SCIENCE FAIR PROJECT GRADE 9

GLAMORGAN SCHOOL

RESEARCH PROJECT LOGBOOK

Does Proton Therapy present a good alternative to other treatment options for cancer?

Devayan Mitra

TABLE OF CONTENTS

Contents

[Question (Assignment 1) 3](#_Toc155554304)

[Hypothesis 3](#_Toc155554305)

[Variables 3](#_Toc155554306)

[Research Notes (Assignment 3) 4](#_Toc155554307)

[General Topic: 4](#_Toc155554308)

[Specific Topic/Research 4](#_Toc155554309)

[Proton Therapy (Hopkins Medicine)1 4](#_Toc155554310)

[What is proton therapy used for? (Hopkins Medicine)1 4](#_Toc155554311)

[How does it work? (Hopkins Medicine)1 5](#_Toc155554312)

[Comparison table of cancer therapies 6](#_Toc155554313)

[How this information helps the world 9](#_Toc155554314)

# Question (Assignment 1)

Does proton therapy present a good alternative to other treatment options for cancer?

## Hypothesis

* My hypothesis is that proton therapy can make a positive impact in oncological treatments, but I think there are some major downsides to proton therapy such as:
  + Availability of treatment centres (so far only in John Hopkins and Mayo clinic)
  + Resources (harnessing protons requires a particle accelerator)
  + Cost (particle accelerators costs millions to maintain)

## Variables

* 1. **Independent Variables:**

1. Different cancer treatments (radon gas, chemotherapy, photon therapy)
   1. **Dependent Variables**
2. Effectiveness of treatment (higher probability of remission)
3. Feasibility and viability of treatment
4. Availability of treatment centres
5. Number of skilled resources such as doctors and clinical technicians
6. Cost of treatment
   1. maintaining the machines, people, and infrastructure
   2. cost of machines
   3. government funding
   4. cost of treatment for the patient
7. Affordability
8. Duration of treatment
9. Side effects
10. Types of cancers it can treat.
    1. **Controlled Variables**
11. Type of cancer it is treating.
12. Quality of treatment of alternative options

# Research Notes (Assignment 3)

## General Topic:

Medicine/Oncology

## Specific Topic/Research

### Proton Therapy (Hopkins Medicine)1

* **Broad Definition of Proton Therapy (PT) –** An advanced and highly precise cancer treatment for tumors. It focuses radiation on the tumor rather than surrounding healthy tissue.
* **PT** or Proton Beam Therapy is a radiation treatment where a **proton beam** is delivered to disrupt and destroy cancer cells without killing healthy tissue.
* **PT** is aimed to improve treatment results and reduce treatment side effects. An example is that regular chemotherapy is put inside the body using an IV bag. The liquid drug is spread through the bloodstream. A disadvantage is that chemotherapy attacks both the healthy cells and the cancerous tumor cells. Therefore, there are many unwanted side effects due to this.
* Because of the high level of precision **PT** has, it is ideal for children with brain and spinal tumors (pediatric tumors).
* The precision also is good for adults with **cancer in the heart/major blood vessels.**

### What is proton therapy used for? (Hopkins Medicine)1

* Proton therapy is usually used to remove cancerous tumors, they can be also to remove cysts and other non-cancerous (benign) tumors. Some examples this therapy treats are:
* Brain Tumors (including base of the skull)
* Spinal Cord Tumors
* Head and Neck Cancer (Angie’s Case)
* Breast Cancer
* Lung Cancers (Thymoma, Mesothelioma, Lymphoma)
* Liver Cancer/Metastatic tumors
* Pancreatic Cancer
* Rectal Cancer
* Prostate Cancer
* Reirradiation
* Sarcomas/Rhabdomyosarcoma
* Eye Cancer/Ocular Melanoma

### How does it work? (Hopkins Medicine)1

* Protons are separated and accelerated in a particle accelerator.
* A gantry, with a large magnet, focuses protons into a 5mm-wide beam.
* The gantry rotates 360 degrees, directing protons at the tumor from multiple angles.
* Proton beam energy is adjustable based on tumor depth for targeted radiation.
* Radiation damages tumor DNA (Bragg peak effect), preventing repair and cell growth.
* Proton beam therapy disrupts tumor DNA and destroys tumor cells.
* Tumor stops growing and starts shrinking.
* Effects vary based on tumor size, location, and other factors.

