FIVE YEARS EXPERIENCE OF NEUTRONTHERAPY WITH THE ORLEANS CYCLOTRON. TECHNICAL ASPECTS.

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(1) Introduction

The Orleans neutrontherapy Unit is settled on the C.N.R.S. (*Centre National de la Recherche Scientifique*) campus, 3 km far from the Hospital with radiotherapy and medical care departments.

The cyclotron (C.G.R. 680 type) is the property of the C.N.R.S. and is used for various applications and studies.

This machine and its medical extensions have allowed, since September 20th 1980, irradiations with a fast neutrons vertical downwards beam.

The collaboration of the *Université Catholique de Louvain* and the *Laboratoire de Métrologie des Rayonnements Ionisants* (Primary Laboratory) enabled us to start dosimetrical and radiobiological studies.

The *Assistance Publique des Hôpitaux de Paris*, the *Centres de Lutte contre le Cancer*, take part in these clinical studies.

This work is carried out in relation with the E.O.R.T.C Heavy Particle Therapy Group.

From January 20th 1981 to December 1985, 578 patients have been treated (tab.1).

	1981	1982	1983	1984	1985	TOTAL
UT. CERVIX	16	13	23	29	27	108
RECTUM	10	6	18	16	11	61
OTHER P. TUMORS	9	7	8	4	4	32
BRONCHUS	3	23	33	12	12	83
HEAD AND NECK	0	22	20	21	24	87
BRAIN	1	17	10	45	33	106
S.T.S.	7	5	11	16	15	54
MISCELLANEOUS	1	5	13	13	15	47
TOTAL	47	98	136	156	141	578

Tab.1 : annual repartition of patients according to tumor type or localization.

(2) Recall of beam characteristics

The neutrons are produced by 34 Mev protons on a semithick beryllium target : p(34)+Be(15.8) (tab.2).

The proton beam current is about 40µA which leads to a total dose rate of 20cGy.min^{-1} for a 10 x 10 cm field at 135 cm (ref.1).

A movable filter holder allows the selection of one of the three different thicknesses of polythene.

A set of 6 heavy collimators (inserts) defines square fields.

Owing to an additional collimator device, any shape of field can be realised at a treatment distance superior to 155 cm (ref.2).

Total dose rate (Gy.min^{-1}.µA^{-1})		D max	3.10^{-3}
D max/2 (cm)	water		12.8
Dγ / D (n + γ) (%)	water	- 2 cm	6 %
		- 10 cm	8,5 %
		- 20 cm	11,5 %
Penumbra (80 % - 20 %)	water	- 10 cm	1,6 cm
Equilibrium depth (build-up)		0.9 D max	2 mm
		D max	7 mm

Tab.2 : on axis main physical characteristics 10 x 10 cm, SSD 169 cm filter and collimators used for irregular fields.

(3) Setting of the cyclotron use

The accelerator is operational 48 weeks per years, 4 consecutive weeks being required for maintenance.

4 sessions per week are saved for therapeutic applications.

Patients's irradiations are planed between 1 p.m. and 6 p.m.

The number of days of treatment has roughly been constant since 1982 (fig.1).

The number of hours saved for each user goes up every year (fig.2).

Clinical protocols result in about 10 irradiations sessions per patient and from 1982 to 1985 a rate of 650 hours of beam per year has enabled the treatment of 130 patients.

It should be observed that research works in biology take advantage of an allowance of overtime hours.

This amount of 650 hours does not take into account the terms of waiting due to technical incidents, but for an identic number of radiation fields, time required for treatment is superior to the one observed in conventional radiotherapy (beam physical characteristics, collimation devices).

An hour allow the treatment of 2.3 patients.

