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1. This literary review is a selection of articles about proton therapy and is not intended to be an exhaustive bibliography.
This user guide for proton and carbon ion therapy in modern cancer treatment covers the physics and radiobiology of proton and ion beams, dosimetry methods, radiation measurements, treatment delivery systems, patient setup, target localization and treatment planning for clinical proton and carbon ion therapy. Detailed reports are also given on the treatment of pediatric cancers, lymphomas, and various other cancers.

This work provides a comprehensive review for practitioners on the current status of PT, its scientific basis and current clinical applications, reviews of the available clinical evidence, discussions of costs and technology development, issues in establishing a PT center, and the future development of PT as a tool in clinical practice.

PAGANETTI H., "Proton Therapy Physics", 2012, Series in Medical Physics and Biomedical Engineering, Massachusetts General Hospital and Harvard Medical School, Boston, USA.  
"Proton Therapy Physics" covers delivery methods of PT (including beam scanning and passive scattering) and clinical aspects (treatment planning and quality assurance), explores research topics such as biological treatment planning, and offers insight on the past, present, and future of PT from a physics perspective.

Here are discussed which conditions are suitable for treatment with PT, how the treatment is delivered, and the current data supporting its use.

Preliminary results here indicate that the use of PT is associated with a significantly lower risk of secondary malignancies compared to RT, even if additional analyses are required given the prolonged latency period for the development of radiation-induced cancers.

Existing utilization patterns of highly conformal RT were used to estimate that about 1/3 of a patients irradiated annually at the institution could be potentially treated with PT, with an incremental cost of 20% across the entire treated patient population.

As it is often unclear whether to adopt a new technology for cancer treatment or to wait for more evidence, a technique originating from financial economics called “real options analysis” can help make this trade-off. Regarding proton therapy, adopt and trial was found to be the preferred option.

Second malignancies in radiation therapy occur mainly within the beam path. Compared to traditional radiotherapy, PT can significantly reduce the risk of developing an in-field second malignancy, depending on treatment planning parameters.

Comparisons of organ-specific equivalent dose were made to assess the risk of secondary cancer after IMRT and PT in patients with prostate and head-and-neck cancer. The results showed the risk was either significantly lower with PT or, at least, did not exceed the risk induced by conventional IMRT.
CENTRAL NERVOUS SYSTEM MALIGNANCIES


- Brown A.P. et al., “Proton beam craniospinal irradiation reduces acute toxicity for adults with medulloblastoma”, PubMed 23433794, International Journal of Radiation Oncology, Biology, Physics, 2013 June 1, 86(2):277-84. This report is the first analysis of clinical outcomes for adult medulloblastoma patients treated with proton CSI. Patients treated with PT experienced less treatment-related morbidity than patients treated with conventional RT, including fewer acute gastrointestinal and hematologic toxicities.

- Chen Y.L. et al., “Definitive high-dose photon/proton radiotherapy for unresected mobile spine and sacral chordomas”, PubMed 23609202, Spine Journal, 2013 July 1, 38(15):E930-6. The purpose of this study is to report the results of high-dose proton based definitive radiotherapy for unresected spinal chordomas. The results support the use of high-dose definitive radiotherapy for patients with medically inoperable or otherwise unresected, mobile spine or sacrococcygeal chordomas.


- Delaney T.F., “Long-term results of Phase II study of high dose photon/proton radiotherapy in the management of spine chordomas, chondrosarcomas and other sarcomas”, PubMed 24752878, Journal of Surgical Oncology, 2014 August, 110(2):115-22. Negative surgical margins are uncommon for spine sarcomas, hence adjuvant radiotherapy may be recommended. However, the dose to the tumor may be constrained by the spinal cord, nerves, and visceral tolerance. This study shows that local control with high dose photon/proton RT is high in patients with primary tumors, and late morbidity appears to be acceptable.

- Deraniyagala R.L. et al., “Proton therapy for skull base chordomas: an outcome study from the university of Florida proton therapy institute”, PubMed 24498590, Journal of Neurological Surgery, 2014 February, 75(1):53-7. Skull base chordoma is a rare, locally aggressive tumor located adjacent to critical structures. Gross total resection is difficult to achieve, and PT has the conformal advantage of delivering a high postoperative dose to the tumor bed. The results obtained in this study are promising in terms of tumor control, and the toxicity profile is acceptable.

