PROTON BEAM RADIATION THERAPY

Effective Date: March, 2013

The recommendations contained in this guideline are a consensus of the Alberta Health Services Cancer Care Proton Therapy Guideline Working Group and Guideline Advisory Group synthesis of currently accepted approaches to management, derived from a review of relevant scientific literature. Clinicians applying these guidelines should, in consultation with the patient, use independent medical judgment in the context of individual clinical circumstances to direct care.
BACKGROUND

Charged particle radiotherapy uses beams of protons or other particles such as helium or carbon instead of photons. In contrast to conventional photon radiotherapy, in which the greatest energy release is at the surface of the tissue and decreases exponentially the deeper the radiation travels, the energy of a proton beam is released near the end of its path, resulting in a sharp and localized dose peak, referred to as the Bragg peak. This allows for better dose distribution when compared to photon beam radiotherapy, thereby decreasing the dose to normal surrounding tissues, and reducing the risk of both acute and long-term side effects. To date, there are no published controlled comparative studies describing outcomes from patients treated with proton beam radiotherapy versus other therapies; thus the advantage of protons over conventional photon therapy is based on the dosimetric advantage of protons over photons for tumours that are in immediate proximity to critical structures. The majority of the published literature is in the form of prospective or retrospective case series and cohort studies; there is also significant variation in the types and stages of cancer for which treatment with proton beam radiotherapy has been reported, as well as the reported doses and fractionation schedules. Published reports focus mainly on toxicity, and include pediatric, adolescent, and adult patients treated with proton beam radiotherapy primarily for ocular cancers, spine or skull base chordomas and chondrosarcomas, spinal and paraspinal bone and soft tissue sarcomas, head and neck cancers, and brain tumours. In addition, there is some literature reporting the use of proton beam radiotherapy for patients with lymphoma, non-small cell lung cancer, prostate cancer, and some gastrointestinal cancers.

As of October 2012, there are 41 facilities worldwide that offer treatment with proton beam radiotherapy. In North America, there are currently 12 facilities in operation, and 8 more under development or being constructed

In early 2012, the Alberta Health Services Cancer Care Proton Therapy Guideline Working Group and Guideline Advisory Group met to evaluate the most current evidence for the use of proton beam radiotherapy in pediatric and adult patients with cancer, and to develop a de novo guideline with recommendations based on an expert review of the available literature. The resulting evidence review, guideline document, and accompanying documents were presented to the Out of Country Health Services Committee, which operates at arm’s length from Alberta Health, in order to establish a process to identify which patients are appropriate candidates to receive out-of-country treatment with proton beam radiation therapy.

GUIDELINE QUESTIONS

- What is the evidence for the use of proton beam radiation therapy for the management of patients with cancer?
- What are the published recommendations for the selection of patients most likely to benefit from treatment with proton beam radiation therapy?
- What are the steps involved in referring a patient for out-of-country proton beam radiation therapy?
DEVELOPMENT

The Alberta Health Services Cancer Care Proton Therapy Guideline Advisory Group took the following steps in producing this guideline:

1. The Guideline Advisory Group members individually reviewed the results of an environmental scan and literature review conducted by a Knowledge Management Specialist from the Guideline Utilization Resource Unit. Members of this group include representatives from Alberta Health, as well as the departments of medical oncology, radiation oncology, and pediatric neurosurgery at the two tertiary cancer centres in Alberta. For a detailed description of the methodology followed during the guideline development process, please refer to the Guideline Utilization Resource Unit Handbook.

2. Based on this review, the Guideline Advisory Group gave support to the Guideline Working Group to draft a guideline containing the recommendations and supporting evidence about the selection of patients most likely to benefit from treatment with proton beam radiation therapy.

3. The Guideline Working Group then distributed the draft document via an anonymous electronic survey to 17 healthcare professionals from various disciplines within the province for review and comment. The response rate was 59%.

4. The comments from the external review were incorporated into the guideline draft by the Guideline Working Group.

5. The final guideline was reviewed and endorsed in February 2013 by the Alberta Health Services Cancer Care Proton Therapy Guideline Advisory Group and Guideline Working Group, and was posted on the external website in March 2013.

SEARCH STRATEGY

Medical journals were searched using the MEDLINE (1950 to April Week 4, 2012), EMBASE (1980 to April Week 4, 2012), Cochrane Database of Systematic Reviews (1st Quarter, 2012), Cochrane Central Register of Controlled Trials (1st Quarter, 2012), and Pubmed electronic databases; the references and bibliographies of studies identified through these searches were scanned for additional sources. The MEDLINE search terms were: Protons (MeSH term) OR Radiotherapy, High Energy (MeSH term) OR particle beam therapy OR charged particle therapy AND Skull Base Neoplasms (MeSH term) OR Spinal Neoplasms (MeSH term) OR Chondrosarcoma (MeSH term) OR Chordoma (MeSH term) OR Sarcoma (MeSH term). The search was limited to studies published in the English language between the years 2000 and 2012. There were no limitations by study design. A search for new or updated guidelines, health technology assessments, and medical policies was conducted by accessing the websites of guideline developers and the National Guidelines Clearinghouse database, and by searching the grey literature using online search engines. Summaries of published clinical practice guideline recommendations and health technology assessments are available in Appendix A.

TARGET POPULATION

The recommendations in this guideline are for pediatric, adolescent, and adult patients who are residents of Alberta and may qualify to receive proton beam radiotherapy at a facility outside of Canada for treatment of their cancer.
SUMMARY OF RECOMMENDATIONS

1. A wide range of factors must be taken into account in assessing if proton beam radiotherapy will confer a significant advantage for the patient over standard conformal or stereotactic radiotherapy available in Alberta – the diagnosis alone is not sufficient.

2. Pediatric and adolescent tumour sites that may be considered for referral for out-of-country proton beam radiotherapy include:
   a. those requiring craniospinal irradiation
   b. the following central nervous system tumours or lesions: arteriovenous malformations, ependymomas, craniopharyngiomas, CNS germ cell tumours, primitive neuroectodermal tumours, and low grade gliomas
   c. the following non-central nervous system tumours: sarcomas including chordoma and chondrosarcoma, rhabdomyosarcoma, Ewing’s sarcoma, pineal tumours, and lymphoma.