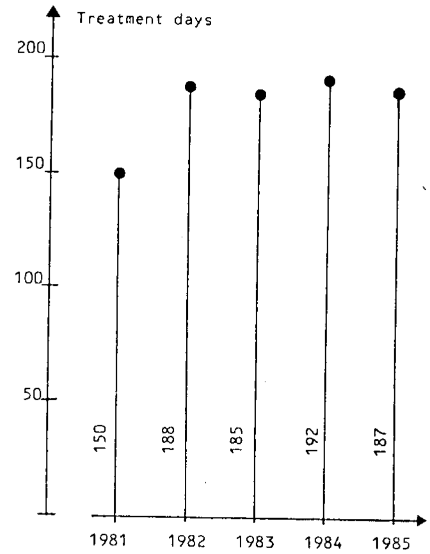


Fig.1 : annual number of treatment days.

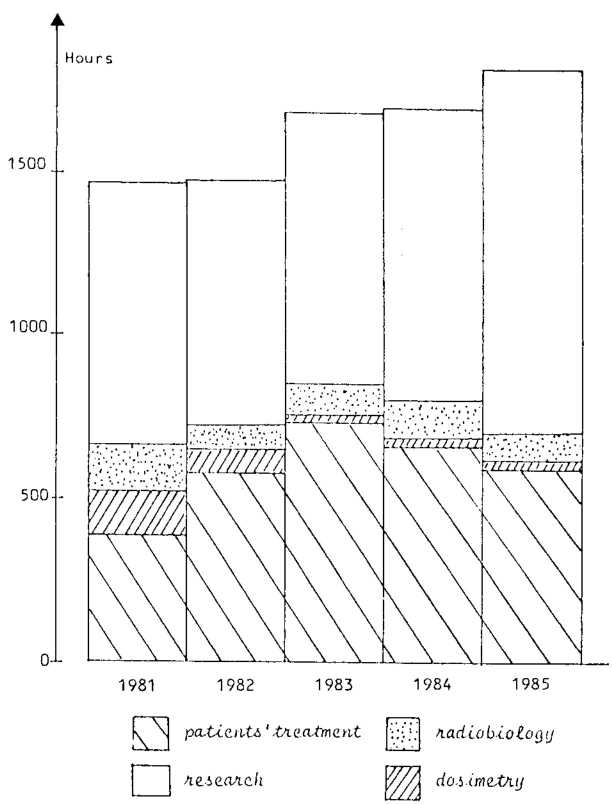


Fig.2 : annual repartition of cyclotron working time.

4 Technical problems

The breakdowns met on the cyclotron and his peripheral installations amount to about 10 % of the cyclotron total working time (fig.3).

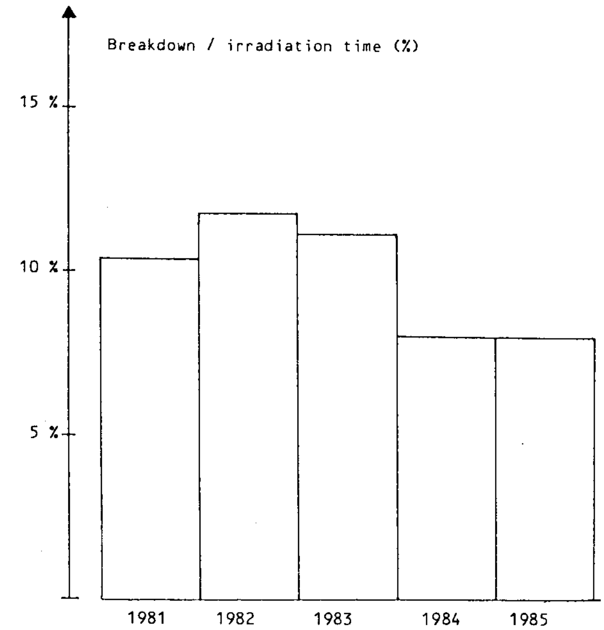


Fig.3 : breakdown time with regard to available time.

During last 2 years, the rate of breakdowns has been reduced in spite of the machine growing old and the time of working increasing.

Thus, a high number of problems have to be faces during the sessions devoted to radiotherapy : the cyclotron then working at its highest power (proton energy, proton beam current...).

Problems are mainly related to the beam extraction (tab.3). A new deflector has been installed in the course of 1985.