- Grosshans D.R. et al., “Spot scanning proton therapy for malignancies of the base of skull: treatment planning, acute toxicities, and preliminary clinical outcomes”, PubMed 25304948, International Journal of Radiation Oncology, Biology, Physics, 2014 November 1, 90(3):540-6. This study describes treatment planning techniques and early clinical outcomes in patients treated with spot scanning PT for chordoma or chondrosarcoma of the skull base. In comparison to passive scattering, treatment plans for spot scanning PT displayed improved high-dose conformity. Clinically, treatment was well tolerated and disease control rates and toxicity profiles were favorable.


- Mizumoto M. et al., “Reirradiation for recurrent malignant brain tumor with radiotherapy or proton beam therapy. Technical considerations based on experience at a single institution”, PubMed 23824106, Strahlentherapie und Onkologie, 2013 August, 189(8):656-63. Radiotherapy for recurrent malignant brain tumors is usually limited because of the dose tolerance of the normal brain tissue. This study shows that reirradiation for recurrent malignant brain tumor using conventional RT, stereotactic RT or PT was feasible and effective in selected cases.

- Shih H.A. et al., “Proton therapy for low-grade gliomas: Results from a prospective trial”, PubMed 25585890, Cancer Cytopathology, 2015 May 15, 121(10):1712-9. This prospective study evaluates the potential treatment toxicity and progression-free survival in patients with low-grade glioma who received treatment with PT. Patients tolerate PT well and only a subset develops neuroendocrine deficiencies.
This study evaluates the efficacy and toxicity of PT for functional pituitary adenomas (FPAs). Proton irradiation is an effective treatment for FPAs, with hypopituitarism remaining the primary adverse effect.

In this study about the long-term clinical results of spot scanning PT for intracranial meningiomas, PT was proved to be a safe and effective treatment modality for patients with untreated, recurrent, or incompletely resected tumors.

OCULAR MALIGNANCIES AND BENIGN CONDITIONS

Radiation therapy can be used to treat uveal metastases with the goal of local control and improvement of quality of life. PT is an effective and efficient means of treating uveal metastases, with minor acute adverse effects.

This study investigates long-term disease and toxicity outcomes for pediatric retinoblastoma patients treated with PT. Long-term follow-up of retinoblastoma patients treated with PT demonstrates that it can achieve high local control rates, even in advanced cases, with many patients retaining useful vision in the treated eye.

This paper reports the clinical features and outcomes of iris melanomas treated by PT. PT appears to be the treatment of choice for the conservative treatment of iris melanomas with excellent tumor control and an acceptable complication rate.

This study evaluates long-term outcomes of PT in the treatment of choroidal melanoma of the intermediate zone of the fundus and demonstrates the effectiveness of PT in tumor control and preservation of the globe in the analyzed patients.

This study evaluates the risk factors, recurrence rates, re-treatments, and long-term patient outcomes following PT for uveal melanomas. It is shown that each globe retaining re-treatment approach can result in satisfying local tumor control. In case of early detection of local recurrence, preservation of the globe can be warranted.

The present analysis evaluates the efficacy and adverse effects of charged particle therapy (protons, helium ions, or carbon ions) for uveal melanoma. CPT was associated with lower retinopathy and cataract formation rates. Better outcomes may also be possible in terms of local recurrence, retinopathy, and cataract formation rates.

LYMPHOMAS

This paper reviews the outcomes of Hodgkin lymphoma treated with PT and discusses the ability of protons to reduce radiation dose to OARs and the impact on the most significant late complications related to the treatment.

This study reviews a single institution’s experience managing patients with non-Hodgkin lymphoma (NHL) treated with PT. PT proved to be a feasible and effective treatment for NHL, with favorable early outcomes.
**HEAD AND NECK MALIGNANCIES**

  Conventional RT can be associated with significant acute and long-term treatment-related toxicities in the treatment of head & neck tumors. Superior dose localization properties of proton radiation therapy allow smaller volumes of normal tissue to be irradiated than is feasible with any photon technique, and initial clinical experience with PT appears promising.