3. Adult tumour sites that may be considered for referral for out-of-country proton beam radiotherapy include:
   a. the following central nervous system tumours or lesions: arteriovenous malformations, benign meningioma, neuromas, craniopharyngioma, CNS germ cell tumours, and low grade gliomas
   b. the following non-central nervous system tumours: sarcoma including chordoma and chondrosarcoma, lymphoma in patients under the age of 30 years, and paranasal sinus and nasal cavity tumours.

4. Adult, pediatric, and adolescent patients with ocular melanomas requiring proton beam radiotherapy should be sent to the TRIUMF Proton Treatment Facility in Vancouver, BC for treatment.

5. Members of the working group do not currently recommend that patients with prostate cancer, non-small cell lung cancer, or most lymphomas be referred for proton beam radiotherapy, due to an insufficient evidence base. However, individual patient cases should be discussed by the multidisciplinary team during a Tumour Board meeting.

6. For adult, adolescent, and pediatric cases, the referral for proton beam radiotherapy must come from the consultant oncologist who has seen and assessed the patient. Before the referral is made, a full multidisciplinary Tumour Board meeting should be held in which all tumour group members, including a radiation oncologist, have the opportunity to provide input on the case. In cases of arteriovenous malformations in which there is no tumour present, discussion at an appropriate multidisciplinary meeting that includes a radiation oncologist should follow the same processes as described for multidisciplinary Tumour Board meetings.

7. Approval of the referral must be submitted to the Out-of-Country Health Services Committee, which operates at arm’s length from Alberta Health. Once approved, the responsibility for referral and communications with the proton beam therapy treatment centre remains with the referring oncologist. The responsibility for follow-up and continuity of care also rests with the referring oncologist.

8. Additional and over-riding principles for approval and funding include:
   a. the treatment should be given with curative intent
   b. the patient should have a good performance status (0-2)
   c. the expected survival of the patient should be greater than 5 years
   d. the patient must be able and willing to travel.
DISCUSSION

I. Indications and Evidence for Proton Beam Therapy

Pediatric Tumours

Radiation therapy has played an important role in the treatment and cure of children diagnosed with malignant tumours over the past 30 years; given that approximately 70% of children with malignancies can now expect to be cured, the late effects of treatment have now become a major focus. Proton beam therapy is associated with a reduction in acute and long-term toxicities, as well as lower rates of radiation-induced second malignancies, and potentially less acute and long-term damage to developing organs in pediatric and adolescent patients with cancer; therefore, the benefits of proton beam radiotherapy are potentially the greatest in this population. Although limited, published reports of pediatric and adolescent patients treated with proton beam radiotherapy have mostly addressed tumours arising on or near critical structures, as well as tumours where organs in the exit path of photon radiotherapy present significant secondary malignancy risk or risk of impaired development and function; such tumours include medulloblastomas, gliomas, ependymomas, retinoblastomas, rhabdomyosarcomas, and pelvic sarcomas.

In one of the larger pediatric series published to date, MacDonald and colleagues reported the results of 17 pediatric patients with WHO grade II or III intracranial ependymomas treated with 3-dimensional conformal proton beam radiotherapy. At a median follow-up of 26 months, the rates of local control, progression free survival, and overall survival rates were 86%, 80%, and 89%, respectively. Similarly, Amsbaugh and colleagues recently published the results of a prospective case series of eight pediatric patients with WHO grade I or II spinal ependymomas treated with proton beam radiotherapy. Five patients were treated with proton beam radiotherapy as part of their primary management, while three were treated for recurrence of their disease. The entire vertebral body was treated in all but two patients, with a mean dose of 51.1 cobalt grey equivalents (CGE). The rates of local control, event-free survival, and overall survival were all 100 percent at a mean follow-up of 26 months, and the investigators reported minimal acute side effects.

In a case series of three pediatric patients with medulloblastoma, Yuh and colleagues reported minimal acute side effects, excellent sparing of surrounding critical structures, and no treatment disruptions when the patients were treated with 36 CGE to the craniospinal axis and 18 CGE to the posterior fossa. Similarly, St. Clair and colleagues compared treatment plans from standard photon therapy to intensity modulated radiotherapy (IMRT) and proton beam radiotherapy for craniospinal axis irradiation and posterior fossa boost in a pediatric patient with medulloblastoma. They reported substantial normal-tissue dose sparing with IMRT and proton treatment of the posterior fossa and spinal column, and also that protons were superior to IMRT in this case. In a modeling study evaluating the consequences of radiotherapy in five year old patients with medulloblastoma, Lundkvist and colleagues reported that proton radiation therapy was cost-effective and was associated with an additional 0.68 quality-adjusted life-years per patient compared with conventional photon radiotherapy. Reductions in IQ loss and growth hormone deficiency contributed most to the cost savings and were the most important parameters for cost-effectiveness. This analysis suggests that proton beam radiotherapy may be cost-saving in comparison to photon radiotherapy for pediatric patients with medulloblastoma due to the reduction of late side-effects. A reduction in side-effects for pediatric patients with medulloblastoma treated with proton beam radiotherapy was also recently demonstrated in a prospective study of 23 pediatric patients who were followed for high-grade ototoxicity, although a cost-benefit analysis was not reported for this trial.
Central Nervous System Tumours
Similar to pediatric patients with favourable prognoses, adult patients with benign lesions and indolent malignant tumours also benefit from proton beam radiotherapy due to a decreased risk of late neurologic toxicities.

