radiotherapy**. J Clin Oncol 2009;**27**:**3290–6**.
5. Partridge M, Tree A, Brock J, **et al**. **Improvement in tumour control probability with active breathing control and dose escalation: a modelling study**. Radiother Oncol 2009;**91**:**325–329**.
6. Ade N, Oderinde OM, **du** Plessis FCP. **Monte Carlo dose in a prosthesis phantom based on exact geometry vs streak artefact contaminated CT data as benchmarked against Gafchromic film measurements**. Phys Med 2018;**54**.
7. Stoiber EM,Bougatf N,Teske H,**et al**. **Analyzing human decisions in IGRT of head-and-neck cancer patients to teach image registration algorithms what experts know [J]. RadiatOncol** 2017;**12**:**104**.
8. Munck Af Rosenschold P, Zelefsky MJ, Apte AP, **et al**. **Image-guided radiotherapy reduces the risk of under-dosing high-risk prostate cancer extra-capsular disease and improves biochemical control [J]**. Radiat Oncol 2018;**13**:**64**.
9. Keall PJ, Mageras GS, Balter JM, **et al**. **The management of respiratory motion in radiation oncology report of AAPM Task Group 76**. Med Phys 2006;**33**:**3874–900**.
10. Wolf J, Nicholls J, Hunter P, **et al**. **Dosimetric impact of intrafraction rotations in stereotactic prostate radiotherapy: A subset analysis of the TROG 15.01 SPARK trial**. Radiother Oncol 2019;**136**.
11. Purdie TG, Bissonnette JP, Franks K, **et al**. **Cone-beam computed tomography for on-line image guidance of lung stereotactic radiotherapy: localization, verification, and intrafraction tumor position**. Int J Radiat Oncol Biol Phys 2007;**68**:**243–52**.
12. Benedict SH, Yenice KM, Followill D, **et al**. **Stereotactic body radiation therapy: the report of AAPM Task Group 101**. Med Phys 2010;**37**:**4078–101**.

13. Incerti E, Gangemi V, Mapelli P, **et al**. **11C-Choline PET/CT based helical tomotherapy as treatment approach for bone metastases in recurrent prostate cancer patients**. Curr Radiopharm 2017;**10**:**195–202**.
14. Siva S, Bressel M, Murphy DG, **et al**. **Stereotactic Abative Body Radiotherapy (SABR) for oligometastatic prostate cancer: a prospective clinical trial**. Eur Urol. 2018;**74**:**455–462**.
15. Ost P, Jereczek-Fossa BA, As NV, **et al**. **Progression-free survival following stereotactic body radiotherapy for oligometastatic prostate cancer treatment-naive recurrence: a multi-institutional analysis**. Eur Urol 2016;**69**:**9–12**.
16. Kneebone A, Hruby G, Ainsworth H, **et al**. **Stereotactic body radiotherapy for oligometastatic prostate cancer detected via prostate-specific membrane antigen positron emission tomography**. Eur Urol Oncol. 2018;**1**:**531–537**.
17. Gerszten PC, Mendel E, Yamada Y. **Radiotherapy and radiosurgery for metastatic spine disease: what are the options, indications, and outcomes?** Spine 2009;**34**.
18. Haley ML, Gerszten PC, Heron DE, **et al**. **Efficacy and cost-effectiveness analysis of external beam and stereotactic body radiation therapy in the treatment of spine metastases: a matched-pair analysis**. J Neurosurg Spine 2011;**14**.
19. PAREKH A,ROSATI L M,CHANG D T,**et al**. **Stereotactic body radiation for pancreatic cancer: results of an international survey of practice patterns[J]**. J Radiat **0ncol** 2017;**6**:**273-278**.
20. Balaban EP, Mangu PB, Khorana AA, **et al**. **Locally Advanced, Unresectable Pancreatic Cancer: American Society of Clinical Oncology Clinical Practice Guideline.[J]**. J. Clin. Oncol 2016;**34**.
21. Zhong J, Patel K, Switchenko J, **et al**. **Outcomes for patients with locally advanced pancreatic adenocarcinoma treated with stereotactic body radiation therapy versus conventionally fractionated radiation[J].Cancer** 2017;**123**:**3486-3493**.
22. Marino C, Garibaldi C, Veronese I, **et al**. **A national survey on technology and quality assurance for stereotactic body radiation therapy**. Phys Med 2019;**65**.
23. Videtic GMM, Donington J, Giuliani M, **et al**. **Stereotactic body radiation therapy for early-stage non-small cell lung cancer: executive summary of an ASTRO evidence-based guideline**. Pract Radiat Oncol 2017;**7**:**295–301**.
24. Haque W, Verma V, Polamraju P, **et al**. **Stereotactic body radiation therapy versus conventionally fractionated radiation therapy for early stage non-small cell lung cancer**. Radiother Oncol 2018;**129**.
25. Wang H, Cooper BT, Schiff P, **et al**. **Dosimetric assessment of tumor control probability in intensity and volumetric modulated radiotherapy plans**. Br J Radiol 2019;**92**.
26. Rit S, Nijkamp J, **van** Herk M, **et al**. **Comparative study of respiratory motion correction techniques in cone-beam computed tomography**. Radiother Oncol 2011;**100**.
27. Bryce-Atkinson A, Marchant T, Rodgers J, **et al**. **Quantitative evaluation of 4D Cone beam CT scans with reduced scan time in lung cancer patients**. Radiother Oncol 2019;**136**.
28. Ibbott GS. **Patient doses from image-guided radiation therapy**. Phys Med 2020;**72**.

