Sugár agysebészet a XXI. század hajnalán:
új korszak az idegsebészetben

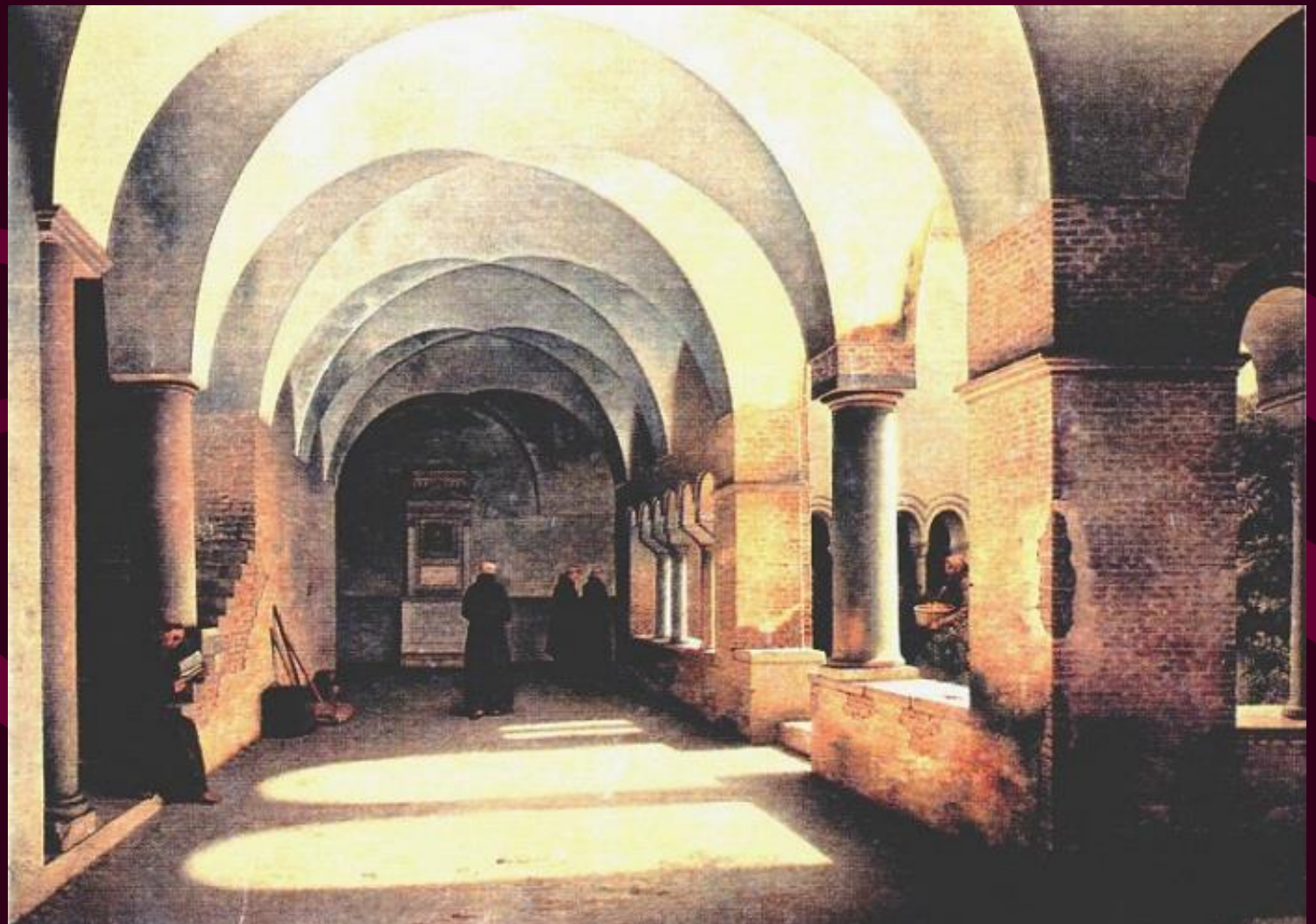
Dr. Szeifert György

egyetemi magántanár

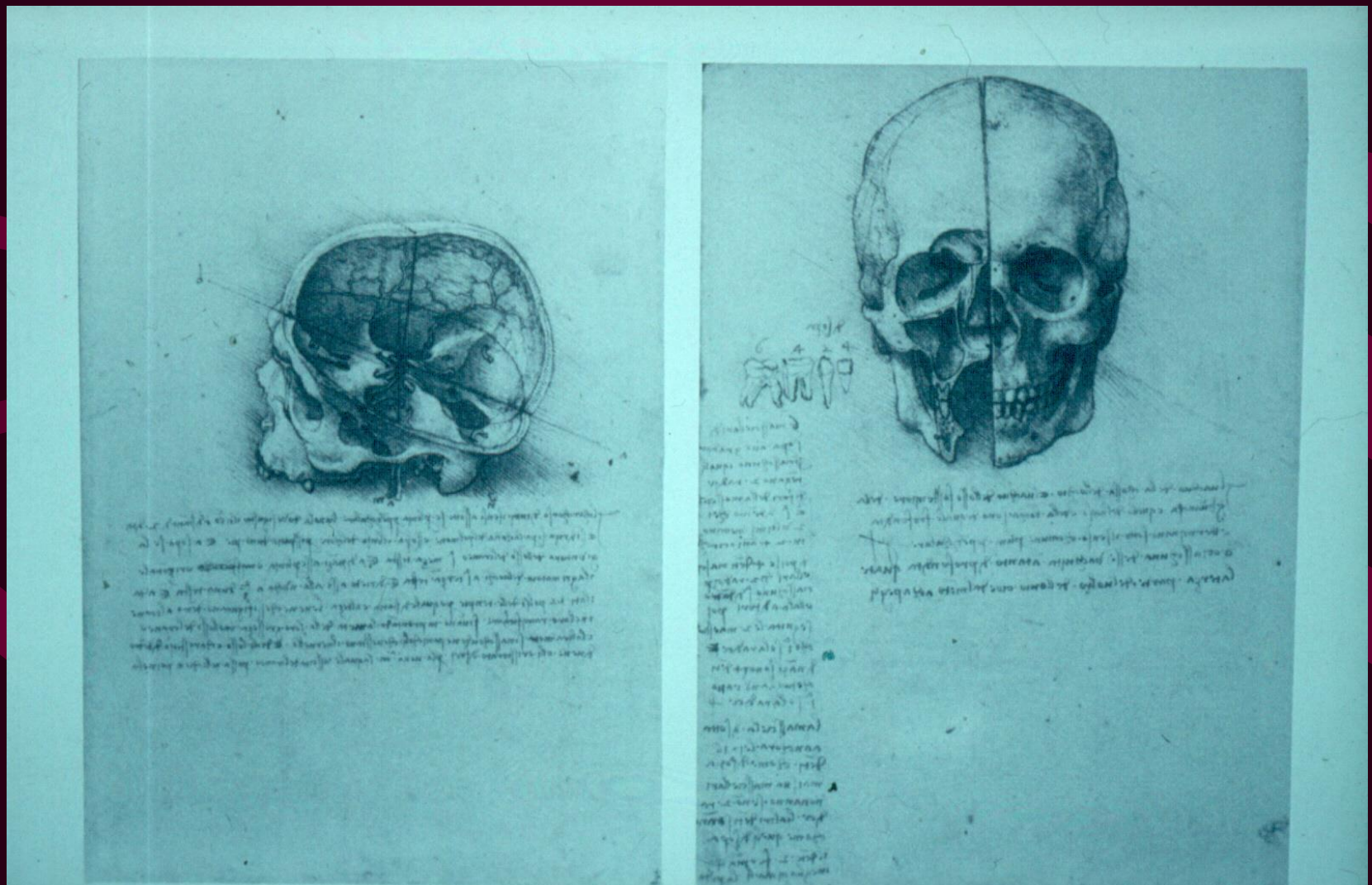
Semmelweis Egyetem Idegsebészeti Tanszék

“Ha nincs elég erőd megállhatsz félúton,
de ne horgonyozz le az út elején.”

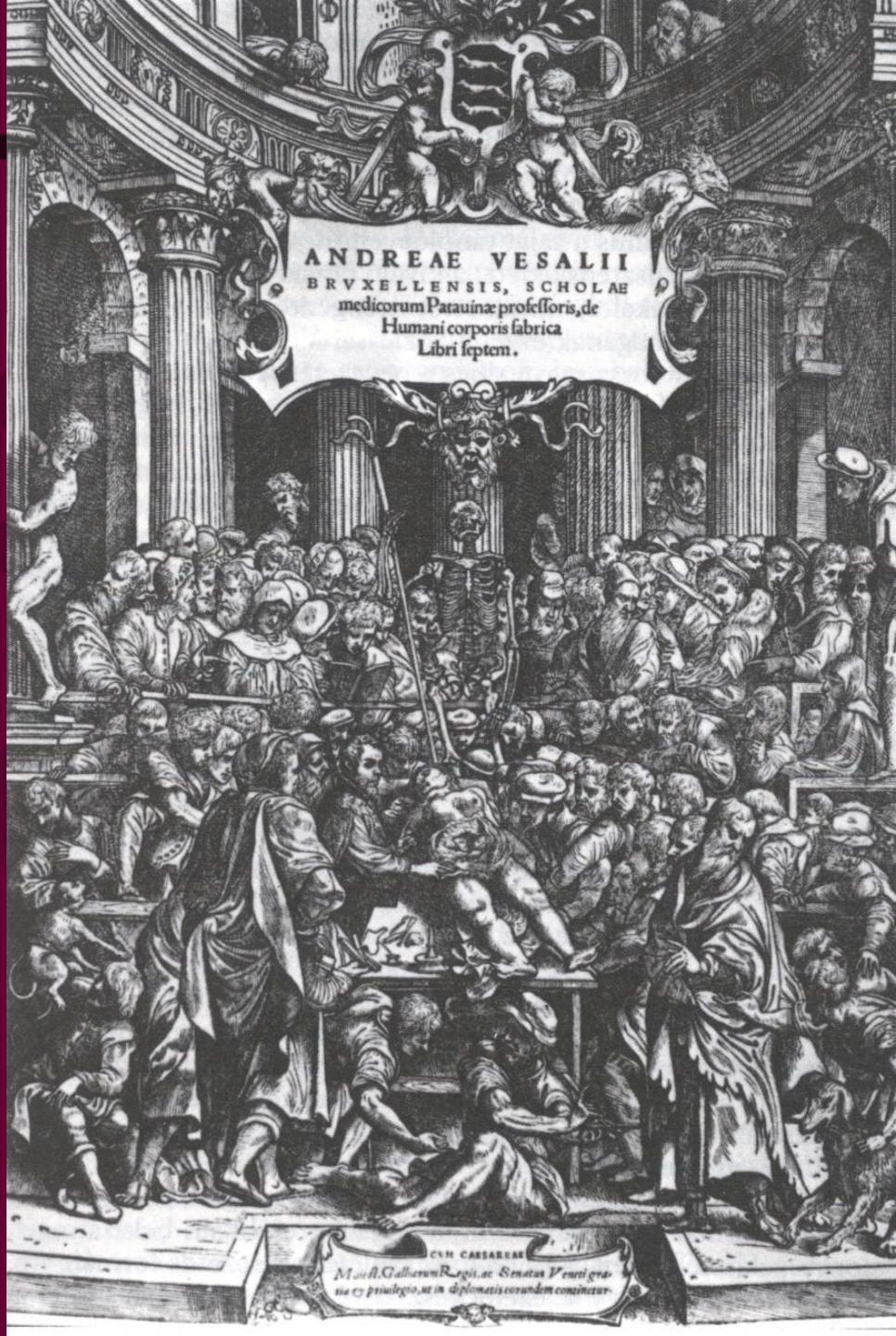
Confucius (Kr.e.: 551-478)



Leonardo da Vinci (1452-1519)



Andreas Vesalius (1514-1564)



Giovanni Battista Morgagni (1682-1771)