  A potential advantage of IMPT over IMRT in the treatment of oropharyngeal carcinoma (OPC) is a decrease in toxicity. This study quantifies the incidence of gastrostomy tube use in OPC patients treated with IMPT and compares it to gastrostomy use in patients treated with IMRT. Preliminary data suggest that IMPT has a lower rate of grade 3 dysphagia.

  The significance of definitive radiotherapy for sinonasal mucosal melanoma (SMM) is still controversial. This study evaluates the role of high-dose PT in patients with SMM. Findings suggest that high-dose PT is an effective local treatment that is less invasive than surgery but with comparable outcomes.

  The major benefits of modern radiation therapy in the treatment of oropharyngeal cancer are reduced xerostomia and better quality of life. Treatment-related toxicities must be kept in mind, particularly because most patients are expected to have a high probability of long-term survival after treatment. In this context, IMPT seems to provide additional advantages over IMRT by reducing radiation beam-path toxicities.

  PT has been used for cancer treatment since the 1950s, and both the number of patients and the variety of tumors treated have increased since then. Great interest has been expressed in evaluating whether PT can improve outcomes, especially early and late toxicity, when used in the treatment of head and neck malignancies. This review summarizes the progress made to date in addressing this question.

  The purpose of this study is to report outcomes of PT in head and neck adenoid cystic carcinoma. Initial outcomes are encouraging.

  IMPT is highly sensitive to uncertainties in beam range and patient setup, which are conventionally addressed using geometrically expanded planning target volume (PTV). This paper evaluates IMPT for head & neck cancer and shows that robust optimization based on clinical target volume (CTV) provides significantly more robust dose distributions to targets and organs than PTV-based conventional optimization.

  PT for head and neck cancer is an area of active research, and the subject of heightened scrutiny due to the significant associated cost. This article highlights recent research into proton dosimetry, its clinical benefit relative to other advanced radiotherapy modalities, key safety and cost considerations.

  Cost-effectiveness analysis based on normal tissue complication probability models and planning studies proved feasible and informative and enables the analysis of individualized strategies. The increased effectiveness of IMPT does not seem to outweigh the higher costs for all head-and-neck cancer patients. However, when assuming equal survival among both modalities, there seems to be value in identifying those patients for whom IMPT is cost-effective.

  This study synthesizes and compares available evidence considering the effectiveness of carbon-ion, proton and photon radiotherapy for head and neck cancer.

  Protons have the potential for a significantly lower normal tissue dose, while keeping similar or better target coverage. Scanned IMPT probably offers the most advantage and will allow for a substantially lower probability of radiation-induced side effects.
Evidence has suggested that RT with a lower dose per fraction may be a reasonable option for the treatment of centrally located NSCLC. The aim of this study — Makita C. et al., “High-dose proton beam therapy for stage I non-small cell lung cancer: Clinical outcomes and prognostic factors”, PubMed — is to evaluate the safety and efficacy of two PT protocols for stage I NSCLC and to determine prognostic factors. Both high-dose PT protocols achieved high local control rates with tolerable toxicities.

Options are limited for patients with intrathoracic recurrence of NSCLC who previously received radiation. This paper reports 5-year experience with the toxicity of conventional concurrent chemoradiation therapy for stage III non-small cell lung cancer. — Chang J. et al., “Phase 2 study of high-dose proton therapy with concurrent chemotherapy for unresectable stage III nonsmall cell lung cancer”, PubMed — shows that using PT to escalate the radiation dose to the tumor could improve the toxicity of conventional concurrent chemoradiation therapy. Adaptive plans seem to have acceptable toxicity and achieve same local, regional, and distant control and overall survival as non-adaptive plans, even in patients with larger tumors.

Concurrent chemoradiation is the standard of care in patients with limited-stage SCLC. While treatment with conventional RT is associated with high toxicity rates (particularly acute esophagitis and pneumonitis), this study shows that PT with radical intent was well tolerated, with no cases of acute toxicities and better sparing of lung and esophagus. — Gomez D.R., Chang J.Y., “Accelerated dose escalation with proton beam therapy for non-small cell lung cancer”, PubMed — reports early experience with IMPT for thoracic malignancies in terms of motion analysis and management, plan optimization and robustness, and quality assurance. IMPT using 4D CT-based planning, motion management, and optimization was implemented successfully and met quality assurance parameters for treating challenging thoracic cancers.