29. Benedict SH, Yenice KM, Followill D, **et al**.**Stereotactic body radiation therapy: the report of AAPM Task Group 101**. Med Phys 2010; **37**:**4078-4101**.

Figures

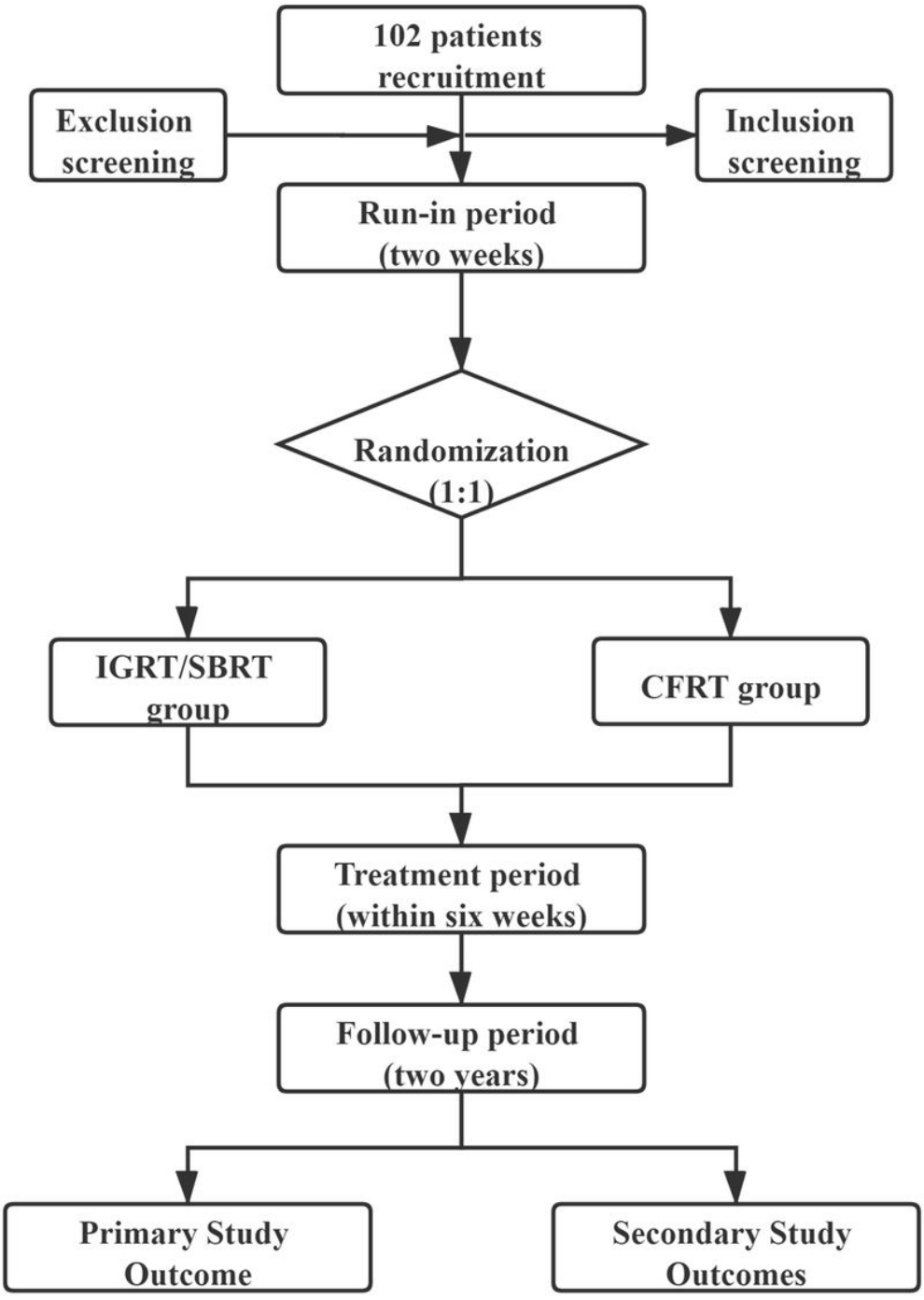

Figure 1

Flowchart detailing the study procedures: IGRT, image guidance technology; SBRT, stereotactic body radiation therapy; CFRT, conventional fractionated radiotherapy

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- spiritchecklist.doc