HADRON THERAPY FOR CANCER TREATMENT

Seminar presented by Arlene Lennox at Fermilab on Nov 21, 2003
CANCER STAGES

LOCAL TUMOR

REGIONAL METASTASIS

SYSTEMIC DISEASE
CANCER TREATMENT

SURGERY

RADIATION THERAPY

CHEMOTHERAPY|IMMUNOTHERAPY
Photon radiation therapy is easily available.

Gantry rotates around patient.

Therapy accelerators are manufactured by several vendors.
Hadron therapy is radiation therapy using strongly interacting particles

- Neutrons
- Protons
- Pions
- Ions (alphas, C, Ne)

Proton and neutron therapy address deficiencies in photon therapy

• Protons: better dose distributions
• Neutrons: better tumor killing

• Clinical Results
• Current Challenges
• Proposed Solution
Protons and photons are low LET radiation. They have similar biological effectiveness.
Suitable for 1.5 cm diameter tumor.
Skin dose ~30% of maximum dose.

Spread-Out Bragg Peak

Koehler et al, Radiology 104:191-95 (1972)
235 MeV Spread Out Bragg Peak
Loma Linda University Medical Center

- Suitable for 9 cm diameter tumor.
- Skin dose 68% of maximum dose.

p(66) Be(49) Neutron Therapy Beam
(same as 8 MV photon beam)
Results of Proton Clinical Trials

Reference: Petti and Lennox, Hadronic Radiotherapy, 

- **Tumors where protons are superior to photons are:**
  - Skull-base chordoma and chondrosarcoma
  - Arteriovenous malformations
  - Uveal melanoma (pages 174-177)

- **Tumors where more research is needed are:**
  - Skull-base meningioma, craniopharyngioma, pituitary adenoma
  - Lung
  - Esophageal
  - Liver
  - Uterine cervix
  - Prostate (pages 174, 178)
  - Wet macular degeneration
High Linear Energy Transfer (LET)

- Neutrons and ions are high LET radiation and have high biological effectiveness (RBE)
Survival of prostate cancer cells after one exposure to photon or neutron radiation

- **Radioresistant** tumors are better controlled by neutrons.
Fermilab 66 MeV neutrons exhibit RBE = 4 for Prostate Cancer

Blazek, Urbon, Lennox, Kroc, Pientak (in press)
Before Neutron Therapy
After 7 treatments
12.25 Gy of neutrons
Inoperable Soft-tissue Sarcoma

Tumor compromises the skin

Biopsy scar
Skin reddening in Caucasians

Treatment mark
Two-month follow-up

Fibrosis
Inoperable neck tumor before neutron therapy

Squamous cell carcinoma from snuff chewing
Two years after Neutron Therapy
• **Tumors where fast neutrons are superior to photons are:**
  - **Salivary glands** - locally extended, well differentiated
  - **Paranasal sinuses** - adenocarcinoma, mucoepidermoid, squamous, adenoid cystic
  - **Head and Neck** - locally extended, metastatic
  - **Soft tissue, osteo, and chondrosarcomas**
  - **Locally advanced prostate**
  - **Melanomas** Inoperable/recurrent
Results of Neutron Clinical Trials


- **Tumors for which more research is needed**
  - Inoperable Pancreatic
  - Bladder
  - Esophagus
  - Recurrent or inoperable rectal
  - Locally advanced uterine cervix
  - Neutron boost for brain tumors (pp13-22)

"The proportion of patients suitable for neutrons ranges from 10-20%, but this is probably a lower limit...with high energy modern cyclotrons neutron therapy will be useful for a larger proportion of patients. " (page 24)
Hadron Therapy is an Important Option for Radiation Therapy Patients.

Radiation Treatment Modes

- **Protons**: 10% 5%
- **Photons**: 5%
- **Neutrons**: 5% 15%

Cancers
The Challenge(s)

• **Difficulty establishing uncontestable advantage of hadron therapy over competing therapies**
  – Inadequate statistics at individual clinics
  – Lack of uniformity in treatment techniques
  – Lack of money to support clinical trials

• **Number of hadron facilities is small**

• **Neutron facilities have pronounced differences in beam characteristics at different facilities**
  – Different energy spectra
  – Different collimation techniques

• **Lack of standardization keeps costs high**
  – Each hadron clinic has one-of-a-kind accelerator
  – Need more standardized engineering

• **Hospitals and physicians are reluctant to refer patients away from their facilities**
The Proposed Solution

- A clinic that provides both hadron and conventional therapy
  - Salaried, research-oriented physicians
  - International collaborations
  - Strong educational outreach program

- Near high-tech institution(s)

- Multidisciplinary research
  - Accelerator development
  - Beam delivery techniques
  - Imaging techniques
  - Radiation sensitizers
  - Detector development
  - Electromedicine
Hadron Therapy Facility
First Floor - Plan View
Institute for Hadron Therapy
A Multidisciplinary Program

• Physicians treat up to 1500 patients per year

• Specialists work to make hadron therapy more cost effective and accessible
  • Accelerator, mechanical, electrical engineers
  • Accelerator and medical physicists
  • Software and controls specialists

• Radiobiologists study biological effectiveness

• Pharmaceutical specialists develop radiosensitizers

• Isotope specialists track changes in tumors

• Basic scientists have access to research isotopes