## Comparison table of cancer therapies

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Comparison dimensions of different therapies** | **Proton therapy (Hydrogen ion therapy)** | **Photon therapy (Traditional radiation therapy)** | **Chemotherapy** | **Proton therapy (Carbon ion therapy)** |
| **Effectiveness of treatment** | 56% of people live longer than 3 years. (Bragg Peak effect reduces tissue damage compared with photon therapy) | 73% and 98% at 5 years lifetime and 54% and 94% at 10 years. Only 30-40% of the photons hit the tumor and destroy it making it lesser effective than proton therapy (hydrogen ion) | Between 54% to 76% chance for 18 – 30 months of lifetime | 1-year local control rate of 87% for a 3 year survival rate |
| **Viability of treatment** | Cost-effective, especially for pediatric brain tumours (incremental cost-effectiveness ratio US$21 716–$26 419 per quality-adjusted life year [QALY], and some head-and-neck cancers (incremental cost-effectiveness ratio US$4254–$143 229 per QALY, depending on the study and radiation techniques), below a commonly accepted willingness-to-pay threshold of $150 000 per QALY.10  However, construction of the treatment centres cost millions of dollars. | Very viable when it comes to the treatment of prostate cancer. It has a 95.5% success rate. For a 5-year survival rate, it is 98.8% overall for all cancers being treated. | Most viable out of all these comparisons because most of the other alterative treatment options are largely unknown to people across the world. | HIghly viable when it comes to acceptable amount of side effects but unviable for building centres which cost $200-$300 million USD. |
| **Availability** | There are only 101 facilities world-wide | Sometimes paired with chemotherapy to increase effectiveness. This makes it quite common and regularly used. | Most common therapy which is available in most hospitals globally | Only 12 centres in the whole of Asia and Europe combined. |
| **Number of skilled resources (doctors, clinical technicians)** | 4 types of doctors’ work:  Radiation Oncologist  Medical Physicist  Dosimetrist  PBT Technicians | 5 types of doctors’ work:  Radiation Oncologist  Medical Physicist  Dosimetrist  Radiotherapy Technicians  Oncology Nurses | 6 skills are required to work in a team::  Medical Oncologist  Oncology Nurses  Pharmacists  Social Workers  Infusion Nurses  Physician Assistants | 5 skills are required to work in a team:  Radiation Oncologist  Medical Physicist  Dosimetrist  PBT Technicians  Oncology Nurses |
| **Cost of treatment** | Small treatments ranging from $4000 - $7000. Large treatments ranging from $16k – $22k.  Costs can be lesser due to reduced rates of hospitalization since patient has lesser toxicity i.e. side effects. | $12 450 per year of treatment. | Cost of treatment depends on 8 factors:  Type of cancer  Stage of disease  Number of treatments  Duration of treatment  Type of chemo  Treatment setting  Geographic location  Side effects  Therefore, with these factors, the price can range between $10k – $200k. |  |
| **Affordability** | Unaffordable since treatment can go up to $200k. Additionally, hospitals are under pressure to grow volumes to keep the business profitable. They can fix this by building a single vault PBT facility inside a radiation therapy centre. This could save $49.79 million over 5 years. But currently this proposition is still under consideration and there are no proton centers in Canada. | Decently affordable because it can be paired with the extra treatment of chemo. This can benefit patients cost-wise. Prices of radiation therapy can range from $8,600 - $25,50016 | It can range from $10k – $200k if people don’t have insurance. | Because facilities are very expensive to build, at $300 million, and only 12 centers across two continents, the price of treatment is very unaffordable. |
| **Duration of treatment** | 15-30 min per session | 15-30 min per session | 5 min – 8 hours per session depending on the cancer and the tolerance of cancer patient | 15-30 min per session |
| **Side Effects** | Red skin in the area proton beam was shot, hair loss in that area, tiredness a low energy | Commonly fatigue, hair loss in area, nausea, vomiting, soreness in area where the beam was shot at. | Nausea  Vomiting  Diarrhea  Hair loss  Loss of appetite  Fatigue  Fever  Mouth sores  Pain  Constipation  Easy bruising  Bleeding | Stage 3 Diarrhea, fatigue, skin stress (hair loss, reddening of skin, conjunctivitis, mucositis, dry mouth, headache and nausea are possible side effects specifically for meningiomas (brain tumors)14 |
| **Types of cancer it can treat** | Cancers that have not spread across the body  (Primary Cancer) | T-cell Lymphoma, squamous cell skin cancer (stage 0), throat cancer, lung cancer. | Leukemia, Lymphoma, Hodgkin’s disease, multiple myeloma, and sarcomas, breast, lung, ovarian sarcomas | Mostly pancreatic cancer, nasopharyngeal cancer, prostate cancer, bone and soft tissue tumors. This treatment is very effective with radiation-resistant cancers due to the weight of the carbon ion. |