Local tumor control remains challenging in many cases of NSCLC, large or centrally located tumors. Concurrent chemotherapy and radiation can maximize tumor control and survival but a large proportion of patients cannot tolerate this therapy. The energy distribution of protons can be exploited to reduce involuntary irradiation of normal tissue and the resulting side effects. — Hoppe B.S. et al., “Proton therapy with concurrent chemotherapy for non-small-cell lung cancer: technique and early results”, PubMed — shows that PT can deliver a more conformal dose distribution than RT and may allow safe dose escalation in stage III lung cancer. Early outcomes are presented here for patients who received mediastinal PT with concurrent chemotherapy for NSCLC, which was associated with acceptable toxicity.

Adaptive planning can reduce normal tissue doses and prevent target misses, particularly for patients with large tumors that shrink substantially during therapy. Adaptive plans seem to have acceptable toxicity and achieve same local, regional, and distant control and overall survival as non-adaptive plans, even in patients with larger tumors. — Koay E.J. et al., “Adaptive/Nonadaptive Proton Radiation Planning and Outcomes in a Phase II Trial for Locally Advanced Non-small Cell Lung Cancer”, PubMed — demonstrates the potential of proton beam therapy for reirradiation and shows that PT is an option for treating recurrent NSCLC.

Intra thoracic recurrence of NSCLC after initial treatment remains a dominant cause of death. IMRT and PT are options for treating recurrent NSCLC, but rates of locoregional recurrence and distant metastasis are high, and patients should be selected carefully to maximize the benefit of additional aggressive local therapy while minimizing the risk of adverse side effects. — Makita C. et al., “High-dose proton beam therapy for stage I non-small cell lung cancer: Clinical outcomes and prognostic factors”, PubMed — has suggested that RT with a lower dose per fraction may be a reasonable option for the treatment of centrally located NSCLC. The aim of this study was to evaluate the safety and efficacy of two PT protocols for stage I NSCLC and to determine prognostic factors. Both high-dose PT protocols achieved high local control rates with tolerable toxicities.
Delivery of post-mastectomy radiation (PMRT) in women with bilateral implants represents a technical challenge, particularly when attempting to cover regional lymph nodes. IMPT provides improved homogeneity to the chest wall and regional lymphatics with improved sparing of surrounding normal structures. It may also enable women with mastectomy to undergo radiation therapy without the need for delay in breast reconstruction.

References:


This study reports on a prospective phase I study of 'in situ' tumor vaccination using CalTUMP, a newly developed immunoadjuvant, following local PT for HCC.

PT has seen an increasing role in the treatment of hepatocellular carcinoma (HCC). This review discusses the physical attributes and rationale for PT in the treatment of HCC.


Dosimetric planning studies have described potential benefits for the use of PT for locally advanced breast cancer. This study shows that PT for postmastectomy radiotherapy is feasible and well tolerated. This treatment may be warranted for selected patients with unfavorable cardiac anatomy, immediate reconstruction, or both that otherwise limits optimal radiotherapy delivery using standard methods.


The delivery of post-mastectomy radiation therapy can be challenging for patients with left-sided breast cancer that have undergone mastectomy. Proton RT enables delivery of radiation to the chest wall and regional lymphatics, including the internal mammary nodes, without compromise of coverage and with improved sparing of surrounding normal structures.


IMPT could significantly decrease the dose to the heart and the region of the left anterior descending coronary artery compared to tangential IMRT with breath-hold, and could be particularly useful for patients at high risk for major coronary events.


Regional node irradiation in patients with invasive breast cancer often results in increased radiation exposure to organs at risk. This study shows that regional node target coverage is inferior with 3D conformal RT compared with either IMRT or 3D conformal RT+PT, with which OARs were exposed to less radiation. PT offers both improved coverage of the regional lymph nodes and decreased dose to the heart, lung, and contralateral normal tissue.

**LIVER MALIGNANCIES**


PT may provide useful local-regional treatment for hepatocellular carcinoma (HCC). In this study, PT was found to be a safe and effective local-regional therapy for inoperable HCC. A randomized controlled trial to compare its efficacy to a standard therapy has been initiated.


