In-vivo proton beam shaping using static magnetic field for cancer therapy

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Abstract

Proton beam of energy up to 250 MeV is currently used for treatment of cancer tumors. Theoretical computations are presented showing that proton beam of energy from 400 MeV up to 600 MeV might be used in cancer therapy. Approximately, 5-10 Tesla static transverse magnetic fields, spatially limited to tumor volume can produce spiral path of high energy proton inside the tumor. It is shown that the proportion of dose received by tumor is increased by a factor of 3.

Key words: Magnetic field; Dose escalation; proton trajectory

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Here we work out the idea of using proton beam with energy much higher than usual (i.e.400 MeV)

Mathematical-Physical model

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ADVANTAGE OF MATHEMATICAL MODELLING

- BASED ON MATHEMATICS AND PHYSICS PRINCIPLES
- RESULTS ARE ACCEPTABLE
- ESPECIALLY DESIRABLE WHEN THE EXPERIMENT IS EXPECSIVE
- COULD BE DONE AS AN ENGINEERING PREDICTION

A NEW METHOD TO DELIVER HIGHER DOSE TO CANCER TUMOR IN HADRON THERAPY

BEAM OF CHARGED PARTICLES,

USUALLY PROTON OR CARBON ION IS

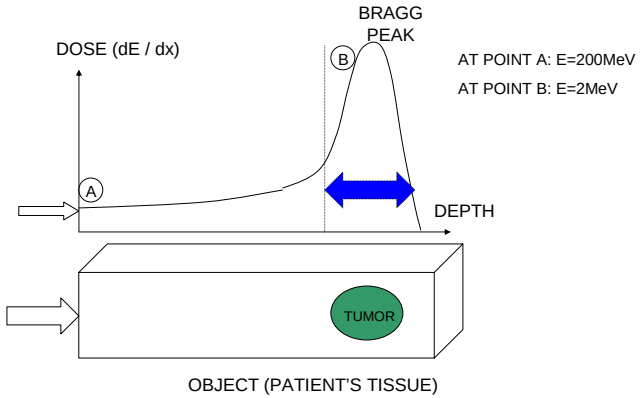
DIRECTED TOWARDS THE TUMOR. IN

CASE OF PROTON E=200-250 MeV FOR

BRAIN OR CHEST TUMORS, AND 60-70

MeV FOR EYE TUMORS.

HADRON THERAPY



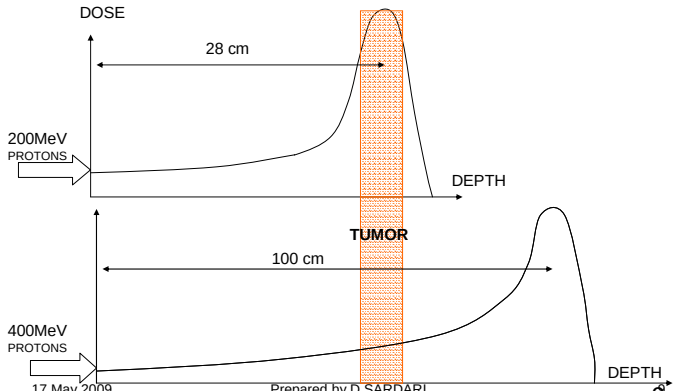
THE FRACTION OF PARTICLE ENERGY DELIVERED TO THE TUMOR

30% - 50%

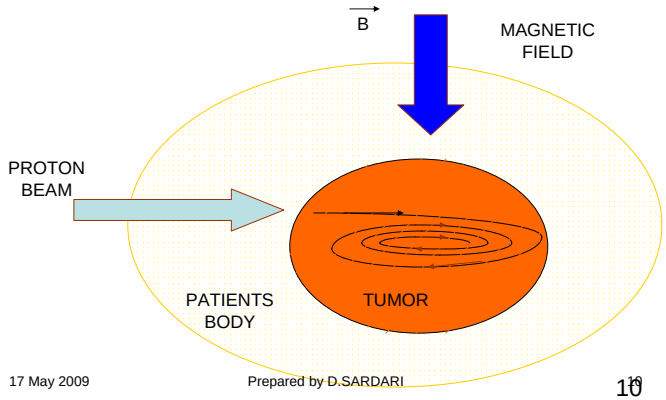
HOW TO INCREASE THIS FRACTION ?