Meningiomas. Meningiomas are the second most common intracranial tumour reported in adults, accounting for 13 to 26% of all primary brain tumours in this population. The management of a patient with a meningioma depends on the signs and symptoms produced by the tumour, the age of the patient, and the location and size of the tumour. In the Meningiomas clinical practice guideline, the Alberta Provincial CNS Tumour Team members recommend surgery as the primary treatment for patients who are not candidates for management by watch-and-wait. This guideline also states that radiotherapy offers reasonable control for patients who are not candidates for surgery, patients whose tumour location or shape is not amenable to surgery (such as a cavernous sinus meningioma), patients who have symptomatic residual disease, or for the treatment of recurrence. Boskos and colleagues reported on 24 patients with either atypical or metastatic meningioma treated at the Centre Protonthérapie d'Orsay with a postoperative combination of proton and photon radiotherapy. The mean local relapse-free survival was 28.3 months (range 10-50) for atypical meningioma and 23 months (range 13-33) for malignant meningioma; ten tumours recurred locally. Overall survival rates were 100% at one year, 80.4% ± 8.8% at three years, 53.2% ± 11.6% at five years, and 42.6% ± 13% at eight years. Noël et al. also reported on the outcomes of 51 patients treated for base of skull meningiomas with a combination of proton and photon radiotherapy. The four-year local control rate was 98%, and the four-year overall survival rate was 100%. The investigators reported tumour stabilization in 38 patients (72%), volume reduction in ten patients (20%), and intra-tumour necrosis in three patients; grade 3 side effects were observed in two patients. Similarly, Wenkel et al. reported on 46 patients with partially resected, biopsied, or recurrent meningiomas who were treated with combined proton and photon radiotherapy at the Massachusetts General Hospital and the Harvard Cyclotron Laboratory. The four-year local control rate was 98%, and the four-year overall survival rate was 100%. The use of stereotactic and hypofractionated stereotactic proton beam radiotherapy were reported by Vernimmen and colleagues in a study of 27 patients with large or complex intracranial meningiomas. Of the 18 patients treated with hypofractionated stereotactic proton beam radiotherapy, 16 remained clinically stable or improved. Of the five patients treated with stereotactic proton beam radiotherapy, two showed clinical improvement and three remained clinically stable. The radiologic control rate was 88% for the patients treated with hypofractionation, and 100% for patients treated without hypofractionation. In a study investigating the use of spot-scanning proton beam radiotherapy, Weber and colleagues reported on 13 patients treated postoperatively for incomplete resection or recurrence and three patients treated radically after presumptive diagnosis based on imaging. The cumulative three-year local control, progression-free survival and overall survival rates were 91.7%, 91.7%, and 92.7%, respectively, and no patient died from recurrent disease. The cumulative three-year toxicity-free survival rate was 76.2%; radiation-induced side effects included grade 3 optic neuropathy, grade 2 retinopathy, and grade 4 brain necrosis.

Arteriovenous malformations. Another type of benign brain lesion is an arteriovenous malformation (AVMs), which occurs in approximately 0.1 percent of the population, and can cause intracerebral hemorrhage, seizures, and focal neurological deficits. Standard interventions for brain AVMs include resection for surgically accessible lesions and embolization; stereotactic radiosurgery with either photons or protons can be used for patients with resectable lesions, or those who are poor candidates or refuse surgery. In a review of 68 patients with cerebral AVMs treated with proton-beam stereotactic radiosurgery, Seifert et al. reported symptoms control in 85.7% in patients with Spetzler-Martin grades I and II AVMs,
54.2% of patients with grade III AVMs, and 24% of patients with grade IV AVMs. Vernimmen and colleagues followed 64 patients with predominantly large AVMs who were treated with hypofractionated stereotactic proton radiosurgery, and reported obliteration rates of 67% for patients with AVM volumes less than 14cc and 43% for AVM volumes greater than 14cc. Grade IV acute complications were observed in 3% of patients, and transient delayed effects were seen in 23% of patients. Complications associated with radiosurgery include radiation necrosis, seizures, and new neurologic deficits, therefore the efficacy of radiosurgery must be weighed against the potential toxicities of treatment.

**Acoustic neuromas.** Acoustic neuromas, also known as vestibular schwannomas, are benign slow-growing tumours that commonly arise from the vestibular portion of the eighth cranial nerve and account for approximately 8% of intracranial tumours in adults. Options for treatment depend on tumour size, tumour growth rate, symptoms, health status, and patient preference, and may include observation, single-session stereotactic radiosurgery, fractionated conventional radiotherapy, fractionated stereotactic radiotherapy, proton beam radiotherapy, or surgery. Although a distinct advantage of proton therapy over photon therapy for acoustic neuromas has not been demonstrated to date, larger tumours may benefit from proton beam radiotherapy because of the reduction of exit dose to the non-targeted brain and surrounding normal tissues. In a review of 88 patients treated with proton beam radiotherapy at the Harvard Cyclotron Laboratory, Weber and colleagues reported two- and five-year actuarial control rates of 95.3% and 93.6% respectively in patients treated with stereotactic proton beam radiotherapy. Facial and trigeminal nerve function was preserved in 91% and 89% of patients, respectively, and the five-year cumulative radiologic response rate was 94.7%. Salvage therapy was required in five patients post-radiotherapy. In a trial of 30 patients with acoustic neuromas treated with fractionated proton beam radiotherapy at the Loma Linda Medical Center, Bush et al. reported no disease progression at a mean follow-up of 34 months, and radiographic regression in 11 patients. The rate of hearing preservation was 31%, however only 13 patients had useful hearing prior to radiotherapy. No transient or permanent treatment-related trigeminal or facial nerve dysfunction was observed.