ELSEVIER

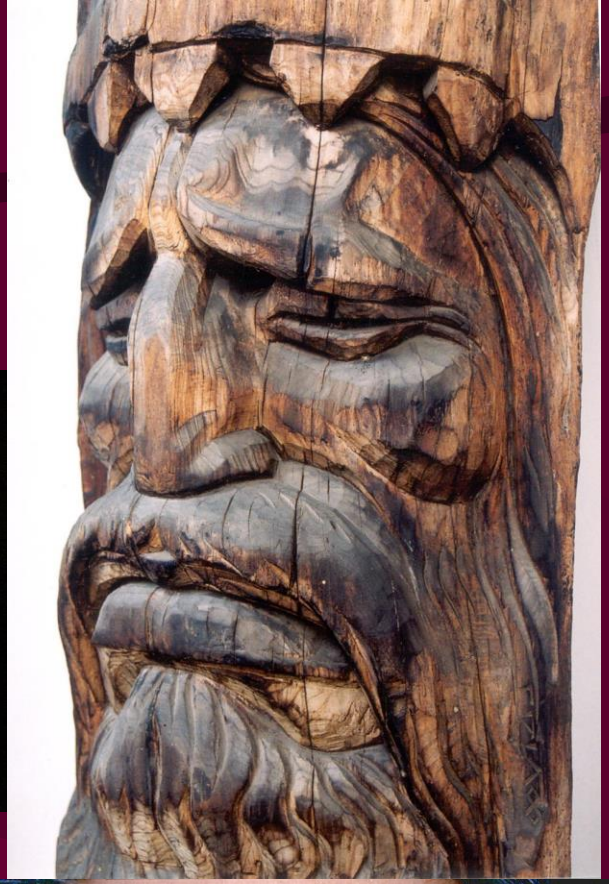
Vascular

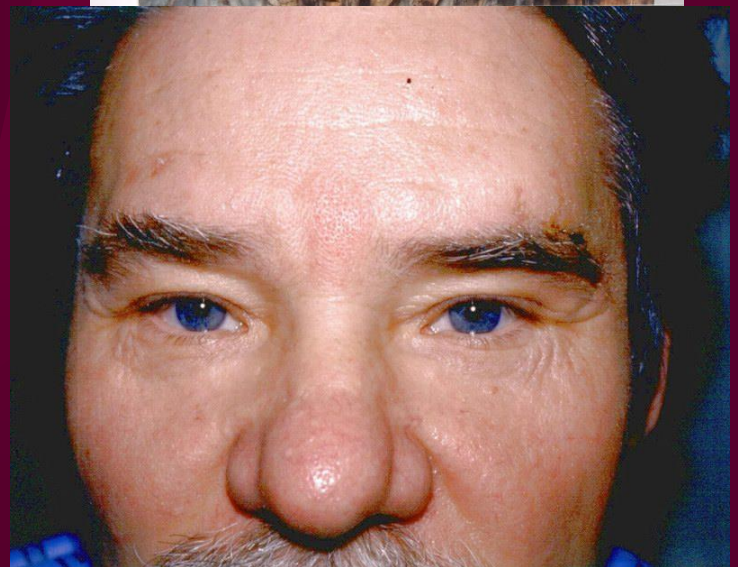
BILATERAL SUPRAORBITAL KEYHOLE APPROACH FOR MULTIPLE ANEURYSMS VIA SUPERCILIARY SKIN INCISIONS

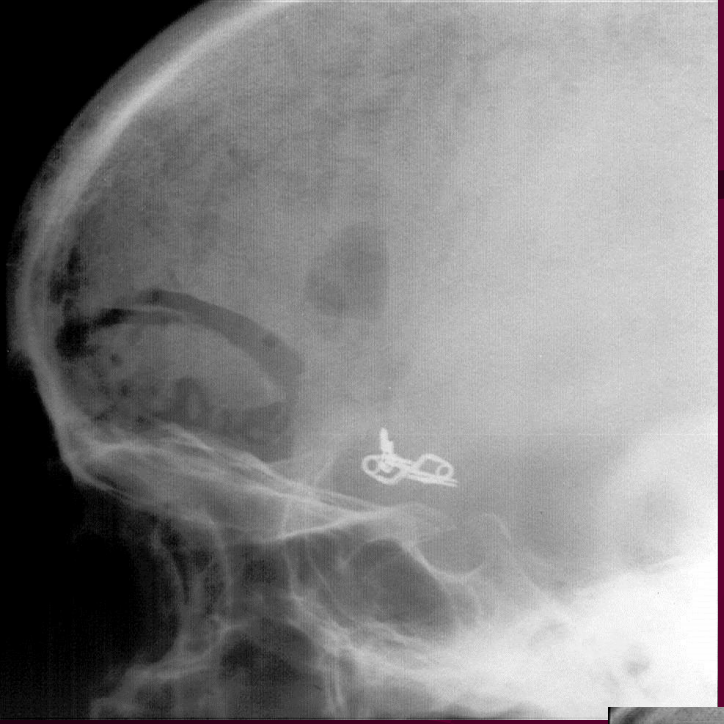
Sándor Czirják, M.D., Ph.D., István Nyáry, M.D., Ph.D., Judit Futó, M.D., Ph.D., and György T. Szeifert, M.D., Ph.D.
National Institute of Neurosurgery, Budapest, Hungary

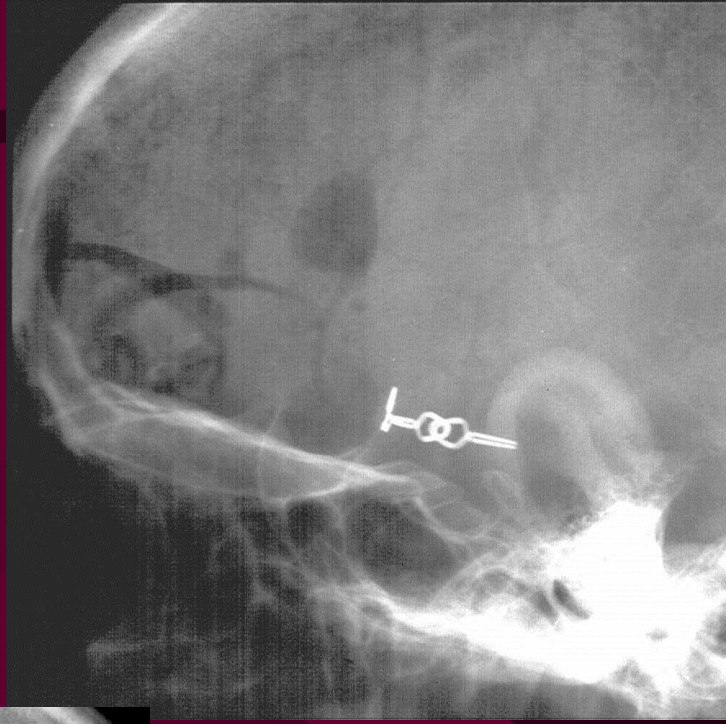
Czirják S, Nyáry I, Futó J, Szeifert GT. Bilateral supraorbital keyhole approach for multiple aneurysms via superciliary skin incisions. Surg Neurol 2002;57:314–324.

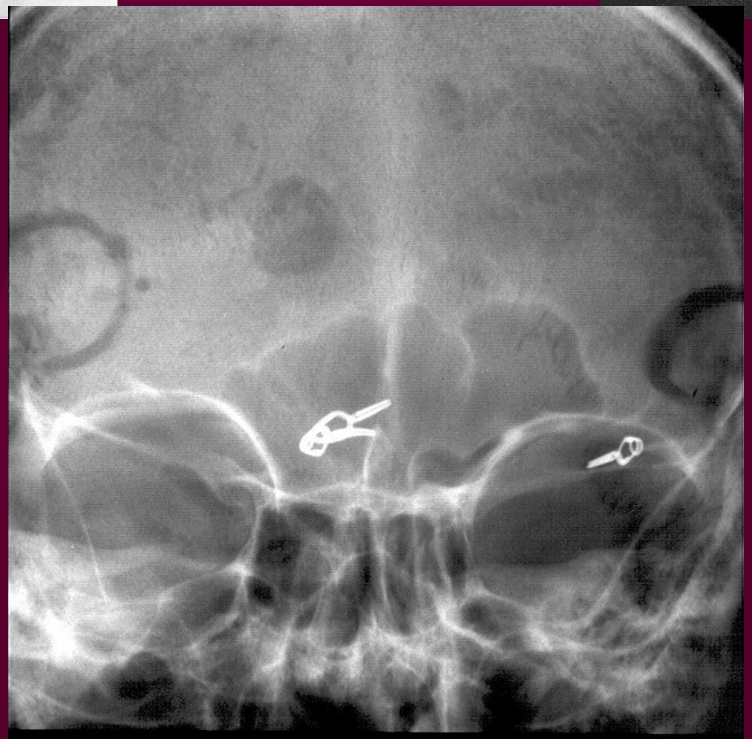
exploration. The operations were carried out through a approximately 2.5 × 3 cm supraorbital keyhole craniomy following a skin incision just above the eyebrow. Th



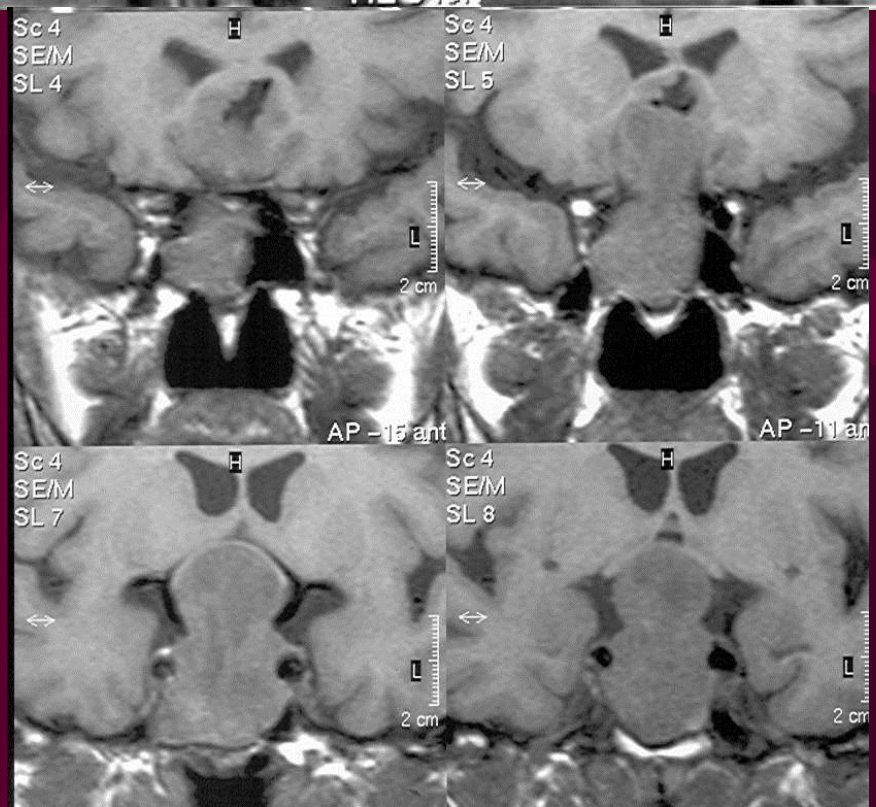


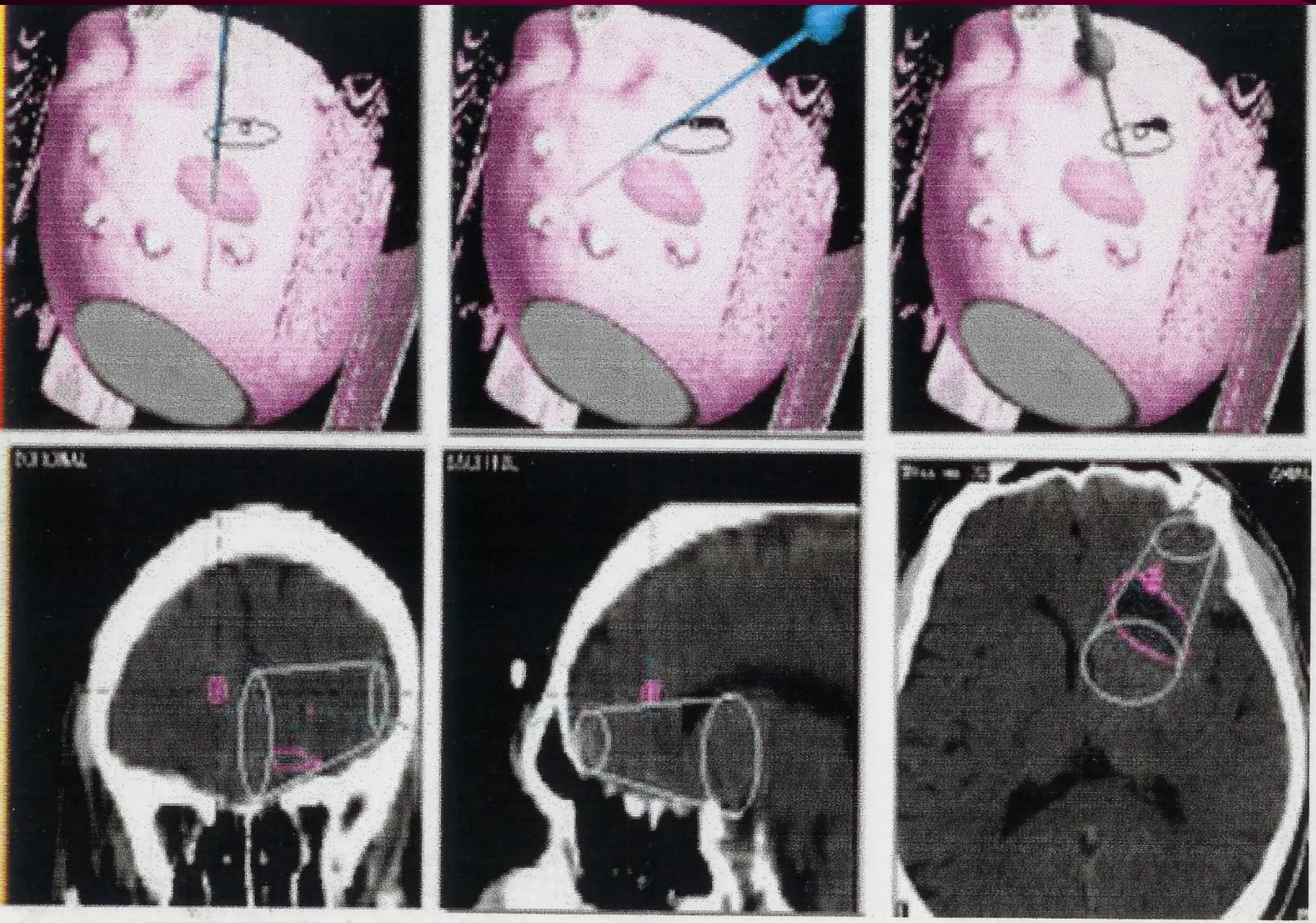







Sc 5
SE/M
SL 5
H
P
3 cm
RL 5 left
Sc 5
SE/M
SL 6
H
P
3 cm
RL 0 left


Sc 4
SE/M
SL 4
H
L
2 cm
AP –15 ant
Sc 4
SE/M
SL 5
H
L
2 cm
AP –11 ant
Sc 4
SE/M
SL 7
H
L
2 cm
Sc 4
SE/M
SL 8
H
L
2 cm



Acta Chirurgica Scandinavica

(102 : 316-319; **1951**)

From the Department of Neurosurgery I (Head: LARS LEKSELL, M. D.) and the Department of Radiation Physics (Head: KURT LIDÉN, Ph. D.), Lasarettet, University of Lund, Sweden.