This paper reviews the literature concerning the systematic use of PT in the treatment of HCC, focusing on clinical results and technical issues. The literature search was conducted according to a specific protocol in the Medline and Scopus databases by two independent researchers covering the period of 1990-2012.


This article reviews the role of PT in the treatment of primary liver cancer focusing on hepatocellular carcinoma (HCC). The dose-sparing physical properties of protons are of great advantage in the treatment of HCC.


The purpose of this study is to determine the optimal dose of PT in hepatocellular carcinoma patients (HCC). PT is safe and effective in patients with inoperable HCC, with at least 78 GyE10 of EQD2 needed to achieve sufficient local tumor control.


This study evaluates the clinical effectiveness and safety of PT in advanced HCC patients with portal vein tumor thrombosis (PVTT). It suggests that PT could improve local progression-free survival, relapse-free survival, and overall survival in advanced HCC patients with PVTT, and that it is feasible and safe for these patients.


PT has seen an increasing role in the treatment of hepatocellular carcinoma (HCC). This review discusses the physical attributes and rationale for PT in HCC. It also reviews recent literature regarding clinical outcomes of using PT for the treatment of HCC.


This study reports on a prospective phase I study of 'in situ' tumor vaccination using CalTUMP, a newly developed immunoadjuvant, following local PT for HCC to prevent the cancer recurrence. The treatment was feasible and safe in patients with heavily pre-treated HCC.

Treatment for unresectable intrahepatic cholangiocarcinoma (ICC) has not been established. The aim of this study is to evaluate the outcomes of PT for patients with unresectable ICC. The results suggest that long-term survival can be achieved for patients without distant metastasis.


Stereotactic body radiotherapy (SBRT) is often the preferred treatment for advanced liver tumors that are out of range of surgical resection or radiofrequency ablation. However, only a minority of patients may be candidates because of the limited radiation tolerance of normal liver and intestine. Due to the favorable depth-dose characteristics of protons, a considerable sparing of normal tissue can be obtained using proton-based SBRT for solitary liver tumors.


The prognosis of patients with advanced hepatocellular carcinoma with portal vein tumor thrombosis is extremely poor, as effective treatment options are limited. This paper shows that PT improves local control and significantly prolongs survival in these patients.


Hepatocellular carcinoma (HCC) is the sixth most common cancer in the world, but radiotherapy remains uncommon because of the likelihood of radiation-induced liver disease. This study suggests that PT may reduce the risk of second malignant neoplasms compared to RT for some HCC patients.

PANCREATIC MALIGNANCIES


This study shows the safety and feasibility of 1 week of chemoradiation with PT and capecitabine followed by early surgery.


The potential role for adjuvant PT for resected pancreatic head cancer was assessed in this study. By reducing small bowel and stomach exposure, protons have the potential to reduce the acute and late toxicities of postoperative chemoradiation.


PT may allow for significant sparing of the small bowel and stomach and is associated with a low rate of gastrointestinal toxicity. The favorable toxicity profile associated with PT may allow for radiotherapy dose escalation, chemotherapy intensification, and possibly increased acceptance of preoperative radiotherapy.


Uncontrolled local growth is the cause of death in ~ 30% of patients with unresectable pancreatic cancers. In this study, the authors investigate the potential use of double scattering and PBS PT in limiting dose to critical OARs. If PT does not appear to reduce OAR volumes receiving high dose, it is however able to reduce the treated volume receiving low-intermediate doses.

GASTROINTESTINAL MALIGNANCIES


This study compares 3D conformal RT, IMRT and PT plans in patients undergoing neoadjuvant chemoradiation for resectable rectal cancer. By reducing bone marrow exposure, PT may reduce the acute hematologic toxicity of neoadjuvant chemoradiation.


Cardiopulmonary late toxicity is of concern in concurrent chemoradiotherapy (CCRT) for esophageal cancer. The aim of this study was to examine the benefit of PT using clinical data and adaptive dose-volume histogram analysis. Irradiation dose, volume and adverse effects on the heart and lung can be reduced using protons; hence PT is a promising treatment modality for the management of esophageal cancer.