**Spinal and Skull Base Chordomas and Chondrosarcomas**

Chordomas are slow growing, locally aggressive bone tumours arising from the remnants of the notochord and most frequently occurring in the sacrococcygeal region or at the base of the skull near the sphenoccipital region. Chordomas are rare in both adults and children, accounting for only three to four percent of all primary bone tumours. Chondrosarcomas are malignant cartilaginous tumours that can occur anywhere in the skeletal system, and most commonly in the long bones and pelvis; in the skull base, chondrosarcomas account for six percent of all tumours, and most commonly occur in the middle, posterior, or anterior fossae. The clinical features of chordomas and chondrosarcomas are quite similar, as is the optimal treatment strategy, which involves maximal surgical resection. Adjuvant postoperative radiotherapy is commonly used for patients with chordomas, and high doses have been associated with lower rates of local recurrence or treatment failure. Postoperative radiotherapy has also been reported for the management of patients with chondrosarcomas. As a result of their proximity to critical neural structures, however, chordomas and chondrosarcomas of the skull base and spine are difficult to manage with conventional radiotherapy techniques, therefore making these tumours one of the main applications for proton beam radiotherapy. Despite the relative rarity of these tumours, the results of over 1,700 patients with spinal and skull base chordomas and chondrosarcomas treated with proton beam radiotherapy have been reported worldwide since the early 1970’s. Ares and colleagues recently reported the results of a long-term follow-up study of 64 patients with skull base chordomas or chondrosarcomas treated with spot-scanning proton beam radiotherapy at the Paul Scherrer Institute. The five-year overall survival rate was 91% for patients with chondrosarcomas, and 62% for patients with chordomas; the five-year local control rate was 94% for patients with chondrosarcoma, and 81% for
patients with chordomas. Adverse events included grade three (N=1) and grade four (N=1) unilateral optic neuropathy, grade three temporal lobe parenchyma (N=2) and grade one leukoencephalopathy (N=5). In the largest series published to date, Munzenrider and Liebsch retrospectively reviewed 621 patients with spinal and skull base chordomas or chondrosarcomas treated between 1975 and 1998 at the Harvard Cyclotron Laboratory. Treatment involved combined proton and photon irradiation, with a dose range of 66 to 83 CGE. For patients with skull base tumours, the five-year overall survival rates were 91% for chondrosarcomas and 80% for chordomas (p=0.010), and the ten-year overall survival rates were 88% for chondrosarcomas and 54% for chordomas (p<0.0001). Local recurrence rates were also better for chondrosarcomas versus chordomas at five years (98% versus 73%, p<0.0001) and ten years (94% versus 54%, p=0.0001). For patients with cervical spine tumours, the five-year overall survival rates were 48% for chondrosarcomas and 80% for chordomas (p=0.008), and the ten-year overall survival rates were 48% for chondrosarcomas and 33% for chordomas (p=0.109). Local recurrence rates for chondrosarcomas and chordomas were 54% and 69% at five years, and 54% and 48% at ten years, with no significant differences between the two groups of patients. In a systematic review of seven studies involving 416 adult and pediatric patients with inoperable or incompletely resected chordomas of the skull who were treated with proton beam radiotherapy, Amichetti et al. reported an average five-year overall survival rate of 79.8% (range 66.7-80.5%) and an average five-year local control rate of 69.2% (range 46-73%). Late toxicity was reported in the range of 5-17%, with some grade three and four toxicities reported. Similarly, in another systematic review of four studies involving 254 patients with chondrosarcomas of the skull base treated post-operatively with proton beam radiotherapy, Amichetti and colleagues reported a five-year overall survival rate of 99-100% and a five-year local control rate of 75-99%.

The use of proton beam radiotherapy has also been described for soft tissue sarcomas of the spine. DeLaney and colleagues recently reported the results of a prospective phase II trial involving 50 patients mostly with spinal and paraspinal chordomas and chondrosarcomas, but patients with liposarcoma, osteosarcoma, Ewing's sarcoma, giant cell tumour, angiosarcoma, malignant schwannoma, and spindle cell sarcoma were also included. Patients were treated post-operatively with high-dose proton-photon radiotherapy at a median dose of 76.6 CGE, and select patients with high-grade tumours also received chemotherapy. Thirty-six patients were treated for primary tumours, and 14 for recurrent disease. The five-year overall and recurrence-free survival rates were 87% and 63% respectively, and the five-year local control rate was 78%. Grade three adverse events included neuropathy, erectile dysfunction, rectal bleeding, and sacral insufficiency fractures.

**Ocular Melanoma**

Uveal melanoma, which includes tumours in the iris, ciliary body, and choroid, is the most common type of primary uveal tumour in adults, accounting for 95 percent of all cases. Depending on the size and location of the tumour, treatment can range from local ablative treatments to complete removal of the eye. The use of proton beam radiation therapy for larger tumours has been reported extensively in the literature, with five recent comparative studies and numerous non-comparative studies showing high rates of local control and minimal adverse effects. However, a recent publication based on data from the SEER database in the United States reported that survival rates for patients with uveal melanoma have not improved from 1973 to 2008, despite a shift toward more conservative treatments such as proton beam radiotherapy during this time period. The members of the Alberta Health Services Cancer Care Proton Therapy Guideline Working Group and Guideline Advisory Group recommend that patients with ocular melanomas undergo assessment by clinicians affiliated with the Provincial Ocular Brachytherapy Program, and those requiring proton beam radiotherapy be referred to the TRIUMF Proton Treatment Facility in Vancouver, BC for treatment. This centre is a collaboration between the BC Cancer Agency, the
University of British Columbia Eye Care Centre, and TRIUMF, and is the only facility of its kind in Canada (For more information, visit: www.triumf.ca/proton-therapy).