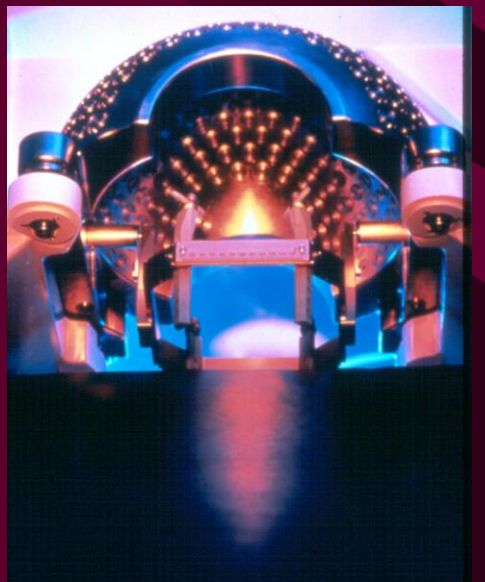
The Stereotaxic Method and Radiosurgery of the Brain.

By

LARS LEKSELL.

Stereotaxiás sugársebészet

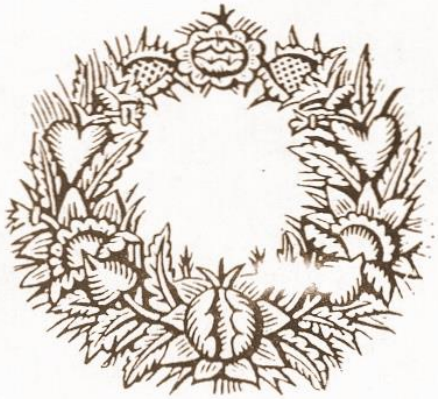
- Célja: “a kóros, vagy normális sejteket tartalmazó meghatározott céltérfogat teljes és pontos megsemmisítése egyszeri, nagy dózisú sugárkezeléssel, a környező szövetek károsítása nélkül.”

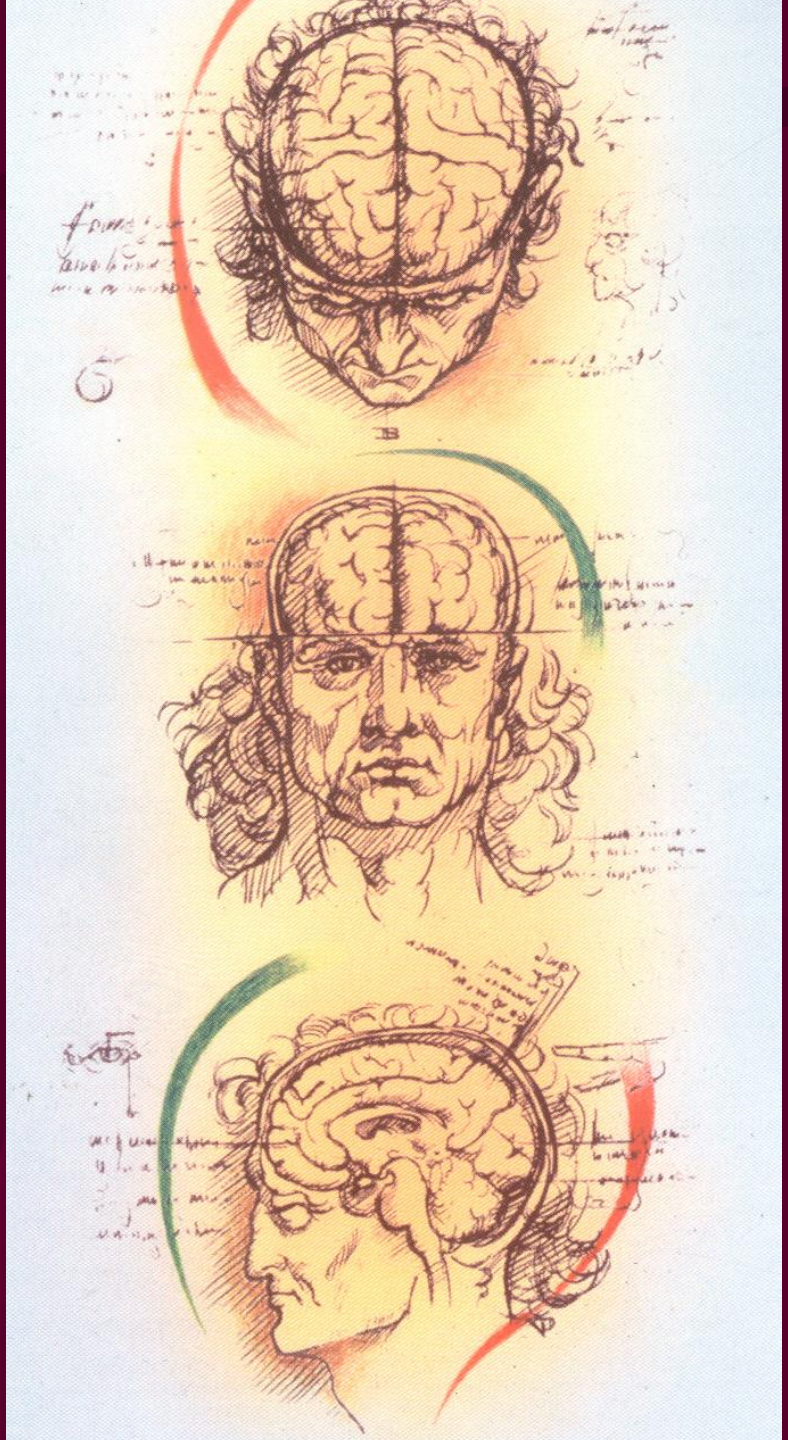


EDITORG KLASSZIKUSOK

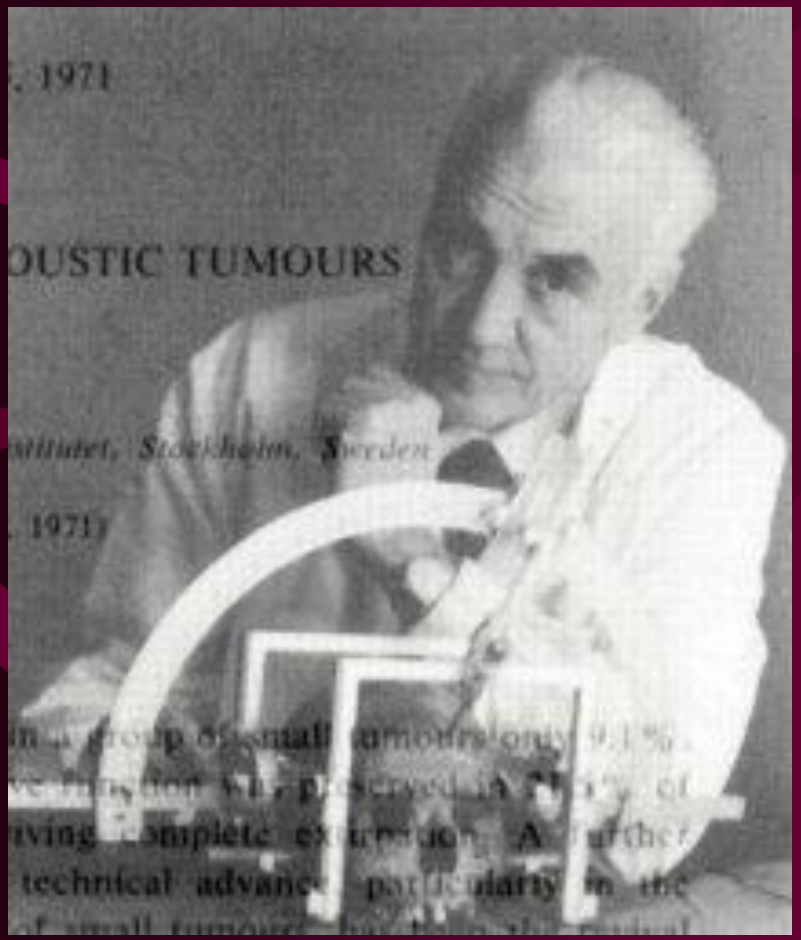
Karinthy Frigyes

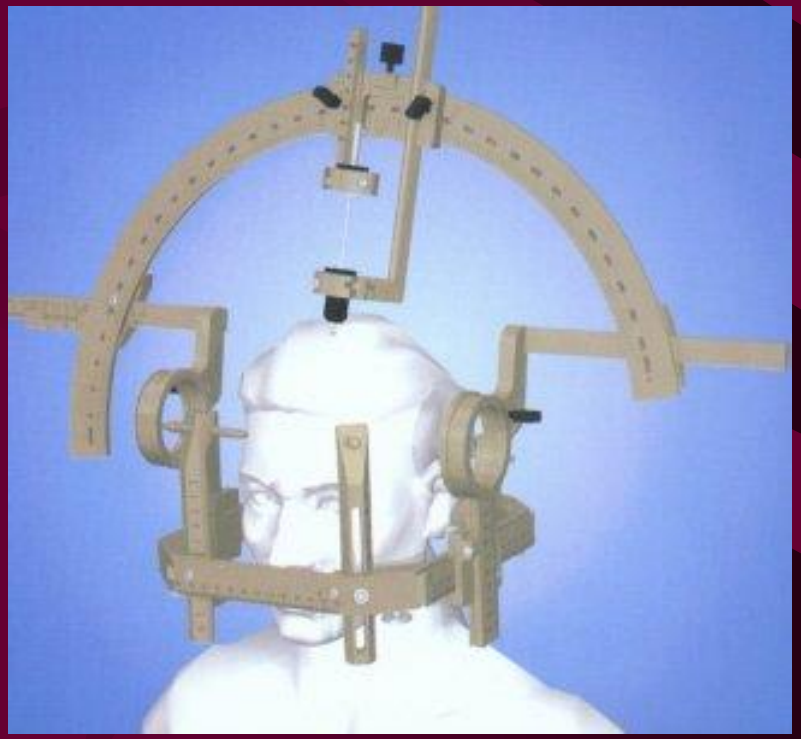
Utazás a koponyám körül





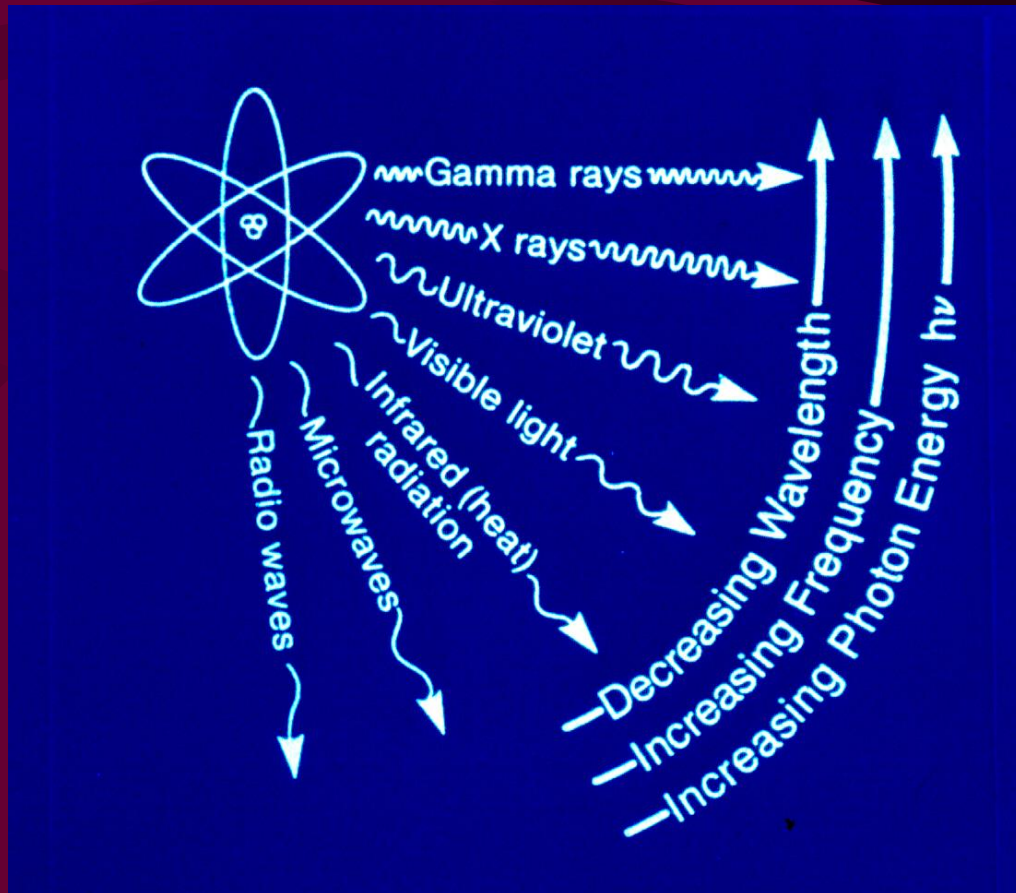
Professor Lars Leksell (1907-1986)