The medical installations take advantage of the cyclotron department technical assistance. The frequency of the incidents for this type of equipment is below 2 % of treatment days. They always last less than one hour.

	DELAYED SESSIONS	CANCELLED SESSIONS
ELECTROSTATIC DEFLECTOR	32 %	55 %
RADIO FREQUENCY SYSTEM	23 %	20 %
POWER SUPPLIES	10 %	10 %
ION SOURCES	20 %	-
BEAM PROBES	5 %	-
VACUUM SYSTEM	5 %	10 %
MISCELLANEOUS	5 %	5 %

Tab.3 : incidents on cyclotron and peripheral installations.

(5) Consequence for treatment planning

The priority given to medical users nearly always make neutrontherapy possible. Yet we still have to cancel some sessions because of some specific incidents.

Sessions cancelling

Each year, about 8 irradiation days have to be cancelled, which is under 5 % of scheduled time (fig.4).

As a comparison, breakdowns on the megavoltage X-Ray machine (Philips SL 75-20) in the Radiotherapy Department lead to a medium rate of 4 days of treatment cancelled per year.

It should be observed that the number of days of cancelled treatment is fairly lower than the number of breakdowns registered, owing to the fact that a technical team of the C.N.R.S. is on the spot.

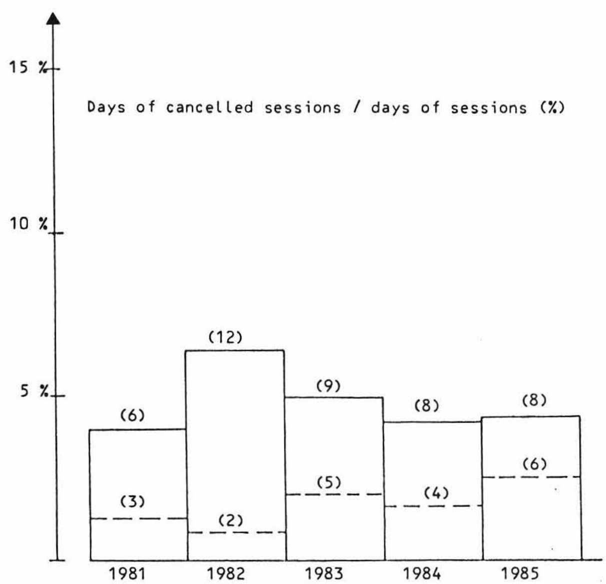


Fig.4 : days of treatment cancelling frequency
(———) cyclotron
(-----) X-ray therapy machine.

( ) number of days when the machine is stopped.

Delays in sessions

The majority of waiting delays before or during the irradiation sessions last less than 1 hour.

Delays are observed for about 30 % of the sessions (fig.5)

From 1981 to 1985, the incidents frequency has increased owing to the cyclotron components wearing out and the deflector mainly.

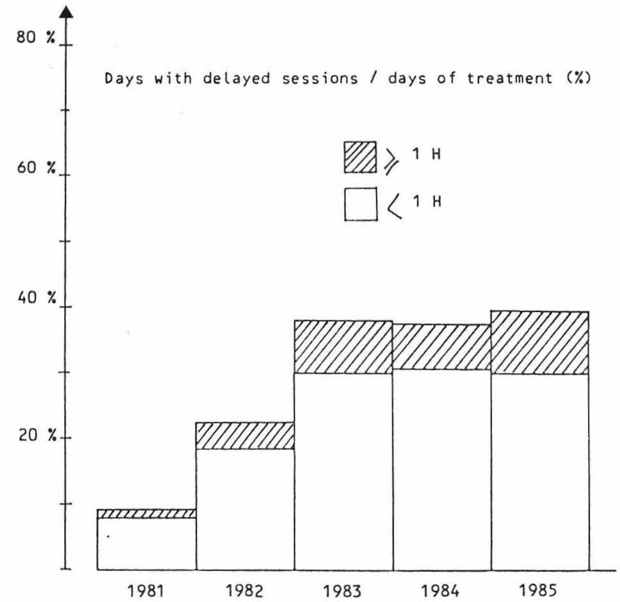


Fig.5 : number of sessions for which delays related to technical problems have been observed.