**Paranasal Sinus and Nasal Cavity Tumours**

Tumours of the paranasal sinuses and nasal cavity are rare, accounting for two to three percent of all head and neck tumours. Optimal treatment involves surgical resection and postoperative radiotherapy; chemotherapy, either alone or in combination with radiotherapy and/or surgery, is also an option for patients who are at high risk of recurrence or for patients with inoperable tumours. For patients with paranasal sinus and nasal cavity tumours who are good candidates, proton beam radiotherapy is the ideal form of radiotherapy, owing to the irregular shape of many of these tumours, the relative radioresistance of some of these tumours, requiring high physical and biologically effective doses, the high risk of recurrence associated with these tumours, and the proximity to critical normal tissues in the ocular globes, optic nerves, and brain. Resto et al. retrospectively reviewed the outcomes of 102 patients with locally advanced sinonasal tumours of varying histologies treated at the Harvard Cyclotron Laboratory, the Francis Burr Proton Center, or the Massachusetts General Hospital between 1991 and 2002. Combined photon and proton beam radiotherapy was given as definitive treatment in 32 patients, as adjuvant treatment after partial resection in 50 patients, and as adjuvant treatment after complete resection in 20 patients. Five-year local control rates were 95% for patients with a complete resection, 82% for patients with a partial resection, and 87% for patients with biopsy only. Five-year overall survival rates were 90% for patients with a complete resection, 53% for patients with a partial resection, and 49% for patients with biopsy only. Also from the Massachusetts General Hospital, Truong and colleagues described 20 patients with primary sphenoid sinus tumours treated with proton beam radiotherapy at a median dose of 76 CGE. The two-year rates of local control, regional control, and freedom from distant metastasis were 86%, 86%, and 50%, respectively. The two-year disease-free and overall-survival rates were 31% and 53%, respectively. The investigators identified brain invasion and involvement of the oropharynx and anterior cranial fossa as important prognostic factors. In a systematic review and meta-analysis which included the Resto et al. study, Ramaekers and colleagues reported a significantly higher pooled estimated five-year local control rate for patients with paranasal and sinonasal tumours treated with proton beam radiotherapy compared to intensity modulated photon therapy (88% vs. 66%; p=0.035). Tokuyue and colleagues reported the results of a retrospective review of 33 patients with head and neck tumours and no history of surgery who were treated with proton beam radiotherapy with or without photon beam radiotherapy at the University of Tsukuba Hospital in Japan. The five-year overall survival rate was 44%, and the five-year local control rate was 74%; acute toxicity greater than grade 3 was reported in one patient, and late toxicity greater than grade 3 was reported in six patients. Similarly, in a retrospective analysis of 39 adult patients with unresectable malignant tumours of the nasal cavity, paranasal sinus, or skull base who were treated with proton beam radiotherapy at a dose of 60 CGE or higher at the National Cancer Center Hospital East in Japan, Zenda and colleagues reported a one-year local control rate of 77%, and three-year progression-free and overall survival rates of 49.1% and 59.3%, respectively. Acute toxicity included grade two dermatitis; long-term grade three-five toxicity was reported in five patients, and one treatment-related death was reported.

**II. Potential Indications and Evidence for Proton Beam Therapy**

**Lymphoma**

Cure rates of early Hodgkin lymphoma are high, and the avoidance of late complications and second malignancies has become increasingly important for these patients; proton beam radiotherapy may therefore offer an advantage over conventional methods for patients with lymphoma requiring...
radiotherapy. In a study of ten consecutive patients with mediastinal masses from lymphoma who were treated with three-dimensional proton beam radiotherapy, Li et al. reported a complete metabolic response rate of 86%.69 The patients ranged in age from 26 to 45 years of age; eight of these patients had nodular sclerosing stage II Hodgkin lymphoma, one had stage II diffuse large B cell lymphoma, and one had disseminated T-cell lymphoblastic lymphoma. At the time of referral for proton beam radiotherapy, seven patients had either primary refractory disease or recurrent disease. When compared to conventional radiotherapy, proton beam radiotherapy resulted in mean lower doses to the lungs, esophagus, and heart, but not to the breasts.69 Hoppe and colleagues also recently reported the results of a phase II trial involving dosimetric comparisons of three-dimensional conformal radiotherapy, intensity modulated radiotherapy, and proton beam radiotherapy for ten patients with stage IA-IIIB Hodgkin lymphoma with mediastinal (bulky or nonbulky) involvement after chemotherapy.70 Proton beam radiotherapy resulted in the lowest mean dose to the heart, lungs, and breasts for all ten patients compared with both the three-dimensional and intensity modulated radiotherapy.

Prostate Cancer
Several studies have suggested that proton beam radiotherapy may be beneficial for patients with locally advanced prostate cancer, due to the low rate of radiation scattering to adjacent structures. The largest report to date comes from an analysis of 1255 patients treated with either proton beam radiotherapy alone or in combination with photons between 1991 and 1997 at Loma Linda University.71 The authors reported minimal morbidity, and a 5-year overall biochemical disease-free survival rate of 73%, which is comparable to rates reported with other modalities in this population of patients. The long-term results of the only randomized trial examining proton beam radiotherapy comparing conventional and high-dose radiotherapy were recently published by Zietman and colleagues.72,73 Three hundred and ninety three patients with stage T1b through T2b prostate cancer and PSA levels less than or equal 15 ng/mL received photon beam radiotherapy at a fixed dose 50.4 Gy, and were then randomized to receive boost proton beam radiotherapy to a total dose of either 70.2 Gy (conventional dose) or 79.2 Gy (high dose). For patients with low-risk disease (N=228), the 10-year biochemical failure rate was significantly different between the two treatment groups (28.2% conventional dose versus 7.1% high dose, p<0.0001). There were no differences in the 10-year overall survival rates among the treatment arms (78.4% versus 83.4%; p=0.41). Treatment with higher-dose radiotherapy was not associated with an increase in acute or late patient-reported prostate cancer symptoms.74 Although these results are promising, this trial was not designed to test whether proton beam radiotherapy is more or less efficacious than other conformal techniques or brachytherapy for the treatment of patients with prostate cancer. In a recent analysis of data from the Surveillance, Epidemiology and End Results (SEER) database, patients treated for primary prostate cancer with IMRT (N=684) were compared to patients treated with proton beam radiotherapy (N=684).75 Patients treated with IMRT had a lower rate of gastrointestinal morbidity (relative risk=0.66, 95% CI=0.55-0.79), but there were no significant differences in rates of other morbidities between IMRT and proton therapy.