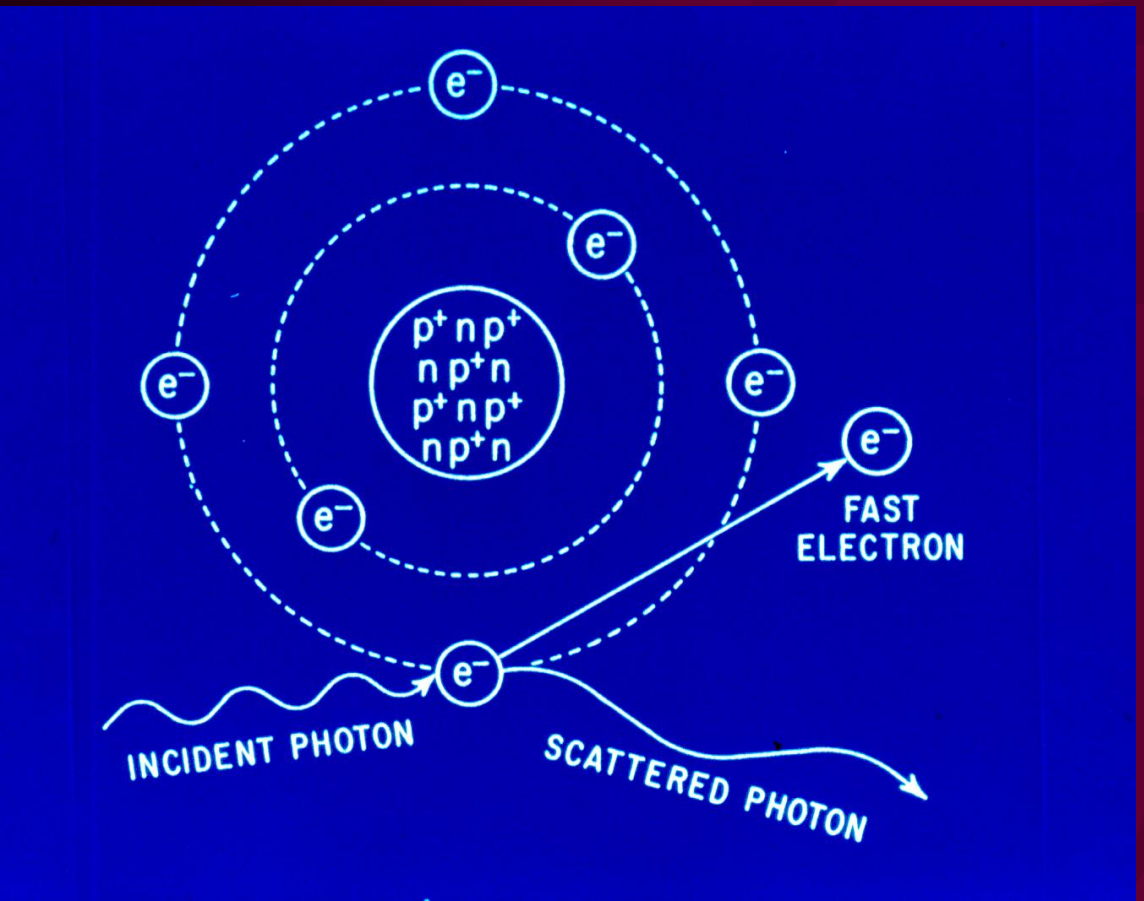


Gamma-sugár

- Co-59>**Co-60**>Ni-60
- hullámhossz: **< 10nm**
- Co-60 izotóp felezési ideje 5,26 év



Fotonok energia közvetítése



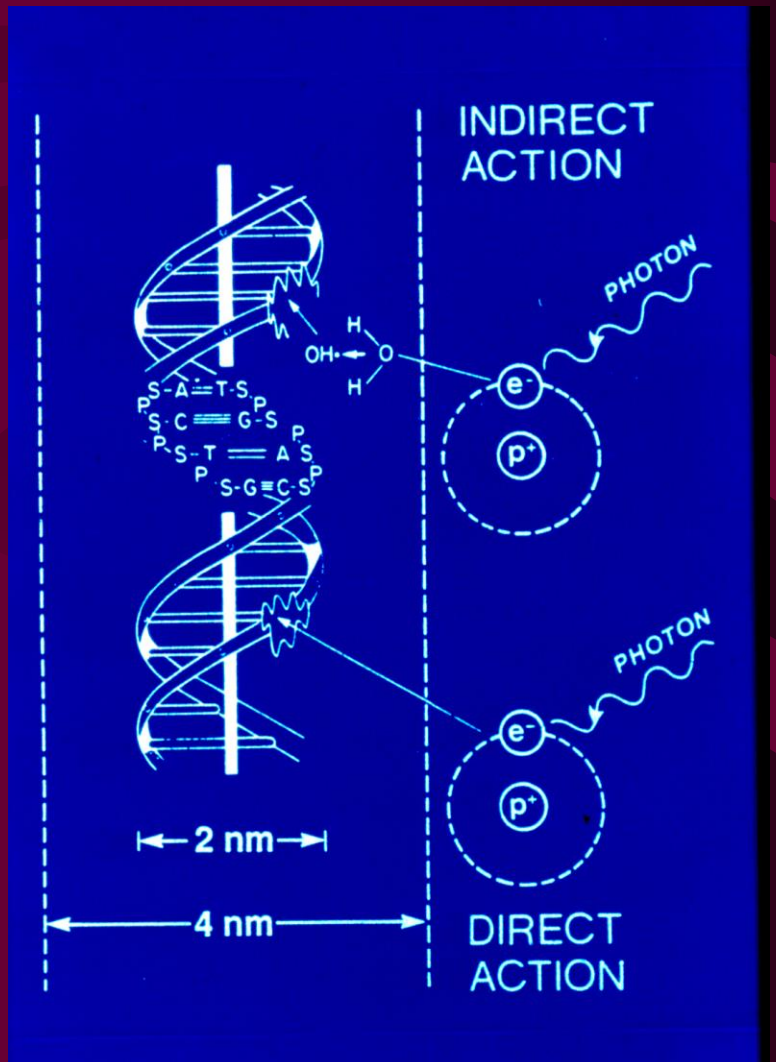
fotoelektrikus hatás

Compton-effektus

párképződés

Sugárbiológiai hatás

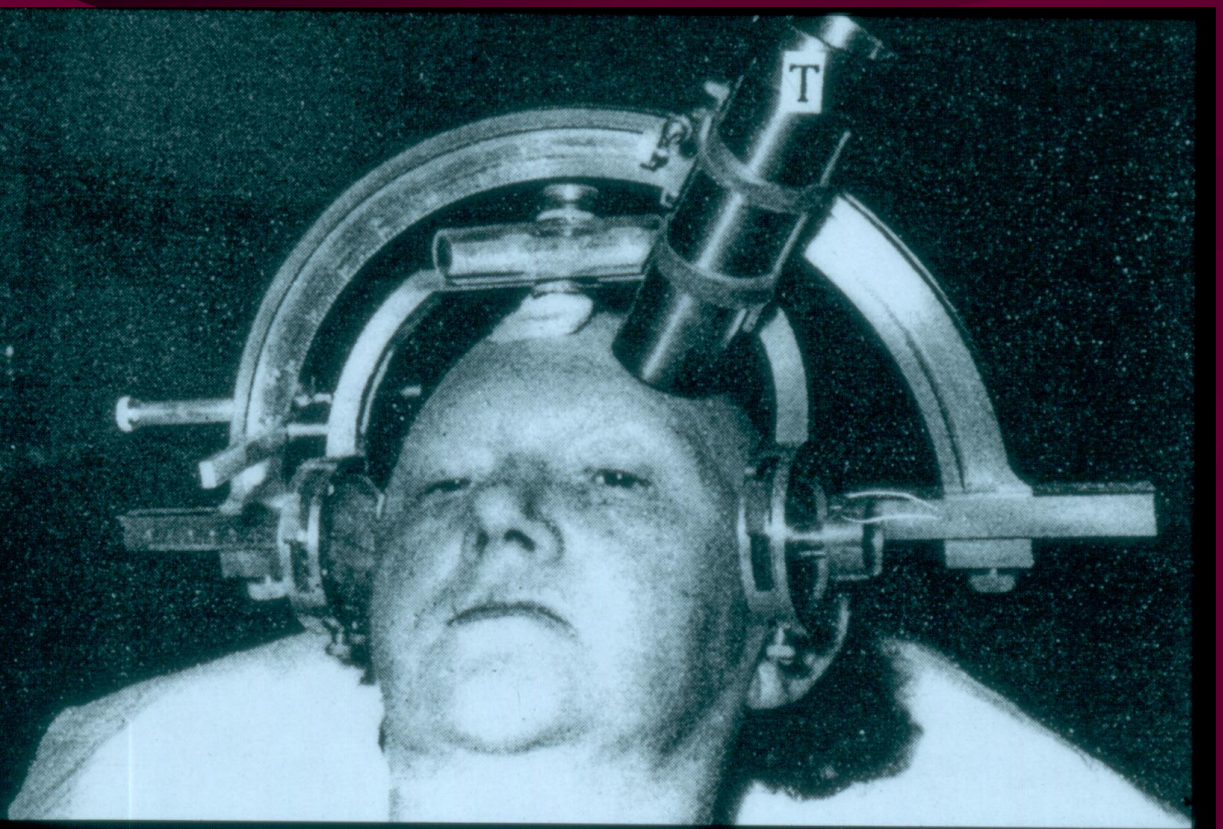
- DNS molekula
- direkt reakció (részecske sugárzás)
- indirekt reakció (elektromágneses sugárzás)
- szabad gyökök (páratlan elektron, nagyfokú kémiai reaktivitás)



Sugársebészeti technikák

- Bragg-peak (proton-sugár)
- Lineáris gyorsító (LINAC, Rtg.-sugár)
- CyberKnife (Rtg.-sugár [photon])
- Leksell Gamma Kés (gamma-sugár [photon])
- Rotating Gamma System (gamma-sugár)
- Interstitialis brachytherapia (Jód-125: béta-sugár [elektron])

Lineáris gyorsító (LINAC)
(mozgó sugárforrás)



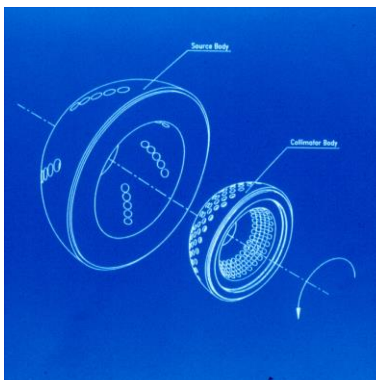
A Gamma Kés (1967)