(6) Problems in organization and consequences

To the delay in treatment related to technical incidents must be added problems in organizing the transport of patients from the hospital to the cyclotron treatment unit.

The order in which patients are treated is planified according to the type of collimation requested for their irradiation.

Each delay is responsible for an equivalent waste of time during the availability of the beam (fig.6). This is entirely paid to the C.N.R.S. Unfortunately, this type of problems increased in 1984 and 1985.

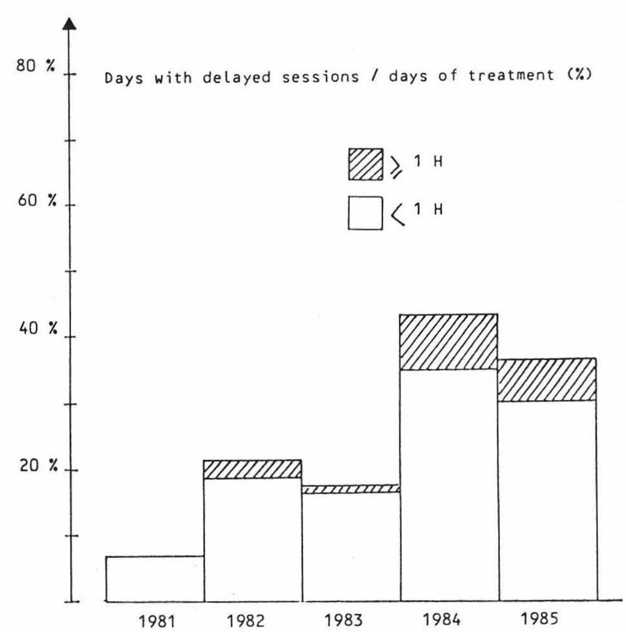


Fig.6 : number of sessions for which delays related to patients conveyance have been observed.

7 Repartition of time assigned to the treatment Unit

69 % of the theorical time of beam availability is for treating patients (preparations and irradiations).
14 % is used for radiobiology and dosimetry.
17 % is wasted time (tab.4).

Compulsory non medical use :		31 %
* dosimetry	3 %	
* radiobiology	11 %	
* cyclotron adjustments	10 %	
* delay in transportation	7 %	
Medical use :		69 %
* preparations	38 %	
* irradiations	31 %	

Tab.4 : repartition of theorical time assigned to neutrontherapy (1983-84-85).

* Hours reserved for dosimetric studies and research in radiobiology must not be cut short without running the risk of having an effect upon the quality of treatments and works in progress.

* Using the cyclotron for medical purpose as well as for research (multiplicity of accelerated particles, beam energies and beam lines) of course has a repercussion on the frequency of incidents whereas a machine only devoted to medical applications is more reliable.

* A treatment unit located far from the hospital makes it imperious to have a very strict organization in transporting patients.

* Real irradiation time represents a minor percentage of treatment time : about 45 %. The absence of a variable collimator fairly increases delays necessary for setting the fields.

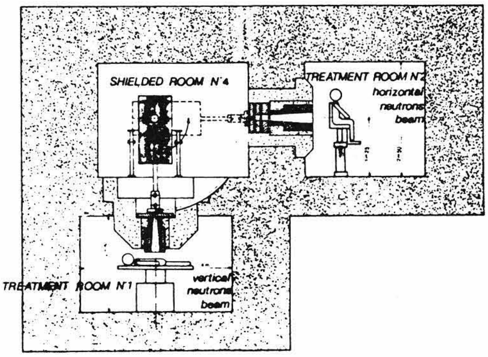
8 Conclusion

Since 1983, the recruitement of patients has been steady and approximately corresponds to the possibilities of the present facility.

Two main difficulties limit the development of treatments with neutrons :
* the fixed beam position,
* the "suboptimal" physical parameters.