## How this information helps the world

These comparisons of cancer therapies will benefit people with cancer and the medical economy. This will also help people to decide which therapy is best for their health. Some of these treatments with this research will probably advance the treatment such as mass scaling and factors I researched about. This research might contribute to the road for the cure for cancer in the future.

## Bibliography

1. *Proton therapy*. (2022, December 16). Hopkinsmedicine.org. <https://www.hopkinsmedicine.org/health/treatment-tests-and-therapies/proton-therapy>
2. *What’s the difference? Photon and proton radiation therapy*. (2021, July 16). City of Hope. <https://www.cancercenter.com/community/blog/2021/12/whats-the-difference-proton-photon-therapy>
3. Kojima, S., Cuttler, J. M., Inoguchi, K., Yorozu, K., Horii, T., Shimura, N., Koga, H., & Murata, A. (2019). Radon therapy is very promising as a primary or an adjuvant treatment for different types of cancers: 4 case reports. *Dose-Response: A Publication of International Hormesis Society*, *17*(2), 155932581985316. <https://doi.org/10.1177/1559325819853163>
4. Middleton, J., Black, K., Ghosh, S., Eisenstat, D. D., & Patel, S. (2021). Indirect costs associated with out-of-country referral for proton therapy: a survey of adult and pediatric patients in Alberta, Canada. *BMC Health Services Research*, *21*(1). <https://doi.org/10.1186/s12913-021-06701-z>
5. Prasad, R. N., Patel, T., Perlow, H. K., Yildiz, V. O., Baliga, S., Brownstein, J., Gamez, M. E., Konieczkowski, D. J., Royce, T. J., & Palmer, J. D. (2022). List prices for proton radiation therapy. *Practical Radiation Oncology*, *12*(3), e163–e168. <https://doi.org/10.1016/j.prro.2021.11.013>
6. Hoeh, B., Würnschimmel, C., Flammia, R. S., Horlemann, B., Sorce, G., Chierigo, F., Tian, Z., Saad, F., Graefen, M., Gallucci, M., Briganti, A., Terrone, C., Shariat, S. F., Tilki, D., Kluth, L. A., Mandel, P., Chun, F. K. H., & Karakiewicz, P. I. (2021). Effect of chemotherapy on overall survival in contemporary metastatic prostate cancer patients. *Frontiers in Oncology*, *11*. <https://doi.org/10.3389/fonc.2021.778858>
7. Liermann, J., Naumann, P., Weykamp, F., Hoegen, P., Debus, J., & Herfarth, K. (2021). Effectiveness of carbon ion radiation in locally advanced pancreatic cancer. *Frontiers in Oncology*, *11*, 708884. <https://doi.org/10.3389/fonc.2021.708884>
8. Okamoto, M., Shiba, S., Okazaki, S., Miyasaka, Y., Shibuya, K., Kiyohara, H., & Ohno, T. (2021). Feasibility and safety of repeated carbon ion radiotherapy for locally advanced unresectable pancreatic cancer. Cancers, 13(4), 665. <https://doi.org/10.3390/cancers13040665>
9. Chemotherapy. (2022, March 22). Mayoclinic.org. <https://www.mayoclinic.org/tests-procedures/chemotherapy/about/pac-20385033>
10. Tsang, D. S., & Patel, S. (2019). Proton beam therapy for cancer. Journal de l’Association Medicale Canadienne [Canadian Medical Association Journal], 191(24), E664–E666. https://doi.org/10.1503/cmaj.190008
11. Kim, J., Wells, C., Khangura, S., Alexander, C., Mulla, S., Farrah, K., Paulden, M., Tsoi, B., DeJean, D., Duthie, K., & Dufour, B. G. (2017). Summary of findings. Canadian Agency for Drugs and Technologies in Health. - <https://www.ncbi.nlm.nih.gov/books/NBK531701/>
12. Foote, R. L., Tsujii, H., Imai, R., Tsuji, H., Hug, E. B., Kanai, T., Lu, J. J., Debus, J., Engenhart-Cabillic, R., & Mahajan, A. (2022). The majority of United States citizens with cancer do not have access to carbon ion radiotherapy. Frontiers in Oncology, 12. <https://doi.org/10.3389/fonc.2022.954747>
13. How chemotherapy works. (n.d.). WebMD. Retrieved January 3, 2024, from <https://www.webmd.com/cancer/how-chemo-works>
14. Li, J.-Y., Li, J.-W., Jin, Y.-C., Li, M.-X., Guo, L.-P., Bing, Z.-T., Zhang, Q.-N., Bai, F., Wang, X.-H., Li, X.-X., & Yang, K.-H. (2021). The efficacy and safety of carbon ion radiotherapy for meningiomas: A systematic review and meta-analysis. Frontiers in Oncology, 11. <https://doi.org/10.3389/fonc.2021.620534>
15. Radiation therapy 95% effective for prostate cancer treatment. (2015, February 20). Targeting Cancer. <https://www.targetingcancer.com.au/2015/02/radiation-therapy-95-effective-prostate-cancer/>
16. Paravati, A. J., Boero, I. J., Triplett, D. P., Hwang, L., Matsuno, R. K., Xu, B., Mell, L. K., & Murphy, J. D. (2015). Variation in the cost of radiation therapy among medicare patients with cancer. Journal of Oncology Practice, 11(5), 403–409. <https://doi.org/10.1200/jop.2015.005694>
17. Radiation therapy for cancer. (2015, April 29). National Cancer Institute. <https://www.cancer.gov/about-cancer/treatment/types/radiation-therapy> 1
18. Heidelberg University Hospital: Proton therapy and carbon ion therapy. (n.d.). Heidelberg-university-hospital.com. Retrieved January 27, 2024, from <https://www.heidelberg-university-hospital.com/diseases-treatments/cancer-and-tumor-diseases/proton-therapy-and-carbon-ion-therapy>