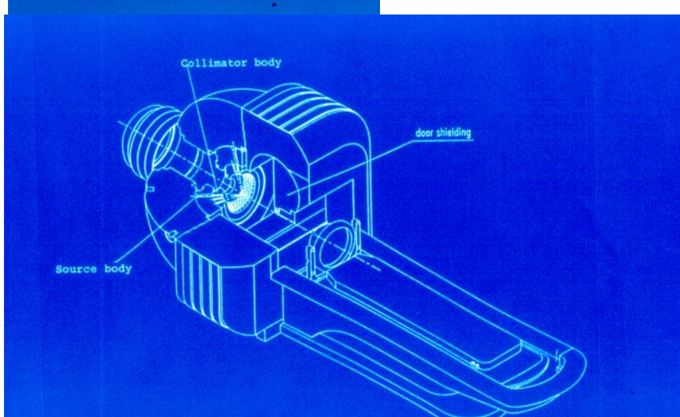
- Fix sugárforrások, fix célpont
- 201 db Co-60 izotóp sugárforrás
- <0.3 mm-es találati pontosság
- mechanikai egyszerűség
- megbízhatóság
- “arany standard”

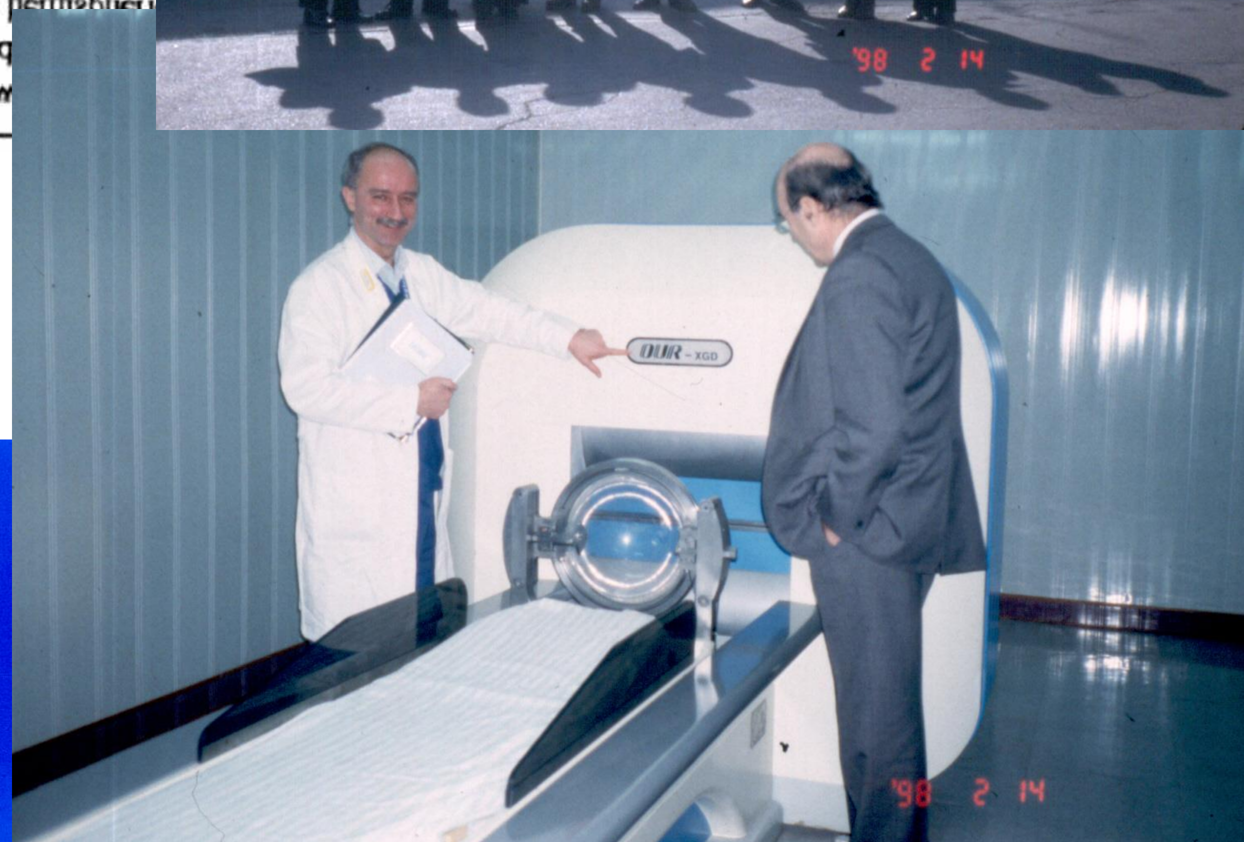
M.D., Ph.D.[1]

KEY WORDS: Radiosurge

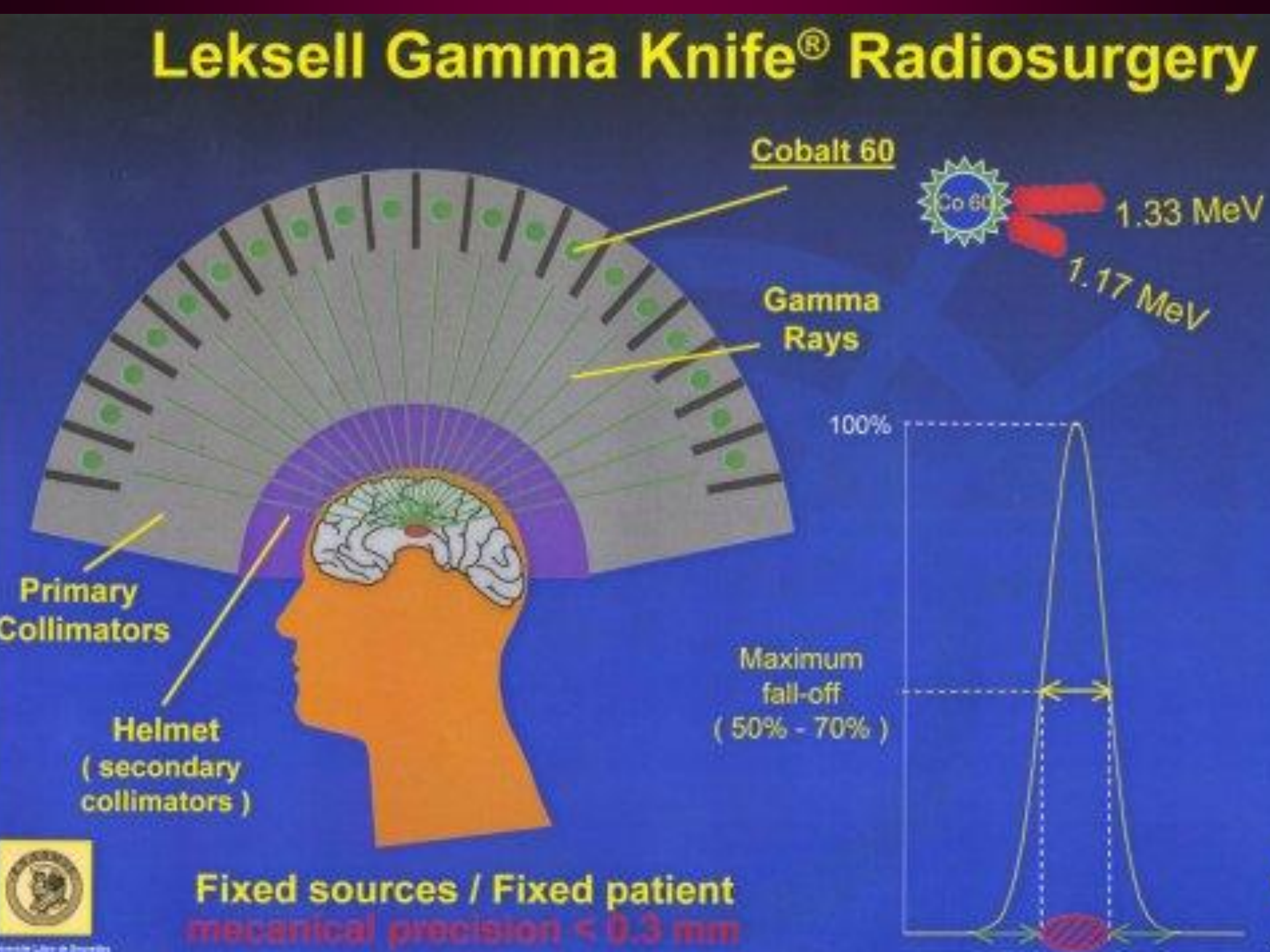
In 1996, a new
stereotactic rad
lical lines in a hemispheri
built-in secondary collima
nonoverlapping, full 360
6000 Ci total initial activ
was to test the geometri
carried out on Gafchromic
the center point of the ra
alyzed with an automatic
50238, Innovative Optica
sition of the pin-prick in
was determined. The calc
cal center point verify the