Concurrent chemoradiotherapy cures most patients with anal squamous cell carcinoma at the cost of significant treatment-related toxicities. If IMRT reduces side effects compared to older techniques, PT offers additional advantages by reducing low dose radiation to important organs at risk.

Multimodality therapy for gastrointestinal cancers carries considerable risk for toxicity, as they inherently occur amid visceral organs particularly sensitive to radiotherapy. In many sites, local recurrences after chemoradiation pose a particular challenge, and reirradiation in these sites may be done successfully with PT.

CERVICAL MALIGNANCIES


In patients who are not eligible for brachytherapy, IMPT as a boost technique additionally to external beam radiation therapy provides good target coverage and conformity and superior dose-volume parameters, compared with recommendations to MRI-guided brachytherapy. For selected patients, IMPT might be a valid alternative to brachytherapy and also superior to reference VMAT plans.

PROSTATE MALIGNANCIES


Young men (≤60 years old) undergoing PT for treatment of prostate cancer have excellent outcomes with respect to erectile dysfunction, urinary incontinence, and other health-related quality of life parameters during the first 2 years after treatment.


Early outcomes with image-guided PT for prostate cancer suggest high efficacy and minimal toxicity, with only 1.9% grade III genito-urinary symptoms and less than 0.5% grade III gastro-intestinal toxicities.


Five-year clinical outcomes with image-guided PT for prostate cancer included extremely high efficacy, minimal physician-assessed toxicity, and excellent patient-reported outcomes.


PT is theoretically an excellent modality for external beam radiotherapy, providing an ideal dose distribution. However, it is not clear whether PT for prostate cancer can clinically control toxicities. This prospective study has revealed that PT for localized prostate cancer can achieve a low incidence of late grade II or greater rectal toxicities.


PT for prostate cancer has become a source of controversy in the urologic community, and the rapid dissemination and marketing of this technology has led to many patients inquiring about this therapy. This article reviews the basic science of the proton beam and examines the literature so that every urologist is able to comfortably discuss this option with inquiring patients.


This randomized controlled trial aimed at testing the hypothesis that increasing radiation dose delivered to men with early-stage prostate cancer improves clinical outcomes. The results showed superior long-term cancer control compared to conventional-dose radiation. This was achieved without an increase in grade III late urinary or rectal morbidity.

SARCOMAS


A study was undertaken to assess clinical outcomes and the role of PT for local control of osteosarcoma. It was shown that PT to deliver high radiotherapy doses allows locally curative treatment for some patients with unresectable or incompletely resected osteosarcoma.
PEDIATRIC MALIGNANCIES


Children treated for CNS tumors with conventional RT or cranial radiation therapy (CRT) are at high risk of neurocognitive impairment or dysfunction. Delaying or reducing CRT and using chemotherapy as primary therapy have improved survival and the neurocognitive trajectory. Similarly, the use of PT may now offer the next step with respect to both survival and long-term neurocognitive functioning.


PT offers a powerful treatment option in the pediatric population, where adverse events related to radiation exposure are of concern. This study reports acute toxicities and preliminary outcomes for pediatric patients with ependymomas of the spine treated with PT at the MD Anderson Cancer Center.


This paper compares PT with IMRT for pediatric craniopharyngioma in terms of disease control, cyst dynamics and toxicity.


The increasing efficacy of pediatric cancer therapy has produced many long-term survivors who now struggle with serious morbidities mostly related to radiation therapy. PT holds great promise to drastically reduce these treatment-related late effects in long term survivors by reducing dose to normal tissue.


This paper reports the clinical outcomes of 7 children with bladder/prostate rhabdomyosarcoma treated with PT and compares PT plans with matched IMRT plans, with an emphasis on dose savings to reproductive and skeletal structures. PT provides significant dose savings to normal structures compared to IMRT and is well tolerated in this patient population.


Primary low-grade gliomas are common brain tumors of childhood, and many of them require radiation therapy as definitive treatment. Increased conformity could decrease the incidence and severity of late effects. PT appears to be associated with good clinical outcomes, especially when the tumor location allows for increased sparing of the left temporal lobe, hippocampus, and hypothalamic-pituitary axis.