Non-Small Cell Lung Cancer
A limited number of studies have reported an 80 to 90 percent rate of local control for patients with stage I non-small cell lung cancer (NSCLC) treated with hypofractionated proton beam radiotherapy.76-79 However, in a recent meta-analysis comparing photon, proton, and carbon-ion radiotherapy for patients with inoperable stage I NSCLC, Grutters and colleagues concluded that proton beam radiotherapy did not offer a statistically significant improvement in overall survival when compared to photon-based stereotactic radiotherapy, although both modalities were significantly better than conventional photon radiotherapy.80 Proton beam radiotherapy may offer an advantage for patients with advanced inoperable NSCLC, and
may spare lung volumes from receiving low-dose irradiation from exiting photon beams. In a retrospective review by Nakayama et al., the progression-free survival rate of 35 patients with stage II and III NSCLC was 59.6% at one year and 29.2% at two years, and the overall survival rate was 81.8% at one year and 58.9% at two years.81 Similarly, in a retrospective review of 57 patients with inoperable stage IIIA-IIIB NSCLC, Oshiro and colleagues reported one- and two-year progression-free survival rates of 36.2% and 24.9% respectively, and one- and two-year overall survival rates of 65.5% and 39.4%, respectively.82 While these results are promising, it is important to note that proton beam radiotherapy planning is particularly challenging for lung tumours, owing to organ motion and changes to lung density during respiration.83

Members of the working group do not currently recommend that patients with prostate cancer, non-small cell lung cancer, or most lymphomas be referred for proton beam radiotherapy, due to an insufficient evidence base. However, individual patient cases should be discussed by the multidisciplinary team during a Tumour Board meeting.

III. Referral and Funding Process for Out-of-Country Treatment

Patient Selection Criteria.

A wide range of factors must be taken into account in assessing if proton beam radiotherapy will confer a significant advantage for the patient over standard radiotherapy – the diagnosis alone is often not sufficient.84 On the basis of the data published to date, combined with the expert clinical experiences of the working group members, we recommend proton beam radiotherapy be considered for pediatric, adolescent, and adult patients who are residents of Alberta, are covered by the Alberta Health Care Insurance Plan (AHCIP), and meet the criteria outlined in the table below.

<table>
<thead>
<tr>
<th>Patient Criteria</th>
<th>Requirements</th>
</tr>
</thead>
</table>
| Age              | • pediatric age ranges = 0 to 20 years  
                  • adult age ranges = 20 to 65 years |
| Fitness          | • treatment given with curative intent  
                  • good performance status (0-2)  
                  • expected survival > 5 years  
                  • ability and willingness to travel |
| Approved diagnoses | Pediatric Patients:  
                        • requiring craniospinal radiation  
                        • CNS cancers or lesions: arteriovenous malformations, ependymoma,  
                          craniopharyngioma, CNS germ cell tumours, primitive neuroectodermal tumours,  
                          low-grade gliomas  
                        • Non-CNS cancers: sarcoma including chordoma and chondrosarcoma,  
                          rhabdomyosarcoma, Ewing’s sarcoma, pineal tumours, and lymphoma  
                      Adult Patients:  
                        • CNS cancers or lesions: arteriovenous malformations, benign meningioma,  
                          acoustic neuroma, craniopharyngioma, CNS germ cell tumours, low-grade  
                          gliomas  
                        • Non-CNS cancers: sarcoma including chordoma and chondrosarcoma, lymphoma  
                          in patients under the age of 30, and paranasal sinus and nasal cavity tumours |
Referral Process.

Who should make the referral and oversee the process?

- A full multidisciplinary Tumour Board meeting should be held in which all tumour group members, including a radiation oncologist, have the opportunity to provide input on the case.
- The responsibility for referral and communications with the proton beam therapy treatment centre remains with the referring oncologist; this discussion should begin prior to the referral to the Out-of-Country Health Services Committee (OOCHSC). The OOCHSC application must ideally contain the specific site, recommended therapy, and dates.
- The responsibility for follow-up and continuity of care also rests with the referring oncologist.

How should the referral be made?

- A completed Application should be submitted to the OOCHSC (found at [http://www.health.alberta.ca/documents/OOCHSC-Application-Form.pdf](http://www.health.alberta.ca/documents/OOCHSC-Application-Form.pdf)). Alternately, a letter of referral with all the required information included in it can also be submitted.
  Note: The OOCHSC does not have access to any electronic medical records; therefore it is important to include all relevant documents from diagnosis to treatment completed to referral date.
- All relevant letters, summaries, operation reports, diagnostic/laboratory/histology reports, and imaging reports should be included with this application and mailed or faxed to:
  
  Chair, Out-of-Country Health Services Committee  
  10025 Jasper Avenue, PO Box 1360 Station Main  
  Edmonton AB T5J 2N3  
  Fax: (780) 415-0963

- OOCHSC applications are considered complete when all the required information has been submitted, and the OOCHSC Chair has notified the referring physician in writing that the application has been scheduled for review at an upcoming meeting.
- Once the OOCHSC chair has determined that the application is complete, the OOCHSC will assess the application and make a decision within 60 days. If the application is urgent for medical reasons (i.e., malignant or fast-growing tumour), the referring oncologist must state this on the application, along with the reasons for the urgency and the timeframe within which it is recommended that the health services/treatment be initiated.
- The multidisciplinary Tumour Board and the referring oncologist should initiate contact with potential proton beam radiotherapy centres to determine the most appropriate centre for the patient, taking in account individual circumstances such as availability, location, and patient preference, in addition to the ability of the centre to provide the service requested in the required timeframe for the patient.

What happens if the case is approved?

- The referring oncologist will be contacted once the OOCHSC has made a decision. The OOCHSC approval letter will:
  1. stipulate approval for payment of the services requested
  2. outline the required next steps for the patient
  3. provide details on what services are covered (all medical treatment and transportation to and from) and what is not covered (all accommodation and special costs).
- The patient will also be requested to complete two release forms that are to be returned to the OOCHSC. These releases allow the medical management company to assist both the patient and the referring physician with the details of the approved medical treatment. The referral letter to the proton beam radiotherapy centre should clearly state that the patient has been approved by the OOCHSC.
## Multidisciplinary Tumour Board Meeting Checklist.