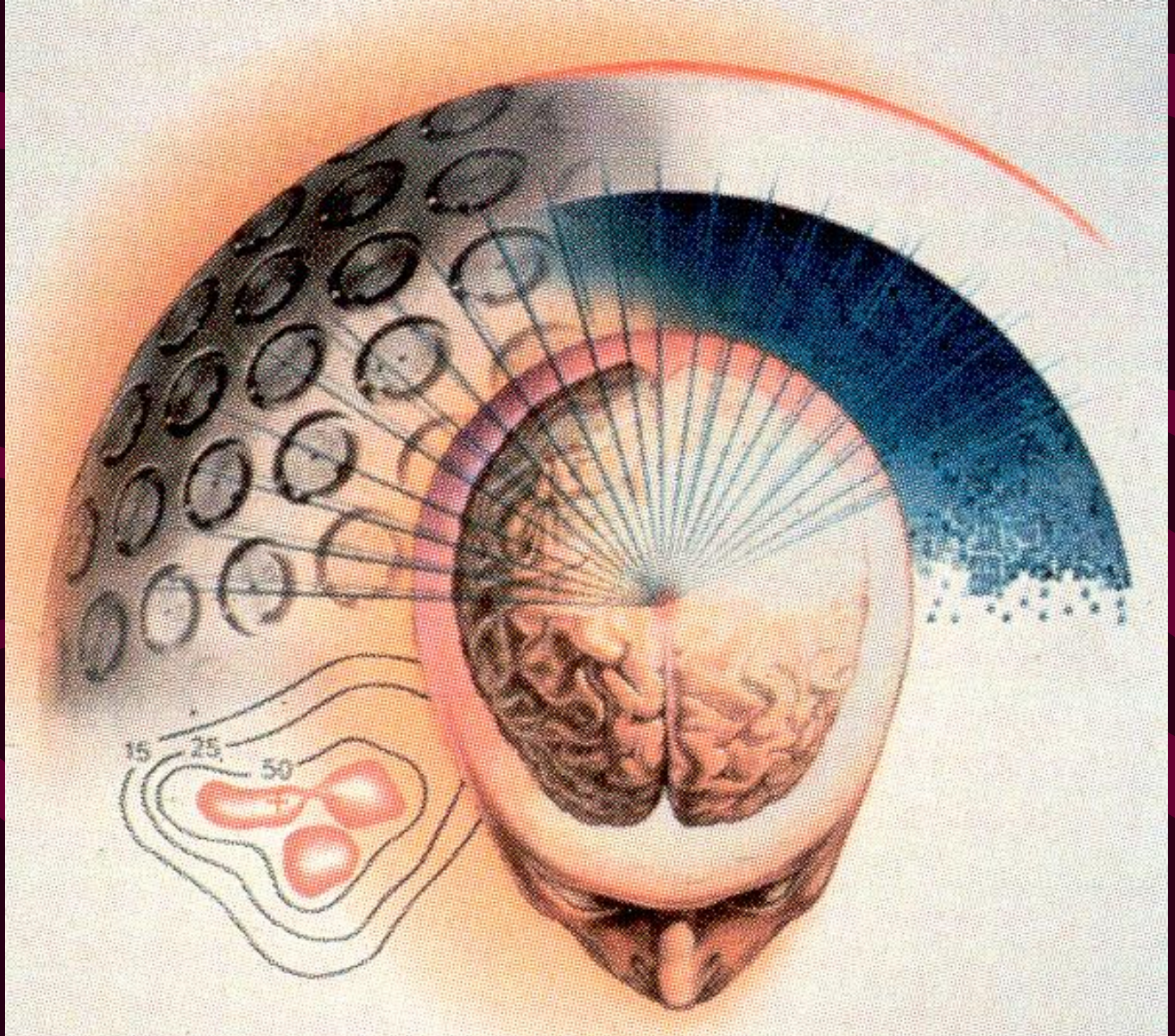






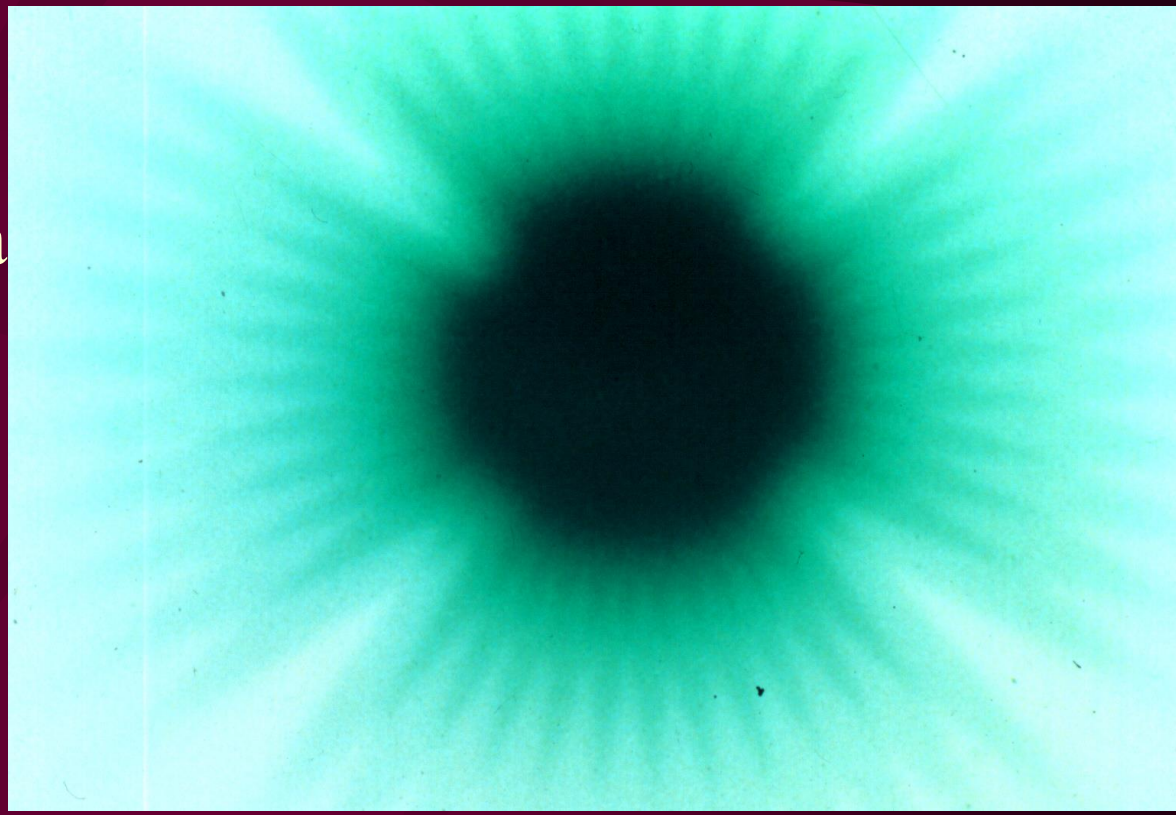
Leksell Gamma Knife® Radiosurgery




15
25
50

“Radiosurgery” effektus

- egyenként ártalmatlan sugárnyalábok
- a fókuszpontban pusztító hatásúvá összegződnek
- hirtelen energia csökkenés az ép környezet felé




'95 8 17


GRAMME
CENTIGRAMME
MILLIGRAMME

A Gamma Kés terjedése

Leksell Gamma Knife®

Indications Treated to December 2003

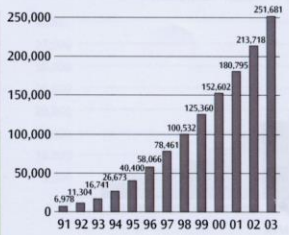
World Wide

193 units in clinical operation December 2003, 167 sites reporting

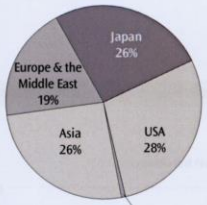
Indications Treated

Vascular Disorders	
AVM	35,455
Aneurysm	127
Cavernous Angiomas	131
Other Vascular Disorders	2,799
Total	**38,512**
Benign Tumors	
Vestibular Schwannoma	24,441
Trigeminal Schwannoma	1,578
Other Schwannoma	109
Benign Glial Tumor (Grade I & II)	139
Meningioma	31,188
Pituitary Adenoma (Secreting)	13,984
Pituitary Adenoma (Non-secreting)	7,159
Pineal Region Tumor	2,342
Hemangioblastoma	1,135
Hemangiopericytoma	680
Craniopharyngioma	2,461
Chordoma	1,219
Glomus Tumor	706
Other Benign Tumors	1,921
Total	**89,062**
Malignant Tumors	
Malignant Glial Tumor (Grade III & IV)	18,663
Metastatic Tumor	81,859
Chondrosarcoma	244
NPH Carcinoma	998
Other Malignant Tumors	3,203
Total	**104,967**
Total Tumors	**194,029**
Functional Disorders	
Trigeminal Neuralgia	14,228
Parkinson's Disease	1,101
Intractable Pain	458
Epilepsy	1,671
OCD	111
Other Functional Disorders	621
Total	**18,190**
Ocular Disorders	
Uveal Melanoma	928
Glaucoma	16
Other Ocular Disorders	6
Total	**950**
Total Indications	**251,681**

Cumulative Number of Patients Treated

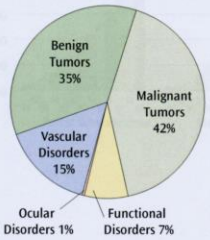


Geographic Distribution of Patients

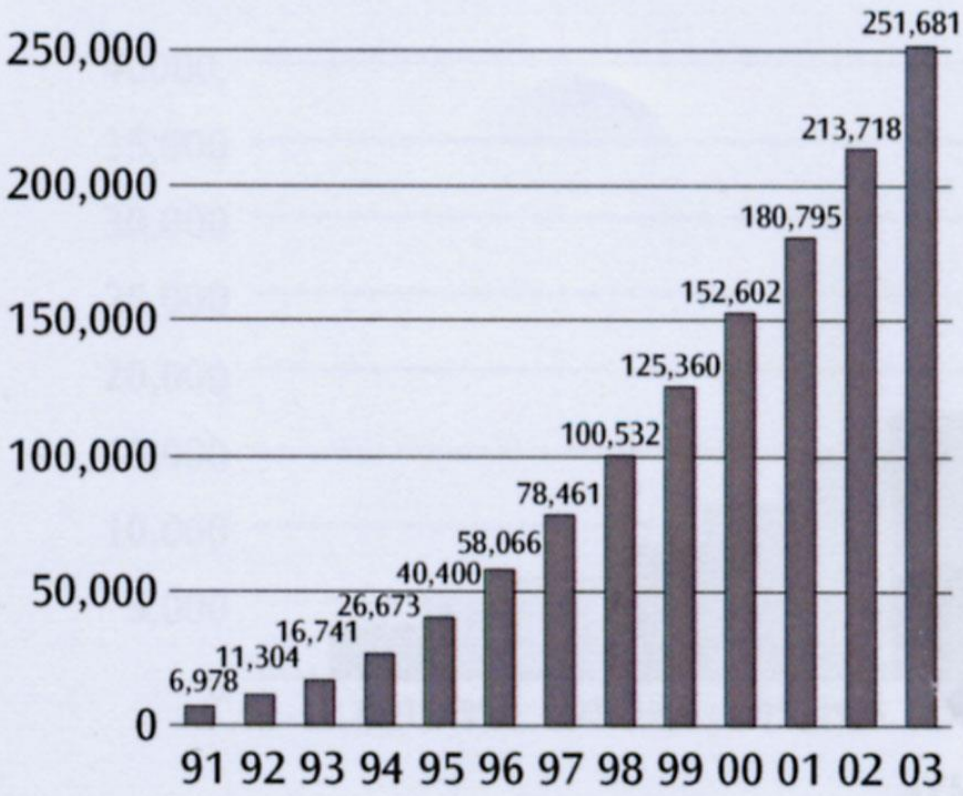


South America & Canada 1%

Cumulative Indications Treated

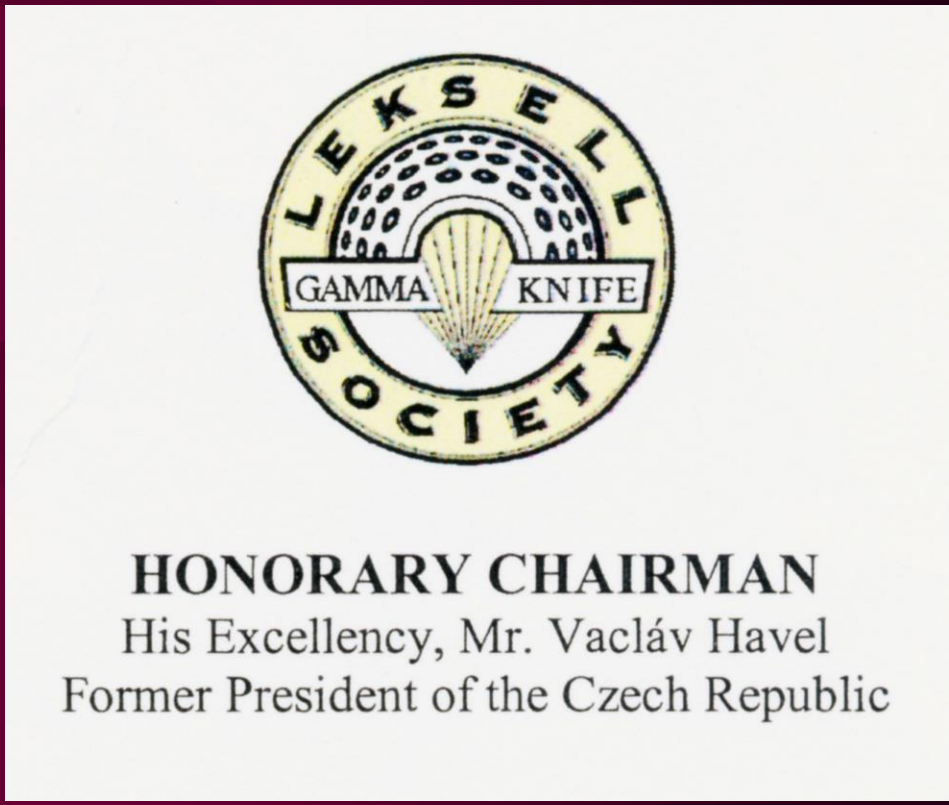


Cumulative Number of Patients Treated



Környező országok

- Prága: 14 éve
- Graz, Bécs: 16 éve
- Zágráb: 2004. Április
- Ankara: (török 2.)
- Bukarest
- Moszkva
- Szt. Pétervár, Kiev tárgyalások folyamatban
- Budapest?



VÁCLAV HAVEL

Prague, 17 March 2004

Dear Friends,

I regret that due to other commitments, I am unable to be present at the opening of the 12th International Leksell Gamma Knife Society meeting in Vienna 2004.

The Leksell Gamma Knife was installed in Prague in 1992, shortly after the Velvet revolution in Czechoslovakia. It was probably the only piece of modern high technology, which was bought for money raised in a nation wide collection, the largest in the modern history of our country.

During the past 12 years almost 6000 patients have been treated by this remarkable surgical instrument in Prague.

Now that so many Gamma Knife clinics from all over the world gather in Vienna, I hope that your congress will be as successful as it was two years ago. I wish you all success in the sharing of important information which I am sure will contribute to even greater clinical advances in the treatment of neurological disorders.

With best wishes,

Václav Havel

Václav Havel
Honorary Chairman Leksell Gamma Knife Society
Former President of the Czech Republic


ELEKTA
LEKSELL GAMMA
8


LEKSELL GAMMA UNIT


'98 6 26

U.L.B. Erasmus Klinika Brüsszel

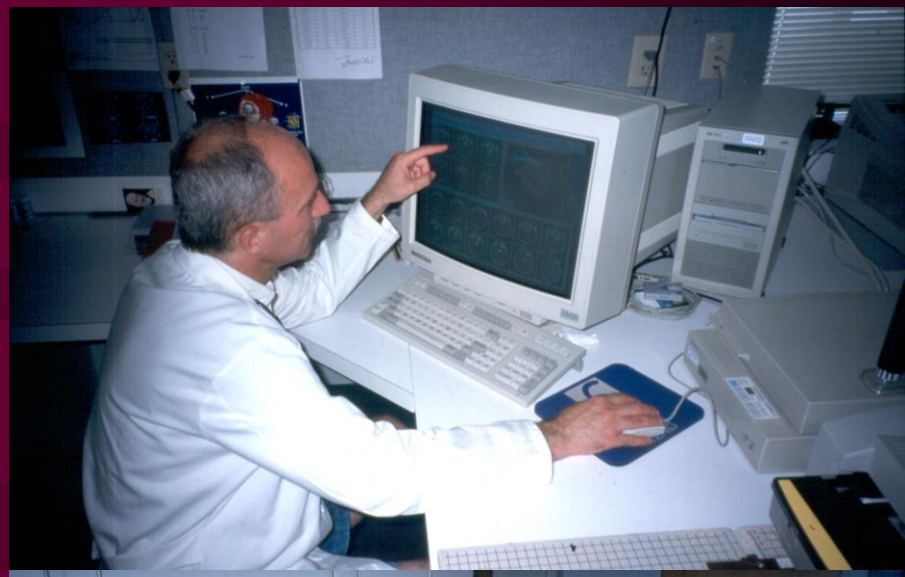
Automata pozicionáló robot-rendszer

A sugársebészet fázisai
(“egynapos sebészet”)

A sugársebészet fázisai

A sugársebészet tervezése (“planning”)