## Results (Assignment 4)

I can conclude that between the two types of proton therapies (Hydrogen ion and carbon ion) that the average survival rate for 3 years is %71.5 chance. These two combined is clearly better than chemotherapy with an average of 65% for only 18-30 months of lifetime.

As you can see, chemotherapy has a soaring high number of side effects. This shows that most radiation therapies have a significantly low amount of side effects compared to chemotherapy, which is inserted through and intravenous wire.

Carbon ion can treat 15 types of cancers due to the heaviness of their charged ions. Hydrogen ion is also extremely effective due to the Bragg Peak Effect, which reduces side effects significantly.

### Conclusion

I conclude that the ion treatments are the most effective with the least amount of side effects. Although when it comes to the social factors, ion therapy is usually unaffordable but I do believe that in the future, technology will advance and ion therapy will get cheaper.

Method (Assignment 2)

I plan to follow a step-by-step approach to explore the research question:

* 1. Understand in detail what proton therapy means, what it does, how it works, and for what it is used. This will help me find the pros and cons of other cancer treatments.
  2. This will also help demonstrate how effective cancer treatments are for different people and ages.
  3. This data will also help in finding different side effects for different treatments. (might also see which cancer has which side effects to the therapy)
  4. Understanding the real-life circumstances such as:
     1. availability of the therapy
     2. how much energy it needs to operate.
     3. cost of treatment, energy, resources, etc.
  5. Understanding how they gather protons from a gantry.