<table>
<thead>
<tr>
<th>Age of Patient</th>
<th>____________________________________________________________________________ age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnosis</td>
<td>____________________________________________________________________________ diagnosis</td>
</tr>
<tr>
<td>Curative Treatment</td>
<td>□ yes □ no</td>
</tr>
<tr>
<td>Performance Status</td>
<td>□ 0 □ 1 □ 2 □ 3 □ 4</td>
</tr>
<tr>
<td>Comorbidities</td>
<td>□ yes □ no __________________________________________________________________ comorbidities</td>
</tr>
<tr>
<td>Metastatic Disease</td>
<td>□ yes □ no</td>
</tr>
<tr>
<td>Referring Oncologist</td>
<td>____________________________________________________________________________ name</td>
</tr>
</tbody>
</table>

### Multidisciplinary Tumour Board Meeting

- Date of Tumour Board meeting _________________
- □ Name and specialties of all members present at Tumour Board meeting documented
- □ Discussion of additional treatments considered or explored
- □ Discussion regarding travel arrangements
- □ Discussion regarding follow-up care

### Out-of-Country Health Services Committee Referral Form

- □ Application completed by referring oncologist
- □ Supporting documentation, medical records, reports, and imaging included
- Date application sent to OOCHSC _________________
GLOSSARY OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVM</td>
<td>arteriovenous malformation</td>
</tr>
<tr>
<td>CGE</td>
<td>cobalt grey equivalent</td>
</tr>
<tr>
<td>CI</td>
<td>confidence interval</td>
</tr>
<tr>
<td>CNS</td>
<td>central nervous system</td>
</tr>
<tr>
<td>Gy</td>
<td>grey</td>
</tr>
<tr>
<td>IMRT</td>
<td>intensity modulated radiotherapy</td>
</tr>
<tr>
<td>NSCLC</td>
<td>non-small cell lung cancer</td>
</tr>
<tr>
<td>OOCHSC</td>
<td>Out-of-Country Health Services Committee</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
</tbody>
</table>

DISSEMINATION

- Present the guideline at relevant local and provincial tumour team meetings and weekly rounds.
- Post the guideline on the Alberta Health Services website as well as the Alberta Health website.
- Send an electronic notification of the new guideline to all members of Alberta Health Services, Cancer Care.

MAINTENANCE

A formal review of the guideline will be conducted annually, beginning in March 2014. If critical new evidence is brought forward before that time, however, the guideline working group members will revise and update the document accordingly.

CONFLICT OF INTEREST

Participation of members of the Alberta Health Services Cancer Care Proton Therapy Guideline Working Group and Guideline Advisory Group in the development of this guideline has been voluntary and the authors have not been remunerated for their contributions. There was no direct industry involvement in the development or dissemination of this guideline. Alberta Health Services Cancer Care recognizes that although industry support of research, education and other areas is necessary in order to advance patient care, such support may lead to potential conflicts of interest. Some members of the Alberta Health Services Cancer Care Proton Therapy Guideline Working Group and Guideline Advisory Group are involved in research funded by industry or have other such potential conflicts of interest. However the developers of this guideline are satisfied it was developed in an unbiased manner.

REFERENCES


## APPENDIX A

### Summary of Published Guidelines

<table>
<thead>
<tr>
<th>Developer</th>
<th>Recommendations</th>
</tr>
</thead>
</table>
| **American Society of Radiation Oncology**<sup>83</sup>  
USA                                | • Current data do not provide sufficient evidence to recommend PBRT outside of clinical trials in lung cancer, head and neck cancer, GI malignancies (with the exception of hepatocellular carcinoma) and pediatric non-CNS malignancies  
• In hepatocellular carcinoma and prostate cancer, there is evidence for the efficacy of PBRT but no suggestion that it is superior to photon based approaches  
• In pediatric CNS malignancies there is a suggestion from the literature that PBRT is superior to photon approaches, but there is currently insufficient data to support a firm recommendation for PBRT  
• In the setting of craniospinal irradiation for pediatric patients, protons appear to offer a dosimetric benefit over photons but more clinical data are needed  
• In large ocular melanomas and chordomas, we believe that there is evidence for a benefit of PBRT over photon approaches  
• In all fields, however, further clinical trials are needed and should be encouraged                                                                                                                                                                                                                           |
| **National Health Service, 2011**<sup>84</sup>  
UK                                  | • Prioritised adult diagnostic categories and sites that have been agreed and funded as the very highest priority for referral for proton treatment abroad include:  
  o Base of Skull & Spinal Chordoma  
  o Base of Skull Chondrosarcoma  
  o Spinal & Paraspinal Bone and Soft Tissue Sarcomas (Non Ewing’s)  
• Additional and over-riding principles for approval and funding include:  
  o treatment should be given with curative intent  
  o patients will have good performance status either 0 or 1 (WHO - Appendix 2)  
  o no other coincident diagnoses that are likely to either limit 5 year survival or make a prolonged period abroad difficult to manage from a practical point of view  
  o there should be no metastatic disease  
  o re-treatment cases will not be accepted  
  o there are weight limits on the treatment couches in treatment centres; the weight of adult patients at the time of referral should be given and should not exceed 150kg  
• A wide range of factors need to be taken into account in assessing if proton therapy confers any significant advantage over conventional radiotherapy or IMRT -- the diagnosis alone is often not sufficient. These factors include the:  
  o timing of radiotherapy in relation to other treatments  
  o site of tumour  
  o radiotherapy target volume  
  o target volume dose and dose gradients required  
  o tumour and target volume proximity to critical dose limiting structures  
  o patient age and performance status  
  o stage and pathology  
  o presence, size and position of metallic implants  
  o views of patients / parents  
  o patients ability to travel  
• For adult and paediatric cases the referral MUST come from a consultant clinical oncologist who has seen and assessed the patient. It is vital that BEFORE a referral is made:  
  o A full multi-disciplinary team has considered the case  
  o the pros and cons of proton treatment compared with conventional radiotherapy and/or IMRT has been discussed in each case with a clinical oncologist  
  o some paediatric clinical trial protocols may preclude proton treatment; the early involvement of a paediatric clinical oncologist where radiotherapy is a possibility in the treatment pathway is thus important and will avoid potential delays and conflicts  
  o the responsibility for the referral and communication with the proton treatment centre should remain with the referring consultant; although there is a central administrative process for approving cases, it is important that this does not remove or devalue the direct knowledge, responsibility and relationship that exist with the clinical team who has met and assessed the wider issues for the patient  
• Follow up and continuity of care rests with the referring centre; treatment centres may ask for detailed radiotherapy follow up data -- this makes a clinical oncologist the best primary managing consultant. |
### Developer