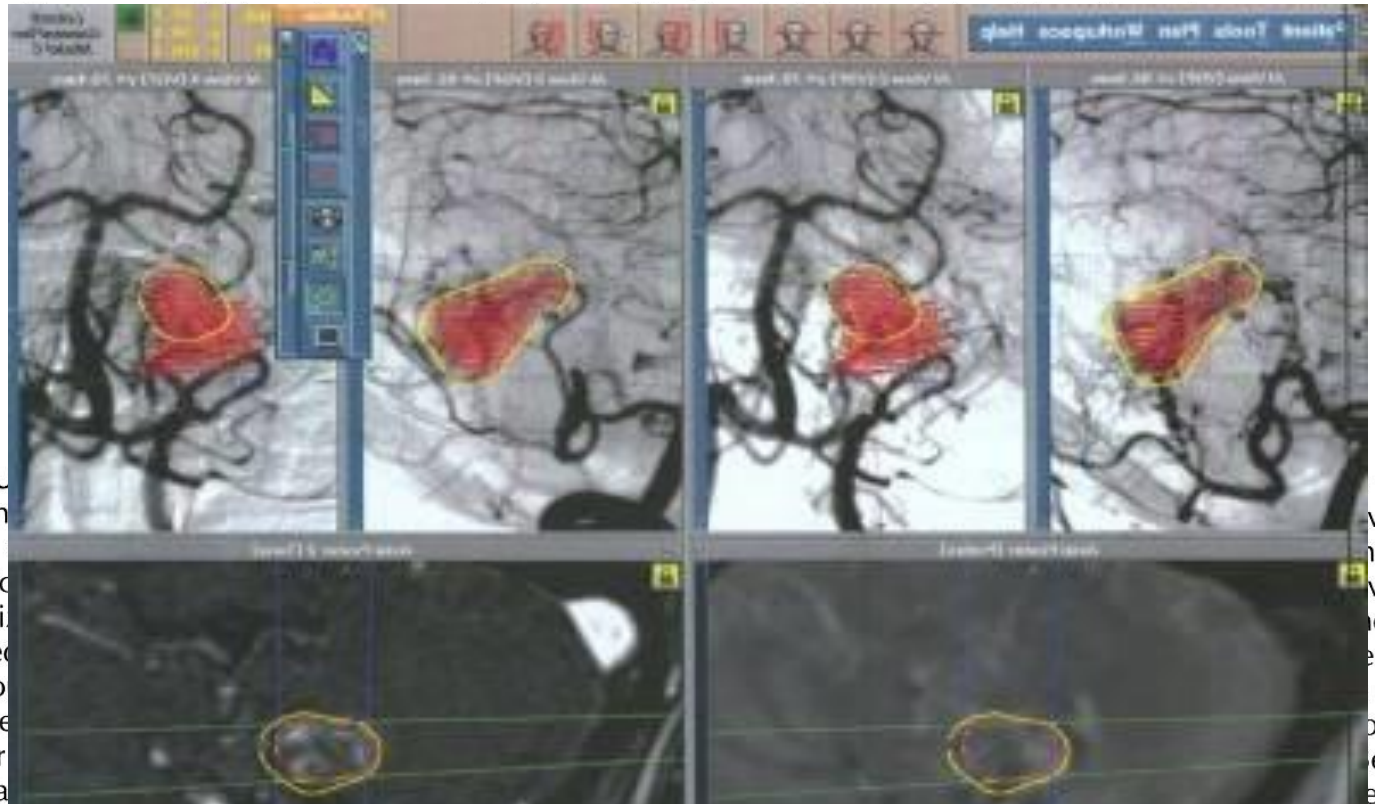
- Team munka:
- idegsebész
- radiológus
- radiotherapeuta
- onkológus
- fizikus



Immunohistochemical analysis of a cerebral arteriovenous malformation obliterated by radiosurgery and presenting with re-bleeding. Case report

György T. Szeifert*, Isabelle Salmon, Danielle Balèriaux, Jacques Brotchi and Marc Levivier

Centre Gamma Knife, Université Libre de Bruxelles, Hôpital Académique Erasme, Brussels, Belgium
**National Institute of Neurosurgery, Budapest, Hungary*



INTRODU
Arterioven
regarded
embryonic
characteri
arterialize
and witho
ful treatme
by Steiner
effective a

ventri-
venous
nucleus
venous
necessi-
ed with
month
on was
ecause
e a left

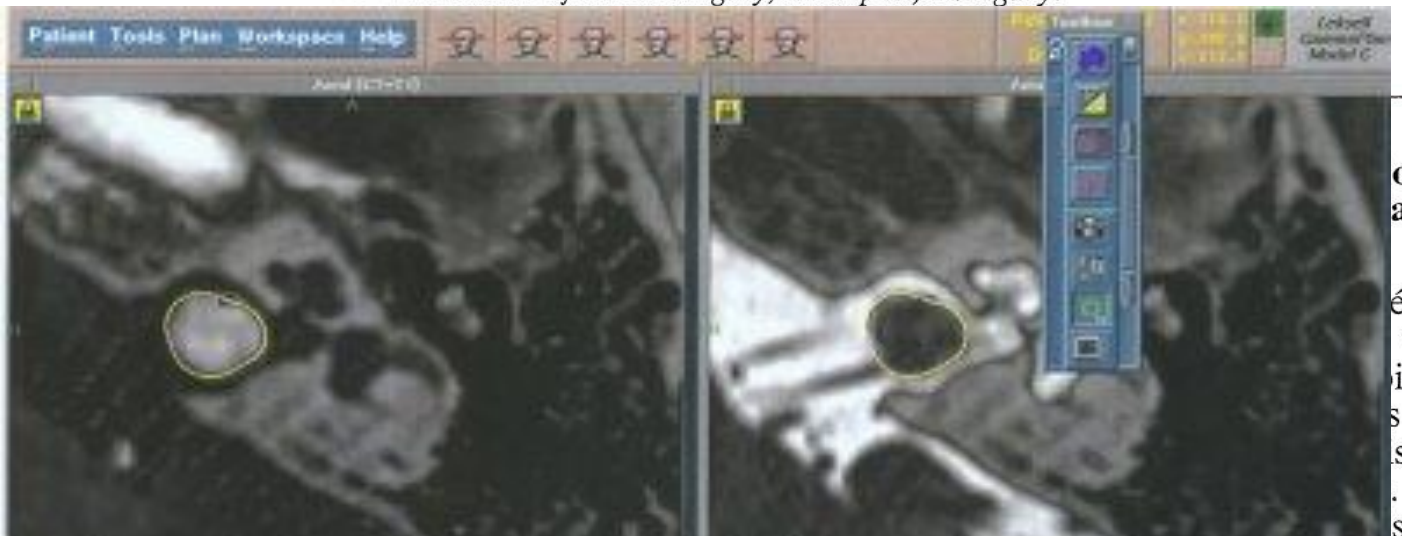
© Masson, Paris, 2004

Neurochirurgie, 2004, *50*, n° 2-3, 327-337

HISTOPATHOLOGICAL OBSERVATIONS ON VESTIBULAR SCHWANNOMAS AFTER GAMMA KNIFE RADIOSURGERY: THE MARSEILLE EXPERIENCE

G.T. SZEIFERT*, D. FIGARELLA-BRANGER, P.-H. ROCHE, J. RÉGIS

Centre Gamma Knife & Department of Pathology and Neuropathology, University Hospital La Timone, Marseille, France.
**National Institute of Neurosurgery, Budapest, Hungary.*



SUMMARY: **H** **ogiques des**
ular schwannon **adiochirurgie**
the Marseille ex

G. T. SZEIFERT ée comme un
CHE, J. RÉGIS (vestibulaires

Background an issant de pa-
a successful trea s de l'irradia-
vestibular schwa ssu tumoral
cades. Although . Cette étude
stopathologi-

A gamma-kés stereotaxiás sugársebészetről. Új korszak az agysebészetben

Szeifert György dr. és Nyáry István dr.

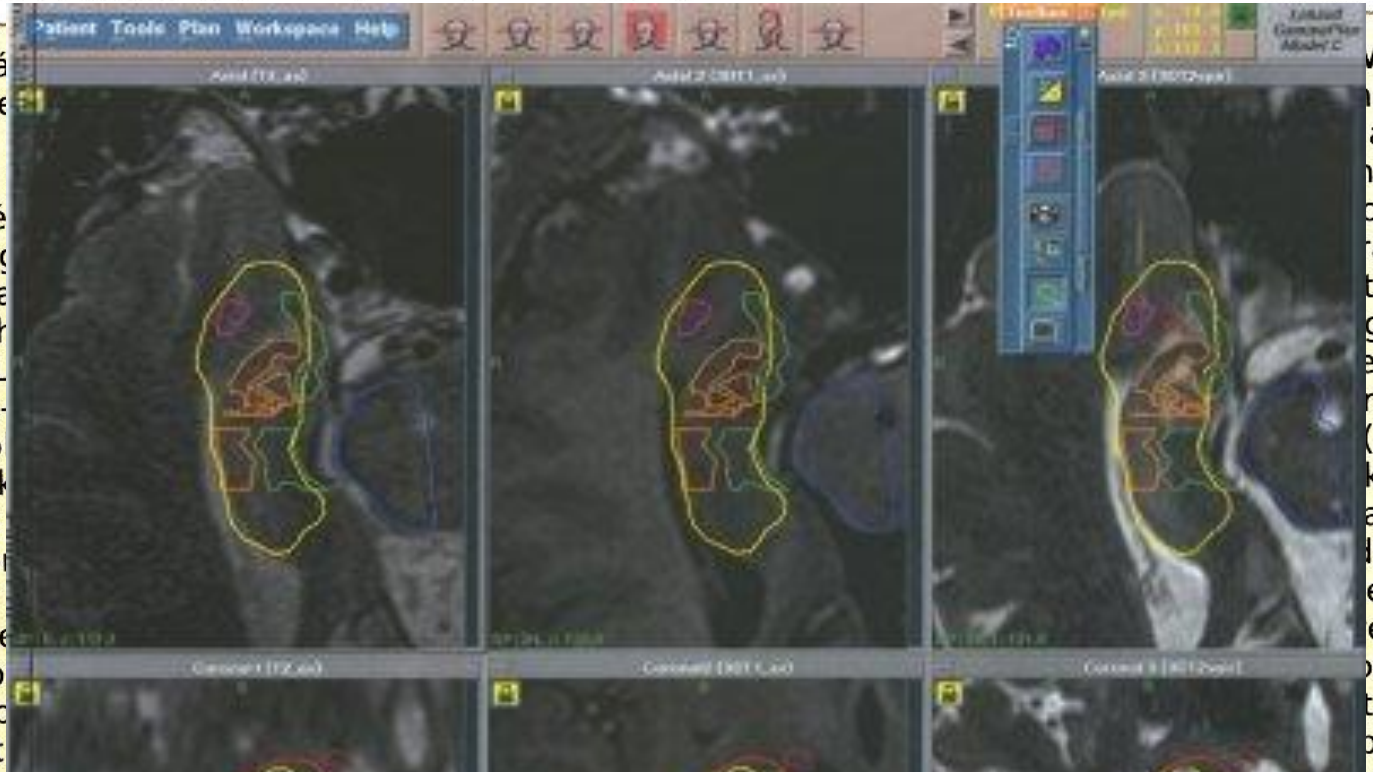
Országos Idegsebészeti Tudományos Intézet, Budapest (főigazgató főorvos: Nyáry István dr.)