This paper evaluates outcomes and tolerance of high-dose RT and PT in the management of skull base and cervical canal primary bony malignancies in children. High-dose combined fractionated photon-proton therapy is well tolerated in children and allows excellent local control with minimal long-term toxicity.


This study describes the early clinical outcomes of a prospective phase 2 study of consolidative involved-node PT as a component of combined-modality therapy in patients with stages I to III Hodgkin lymphoma with mediastinal involvement.


PT offers superior low and intermediate radiation dose distribution compared with photon RT for brain and skull base tumors. This article investigates the tolerance of the pediatric brainstem to PT and shows that the utilization of current national brainstem dose guidelines is associated with a low risk of brainstem toxicity in pediatric patients.


Upfront chemotherapy followed by 3D PT presents good disease early outcomes for very young children with medulloblastoma or supratentorial primitive neuroectodermal tumor.


Early screening for breast cancer may be unnecessary after craniospinal irradiation with PT, whereas it should be considered with X-ray therapy, given doses to the breast that approach the Children’s Oncology Group-recommended threshold.


Radiotherapy plays an integral role in the local control of pediatric sarcomas, which often arise adjacent to critical structures and growing organs. PT shows either equivalent or improved outcomes, and lower toxicity for soft tissue sarcoma compared to RT. For bone and cartilaginous sarcomas, a clearer advantage exists for PT due to its ability to increase total dose while respecting adjacent structures.
PT has been used safely and effectively for medulloblastoma, primitive neuro-ectodermal tumors, craniopharyngioma, ependymoma, germ cell intracranial tumors, low-grade glioma, retinoblastoma, rhabdomyosarcoma and other soft tissue sarcomas, Ewing’s sarcoma and other bone sarcomas. Other possible applications are emerging. The main advantage of PT is the sparing of intermediate-to-low-dose to healthy tissue.

This study presents preliminary clinical outcomes including late effects on pediatric Ewing’s sarcoma patients treated with PT. This treatment modality was well tolerated with few adverse events. This study presents preliminary clinical outcomes including late effects on pediatric Ewing’s sarcoma patients treated with PT. This treatment modality was well tolerated with few adverse events.

PT has been used safely and effectively for medulloblastoma, primitive neuro-ectodermal tumors, craniopharyngioma, ependymoma, germ cell intracranial tumors, low-grade glioma, retinoblastoma, rhabdomyosarcoma and other soft tissue sarcomas, Ewing’s sarcoma and other bone sarcomas. Other possible applications are emerging. The main advantage of PT is the sparing of intermediate-to-low-dose to healthy tissue.
Song S., “Proton beam therapy reduces the incidence of acute haematological and gastrointestinal toxicities associated with craniospinal irradiation in pediatric brain tumors”, PubMed 24913151, Acta Oncologica, 2014 March, 10:1-7. This study shows that the acute toxicity of proton beam craniospinal irradiation (CSI) was lower compared to that of conventional photon beam CSI in children with brain tumors.

Song S. et al., “Proton beam therapy reduces the incidence of acute haematological and gastrointestinal toxicities associated with craniospinal irradiation in pediatric brain tumors”, PubMed 24913151, Acta Oncologica, 2014 September, 53(9):1158-64. This paper compares the acute toxicity of PT craniospinal irradiation (CSI) to that of conventional RT CSI in children with brain tumors: the incidence rates of thrombocytopenia and diarrhoea were lower with PT than with RT, and one month after treatment, the recovery from leukopenia and thrombocytopenia was better in patients treated with PT.


Zhang R. et al., “Comparison of risk of radiogenic second cancer following photon and proton craniospinal irradiation for a pediatric medulloblastoma patient”, PubMed 23322160, Physics in Medicine and Biology, 2013, 58(4):807-23. Pediatric patients who received radiation therapy are at risk of developing side effects such as radiogenic second cancer. PT confers lower predicted risk of second cancer than RT for pediatric medulloblastoma patients receiving craniospinal irradiation.

WEB REFERENCES

National Association for Proton Therapy: www.proton-therapy.org
OncoLink: www.oncolink.org
Pediatric Proton Foundation: www.pediatricprotonfoundation.org
Proton Therapy Today: www.protontherapytoday.com
Particle Therapy Co-Operative Group: http://www.ptcoq.ch/
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