**National Services Scotland, 2011**

**Scottish Pathway for Consideration of Funding**

The core principles to be achieved include:
- Treatment should be given with curative intent.
- The patient should have a good performance status WHO 0 or 1
- No other coincident diagnoses that are likely to limit 5 year survival

Currently the list of potentially funded conditions includes the following:

- **Adult**
  - Base of Skull & Spinal Chordoma
  - Base of Skull Chondrosarcoma
  - Spinal & Paraspinal Bone and Soft Tissue Sarcomas (Non Ewing’s)

- **Paediatric**
  - Base of Skull & Spinal Chordoma
  - Base of Skull Chondrosarcoma
  - Spinal & Paraspinal ‘adult type’ Bone and Soft Tissue Sarcomas
  - Rhabdomyosarcoma (Orbit, Parameningeal & Head & Neck)
  - Pelvis
  - Ependymoma
  - Ewing’s Sarcoma
  - Retinoblastoma
  - Pelvic Sarcoma
  - Optic Pathway and other selected Low Grade Gioma
  - Craniopharyngioma
  - Pineal Parenchymal Tumours (not Pineoblastoma)
  - Esthesioneuroblastoma

---

**Royal College of Radiologists, Proton Therapy Working Party, 2000**

- Protons of sufficient energy to treat base of skull tumours are not available in the UK. Patients have been referred to the proton facilities at the Harvard cyclotron, and at Orsay, France. They will continue to require referral abroad for proton therapy for base of skull tumours.
- Proton therapy has become standard treatment for ocular melanoma and this is available at the Douglas cyclotron at Clatterbridge Hospital.

### Summary of Published Health Technology Assessments

<table>
<thead>
<tr>
<th>Organization</th>
<th>Summary</th>
</tr>
</thead>
</table>
| **Health Council of the Netherlands, 2009** | Standard Indications: Cases where proton radiation is the optimal form of therapy. These cases include: intra-ocular melanoma (plus certain other cancers of the eye), skull base tumours and paraspinal (chordoma and chondrosarcoma) tumours, and certain pediatric tumours. The estimated number of patients in the Netherlands for whom proton radiotherapy is considered standard treatment is 252 annually (approximately 0.6% of the total number of patients eligible for radiotherapy). Potential Indications: Includes cases for which protons may be utilized to improve local tumour control. Specifically, either cases where:
  - the current standard radiation dose can not be administered without delivering a certain amount of radiation to the critical organs, which carries an unacceptable risk of radiation-induced side effects, or
  - cases where RCTs should be performed to investigate the potential benefit of protons in achieving dose escalation and subsequent improvement of local control

  The estimated number of patients that could benefit from protons based on potential indications is 1,215 (approximately 3.0% of the total number of patients eligible for radiotherapy). |
| **American Society for Radiation Oncology (ASTRO), Emerging Technology Committee, 2009** | Skull Base and Cervical Spine Chordomas and Chondrosarcomas:
  - The absolute clinical benefit for PBRT is less clear for lesions in which the dosimetry of photon radiosurgery provides for adequate sparing of normal tissues.
  - PBRT has multiple theoretical advantages over photon radiotherapy for CNS tumours due to the ability of PBRT to deliver high dose radiotherapy with steeper dose gradients to proximal critical structures than can be achieved with photon radiotherapy.
  - For the majority of CNS malignancies, the potential benefit of using PBRT remains theoretical and |
<table>
<thead>
<tr>
<th>Organization</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organization</strong></td>
<td><strong>Summary</strong></td>
</tr>
<tr>
<td>Canadian Agency for Drugs and Technologies in Health, 2008</td>
<td>Rapid response report listing results of a limited literature search (2003-2008).</td>
</tr>
<tr>
<td>Australia and New Zealand Horizon Scanning Network, 2007</td>
<td>States that the evidence for proton beam therapy in neoplasms involving or adjacent to cranial structures remains inconclusive. Further studies are required to determine if proton therapy is indeed substantially better compared to conventional radiotherapy, as inferred by numerous model/treatment-planning studies.</td>
</tr>
<tr>
<td>(neoplasms involving cranial structures)</td>
<td></td>
</tr>
<tr>
<td><strong>Ocular Melanoma:</strong></td>
<td><strong>PBRT for uveal melanoma can provide excellent local control and good rates of eye preservation with minimal late side effects.</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Compared with PBRT, alternatives such as brachytherapy, stereotactic irradiation, trans-scleral local resection, transretinal resection, and diode laser phototherapy appear to have a lower chance of achieving local control.</strong></td>
</tr>
<tr>
<td></td>
<td><strong>There are potential late toxicities of PBRT for uveal melanomas that may necessitate enucleation, including development of a tumour scar exudate and glaucoma.</strong></td>
</tr>
<tr>
<td>Head and Neck Tumours:</td>
<td><strong>PBRT has been shown to be well suited for targeting tumours near critical structures, especially at the base of skull.</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Tumours that are good candidates for PBRT at this time include those for which the prescription dose does not exceed the tolerance of surrounding critical structures and the goal of treatment is to decrease the dose-volume effect to structures receiving a lower dose.</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Currently, there is insufficient data to recommend PBRT for routine head and neck radiation therapy outside of clinical trials.</strong></td>
</tr>
</tbody>
</table>