Limited avaibilities of the cyclotron for medical applications have very seldom been responsible for delayed treatments.

Realizing two projects will allow improvements in neutrontherapy modalities :
* a few Mev increase in the energy of incident protons will lead to more suitable physical parameters (dose rate, depth dose).
* the construction of a 2nd treatment room will allow to have two incidences at our disposal. This will permit to set new treatment protocols and to better use the beam time (preparation of an irradiation while patient is treated is the other room) (fig.7 a & b).



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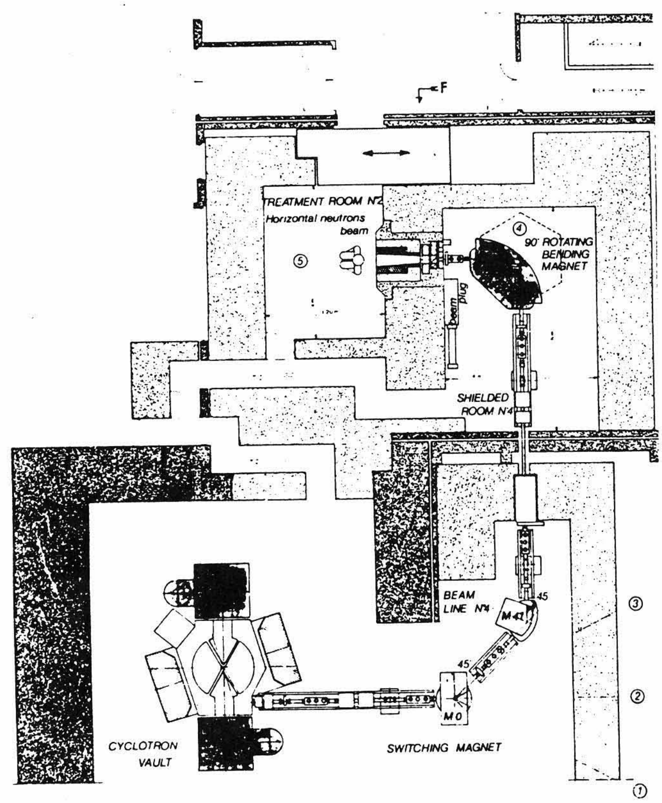

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Fig.7 a & b : plans for extension : construction of a 2nd treatment room

The renovation of the pool of neutrontherapy centers makes these improvements a duty for the Orleans facility, so that the therapeutic evaluation of the use of neutrons in external radiotherapy can be carried on in the best conditions and on equal terms with other centers.

From 1980 to 1985, the pool of neutrontherapy facilities has moved in terms of ballistic properties of the neutron beam (tab.5).

d (50 %)	FACILITIES 1980	FACILITIES 1985
50 % ≦ 9 CM	CHICAGO CRACOVIE DRESDE EDINBURG + ESSEN + LONDON TOKYO	CHICAGO CRACOVIE ESSEN + GAND + LONDON ° MUNICH PRETORIA ° TOKYO
9 < 50 % ≦ 11	AMSTERDAM + CLEVELAND HAMBOURG + HEIDELBERG + MANCHESTER + SEATTLE	HAMBOURG + HEIDELBERG + MUNSTER + PHILADELPHIE + RIYADH +
11 < 50 % ≦ 13	CHIBA ° ORLEANS WASHINGTON	CHIBA ° ORLEANS
13 < 50 % ≦ 15	HOUSTON LOUVAIN	CLEVELAND + HOUSTON + LOS ANGELES + SEATTLE + °
50 % > 15	BATAVIA	BATAVIA (FAURE +) LIVERPOOL + ° LOUVAIN (+ °)

(tab.5) : neutrontherapy facilities in 1980 and 1985.

+ facilities with an isocentric head or many incidences available.
° facilities with variable of multi-leaf collimator
( ) under construction

d (50 %) : the depth in water at which the total (n + γ) absorbed dose is reduced to half its maximum value. 10 x 10 cm field.

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