WITH STATIC MAGNETIC FIELD

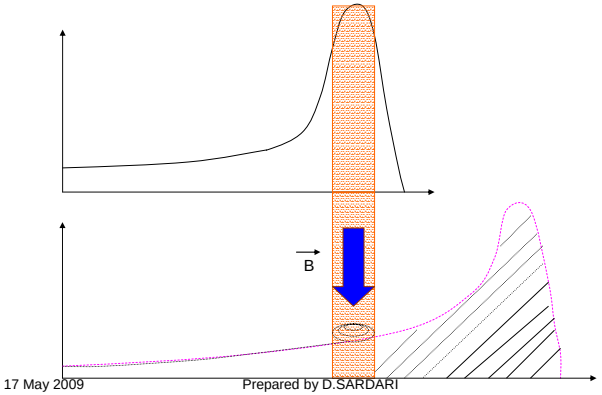
HIGHER ENERGY PROTONS WILL PASS THROUGH THE TUMOR BEFORE THEIR BRAGG PEAK



MAGNETIC FIELD TURNS THE DIRECT TRACK OF THE BEAM INTO A SPIRAL



THUS BIGGER PORTION OF DOSE CONCENTRATES INSIDE THE TUMOR



THE RATIO OF ABSORBED DOSE BY THE TUMOR INCRESES

TO: 80% - 90%

$$\frac{mV^2}{r} = q.\vec{V} \times \vec{B} \Longrightarrow B = \frac{mV}{qr}$$

r= tumor radius

V= proton speed

m= proton mass (*)

q= proton electric charge

B= the required magnetic field

(*) RELATIVISTIC EFFECTS IN MASS MUST BE CONSIDERED

NUMERICAL EXAMPLE
TUMOR RADIUS = 5 cm

PROTON ENERGY	PROTON VELOCITIY	MAGNETIC FIELD
200 MeV	0.57C	4 Tesla
400	0.71C	6 Tesla
600	0.77C	7 Tesla

Tumor depth (cm)	Proton range (cm)	Proton initial energy (MeV)	Energy delivered to healthy tissue (MeV)	Percent of dose in tumor
18	28	200	86	**64**
13	28	200	57	76
8	28	200	33	87
6	28	200	24	90
2	28	200	7	96

Tumor depth (cm)	Proton range (cm)	Proton initial energy (MeV)	Energy delivered to healthy tissue (MeV)	Percent of dose in tumor
90	100	400	286	36
80	100	400	233	50
60	100	400	154	67
40	100	400	93	81
*25	100	400	52	89
*22	100	400	47	90
*10	100	400	15	97

PROSPECTS

- IN MAGNETIC RESONANCE IMAGING 1-3 Tesla MAGNETIC FIELDS ARE BEING USED.
- THE MAGNETIC FIELDS CALCULATED ABOVE ARE NOT EXTREMELY HIGH.
- THE EFFECT OF HIGH INTENSITY MAGNETIC FIELD ON PATIENT MUST BE CONSIDERED.
- PRODUCTION OF STRONG MAGNETIC FIELD IN A SMALL AREA COULD BE A TECHNICAL CHALANGE.
- THIS IDEA IS VERY NEW AND NO EXPERIMENT IS DONE YET.

CONCLUSION

-In this method higher proportion of total dose (more than 90%) is delivered to the tumor.

-Proton beam of 400MeV and above is technically available.

-Tumor volume is swept automatically, but needs more elaboration.

THANK YOU

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-QUESTIONS

-COMMENTS