Radiotherapy
Hadrons: new devices

Sandro Rossi

CNAO FOUNDATION

Rome, Palazzo Barberini
Outline of the presentation

Short rationale for hadrontherapy

Hospital based facilities in the World

The Italian National Centre: CNAO
“Hadrontherapy” uses beams of hadrons

- Hadrons are made of quarks.
- Carbon ion = 6 protons + 6 neutrons
- Proton or neutron
- Quark “u” or “d”
- Electron “e”

Atom
Carbon Ions: biological efficacy

10 – 20 keV/mm = 100 – 200 MeV/cm = 20 – 40 eV/(2 nm)

Reduced effect dependence from Oxygen content
### WORLD WIDE CHARGED PARTICLE PATIENT TOTALS
**January 2005**

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<th>WHO</th>
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</table>

**Total protons:** 40,801

**Total ions:** 4,511

Overall hadrontherapy patients from Particles Newsletter (January 2005):
Experience at Chiba

Number of Patients registered in Carbon ion Therapy at NIRS
(Period: June 1994 ~ August 2005)

- Skull Base 39(2%) : 10
- Esophagus 36(2%)
- Lacrimal gl 11(0%)
- Miscellaneous 352(15%) : 146
- Pancreas 56(2%)
- Lung 395(17%) : 11
- Eye(Melanoma) 57(2%) : 15
- Prostate 393(17%) : 120
- Rectum 58(2%) : 20
- Head & Neck 335(14%) : 61
- Brain 88(4%)
- Liver 194(8%)
- Bone/Soft Tissue 257(11%) : 83

Total 2,371
HAMT : 466

Highly Advanced Medical Technology

December 2005
Hospital centres for deep protontherapy (>500 pts/year)

5 in USA, 4 in Japan, 2 in China, 1 in Switzerland, 1 in Germany, 1 in Korea, 1 in Italy

(running or financed)

Four companies offer turn-key centres
Loma Linda University Medical Center: first patient 1992

- First hospital-based proton-therapy centre
- 2005: 160 sessions/day

7m synchrotron
The situation in Japan:

- **KASHIWA CENTER**
  - Chiba (1998)
  - Protons ($\leq 235$ MeV)
  - Cyclotron (IBA – SHI)
  - 2 gantries + 1 horizontal beam

- **HYOGO MED CENTRE**
  - Hyogo (2001)
  - Protons ($\leq 230$ MeV) - He and C ions ($\leq 320$ MeV/u)
  - Mitsubishi synchrotron
  - 2 p gantries + 2 fixed p beam + 2 ion rooms

- **TSUKUBA CENTRE**
  - Ibaraki (2001)
  - Protons ($\leq 270$ MeV)
  - Synchrotron (Hitachi)
  - 2 gantries
  - 2 beams for research

- **WAKASA BAY PROJECT**
  - Fukui (2002)
  - Protons ($\leq 200$ MeV)
  - Synchrotron (Hitachi)
  - 1 horizontal beam + 1 vertical beam + 1 gantry

- **SHIZUOKA FACILITY**
  - Shizuoka (2002)
  - Protons cyclotron or synchrotron
  - 2 gantries + 1 horizontal beam

SHIZUOKA FACILITY  
Shizuoka (2002)  
protons cyclotron or synchrotron  
2 gantries + 1 horizontal beam
GSI pilot project → HEIDELBERG

200 patients treated with carbon ions
Treatment of ocular melanoma: **First time for protons in Italy!**
CNAO Foundation

Created in 2001 by the Ministry of Health with two main goals:

- To treat patients using hadrontherapy
- To perform clinical and radiobiological research
Council Board:

E. Borloni  F - “Fondazione Policlinico”  President
G. Azzaretti  F - Policlinico San Matteo  Vice-president
G. Arbosti  F - Istituto Neurologico C. Besta
C. Ciani  F - Istituto Europeo di Oncologia
U. Amaldi  F - Fondazione TERA
L. Maspes  F - Istituto Nazionale dei Tumori
E. Iarocci  PI - Istituto Nazionale di Fisica Nucleare
G. Coggi  PI - Università di Milano
A. Pedotti  PI - Politecnico di Milano
G. Goggi  PI - Università di Pavia
P. Capitelli  PI - Comune di Pavia
COLLABORATIONS

CNAO (almost 40 fte personnel) is coordinating the effort of many Institutions

NATIONAL

INFN: co-direction, involvement/responsibility in many technical issues (15), formation

Town of Pavia: land and authorisations

University of Milan: medical coordination and formation

Polytechnic of Milan: patient positioning, radioprotection and authorisations

University of Pavia: electrical plants, special power supplies and betatron, formation

Province of Pavia: logistics and authorisation

INTERNATIONAL

CERN: special magnets, dipole measurements and diagnostics (+ PIMMS heritage)

GSI: linac and special components

LPSC: optics, betatron, low-level RF, control system
A closer look to CNAO...
SITEPLAN  TERRITORIAL CONTEXT

- Project area
- Historical center
- Rivers
- Medical centers and hospitals
- Main street
- Strade principali distr.
- High-way
- Railway
Three treatment rooms (3H+1V)

One experimental room

LEGENDA

AREE FUNZIONALI

- Ambulatori mq 453
- Area immagini mq 1146
- Ingresso accettazione mq 337
- Bar mq 144
- Centrali tecnologiche mq 736
- Collegamenti verticali mq 227
CNAO SITE - Saturday, December 3rd, 2005
The heart of CNAO

The synchrotron

Linac

HE lines

Treatment rooms
“Bunches” of more than 30 billions of protons or 10 millions of carbon ions are produced.
Conventional magnets and power supplies

The particles, “guided” by magnetic fields, turn 1 million times in the ring in less than 1 second!
Beam monitoring

Prototype of a pixel chamber

In collaboration with:

INFN Torino

December 2005
Irradiation technique: active scanning

Energy variation from the synchrotron

Fast scanning

Slow scanning

Horizontal scanning

Vertical scanning

Patient

Field 22 $E_{22}$

Field 4 $E_4$

Target volume

Total thickness

Scanning system

(GSI)

(PSI)
### The Challenge is to guarantee:

- Safety
- Efficiency
- Reliability
- Maintainability

Adequate for an hospital based facility
Timeplan - Summary Tasks

2004-2005:

N. 12 European tenders (completed)
N. 2 Private European Bids
> N. 30 Direct orders

Presently: N. 45 firms (30 Italian) working for CNAO

2006: Installation

2007: Operation commissioning and start treatments
To be ready for the CNAO start-up

Formation of personnel
(doctors, medical and accelerator physicists)

Authorisation procedures
Permissions to use beams for patient treatments

Medical Service
to support and inform doctors and patients

Creation of a multimedia network
to connect the CNAO to the hospitals and to the research institutes
Running Phase

Day-hospital

80% trattaments with ions and 20% with protons - time for R&D

Session duration: 20-30 minutes

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... NEW devices, BUT

hadrontherapy is a further step,
with good results and
very promising developments,
in radiotherapy evolution