A gam is a dedi-
kifejle y to treat
kopor gical tar-
agysz ging the
sugár- method
forrás biological
ionizá sed ioni-
mány rces. The
ben a us advan-
zelés y-related
szövő al effica-
tással, pital stay
műtét vas origi-
kezelé gical dis-
forma ions and
nyát. od, and a
Stockh in patho-
séget e was in-
teget then 85
nagy r patients
bízhat e simple
Mára nd beam
tárána effective
(pl. m . This re-
get m

Sugár agysebészet a XXI. század hajnalán: a gamma-kés C-modell automata pozícionáló robot rendszerrel*

Szeifert György dr.[1,2], Levivier, Marc dr.[2], Kondziolka, Douglas dr. [3], Lunsford Dade dr.[3], Brotchi, Jacques dr.[2] és Nyáry István dr.[1]

Országos Idegsebészeti Tudományos Intézet, Budapest (főigazgató: Nyáry István dr.)[1]
Centre Gamma Knife, Université Libre de Bruxelles, Hôpital Académique Erasme, Brüsszel, Belgium (igazgató: Jacques Brotchi dr.)[2]
Center for Image-Guided Neurosurgery, Presbyterian University Hospital, University of Pittsburgh, Pennsylvania, U.S.A. (igazgató: Dade Lunsford dr.)[3]



A stereotaxiá
normális sejte
fogat teljes
nagy dózisú
károsítása né
energiájú sug
fókuszálásáva
ka alkalmazh
(accelerator, L
és a gamma-
kés® (LGK) o
készített eszk
kül roncsolja
sát egy félgö
centrált, 201
sugarain kere
zül az LGK b
találati ponto
idegsebészet

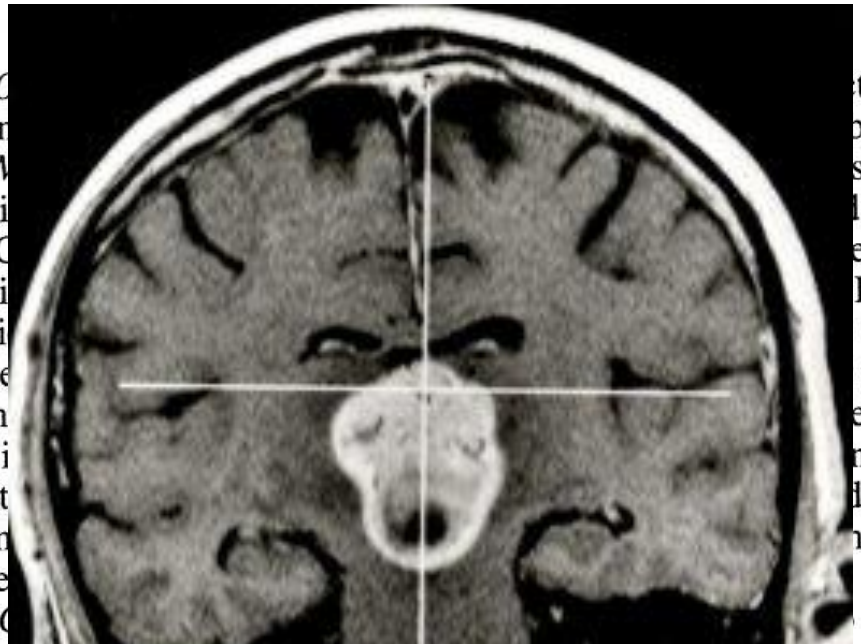
Model-C. The
ition is „the
allowing the
osen target
ological cells,
adiation da-
tained by the
gy radiation
ent techniqu-
r accelerator
(proton) the-
ksell Gamma
al device for
l intracranial
es via the ra-
ected, highly
obalt-60 sour-
target during
bout 0.3 mm,

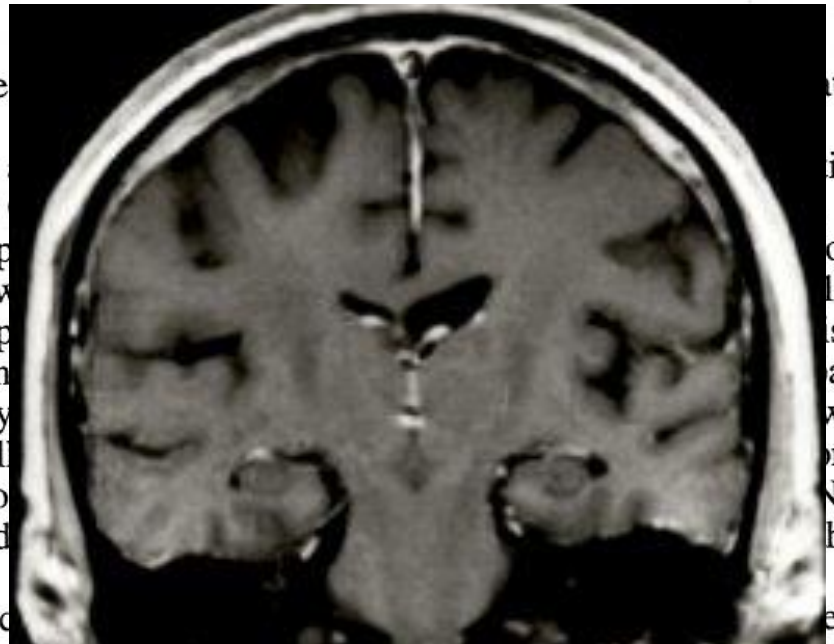
J Neurosurg 92:760–765, 2000

Gamma surgery for intracranial metastases from renal cell carcinoma

Bryan Rankin Payne, M.D., Dheerendra Prasad, M.D., György Szeifert, M.D., Ph.D., Melita Steiner, M.D., and Ladislau Steiner, M.D., Ph.D.

Lars Leksell Center for Gamma Surgery, Department of Neurological Surgery, University of Virginia, Charlottesville, Virginia



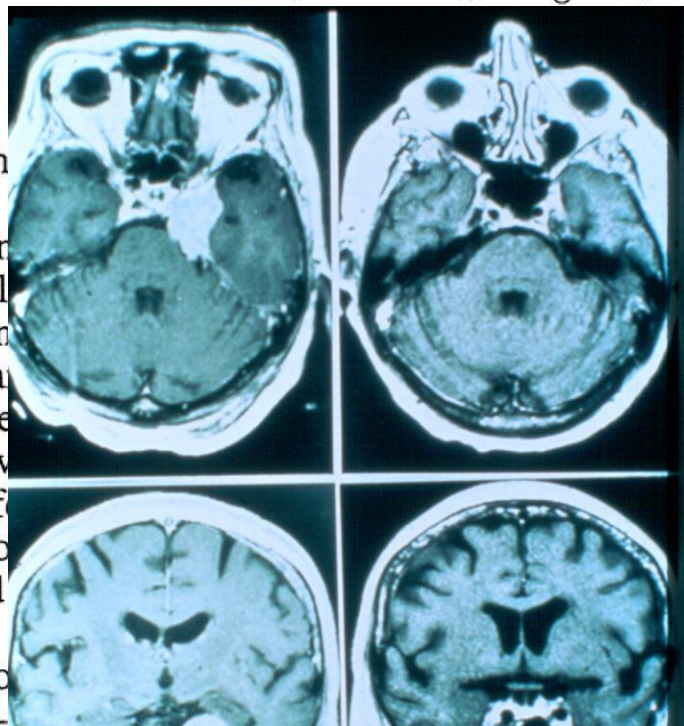


J Neurosurg (Suppl 5) 97:623–626, 2002

Observations of intracranial neoplasms treated with gamma knife radiosurgery

György T. Szeifert, M.D., Ph.D., Nicolas Massager, M.D., Daniel DeVriendt, M.D., Philippe David, M.D., Françoise De Smedt, M.S., Sandrine Rorive, M.D., Isabelle Salmon, M.D., Ph.D. Jacques Brotchi, M.D., Ph.D., and Marc Levivier, M.D., Ph.D.

Centre Gamma Knife, Hôpital Académique Erasme, Université Libre de Bruxelles, Brussels, Belgium; and National Institute of Neurosurgery, Budapest, Hungary



Kondziolka D (ed): Radiosurgery.
Basel, Karger, 2002, vol 4, pp 93–101

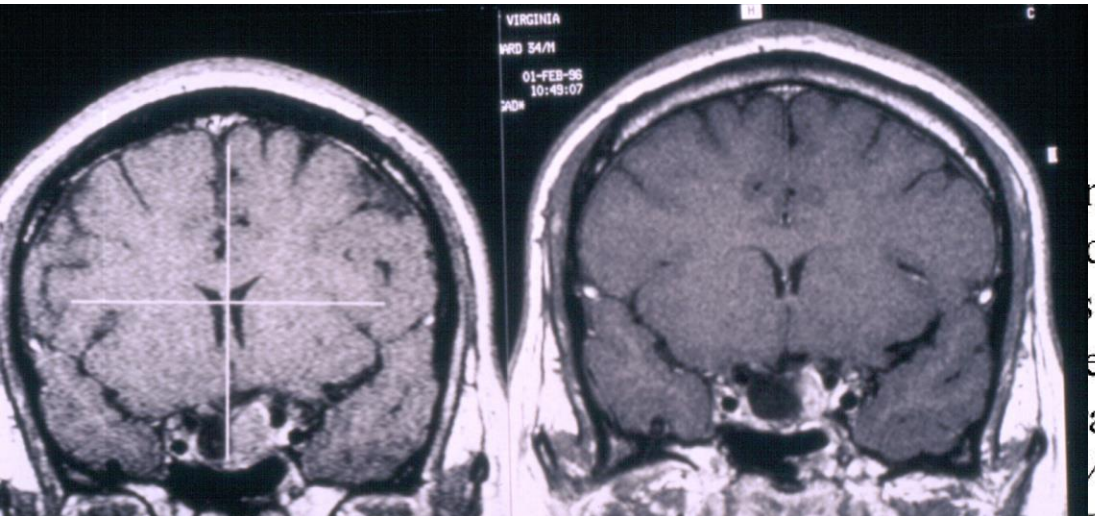
Dr György with many thanks for your work + delightful time in Hungary

12 May 2002

Gamma Knife Radiosurgery for Growth Hormone-Secreting Pituitary Adenomas

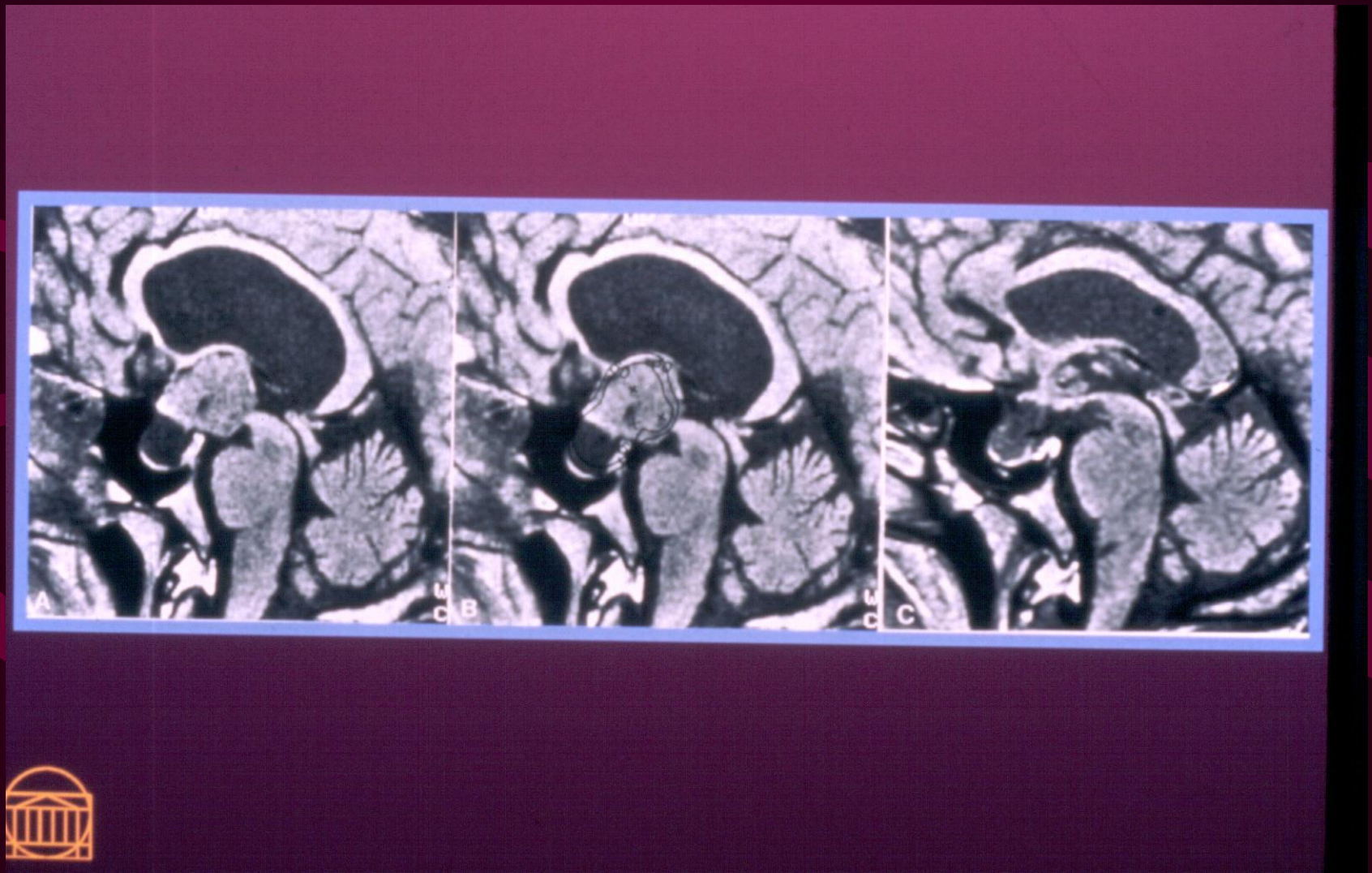
Ajay Niranjan, György T. Szeifert, Douglas Kondziolka, John C. Flickinger, Ann H. Maitz, L. Dade Lunsford

Departments of Neurological Surgery and Radiation Oncology, University of Pittsburgh Medical Center-Presbyterian, Pittsburgh, Pa., USA



ment for most patients
d as the primary choice
associated with acro-
edure usually results in
ate is low (ranges from
% in experienced hands

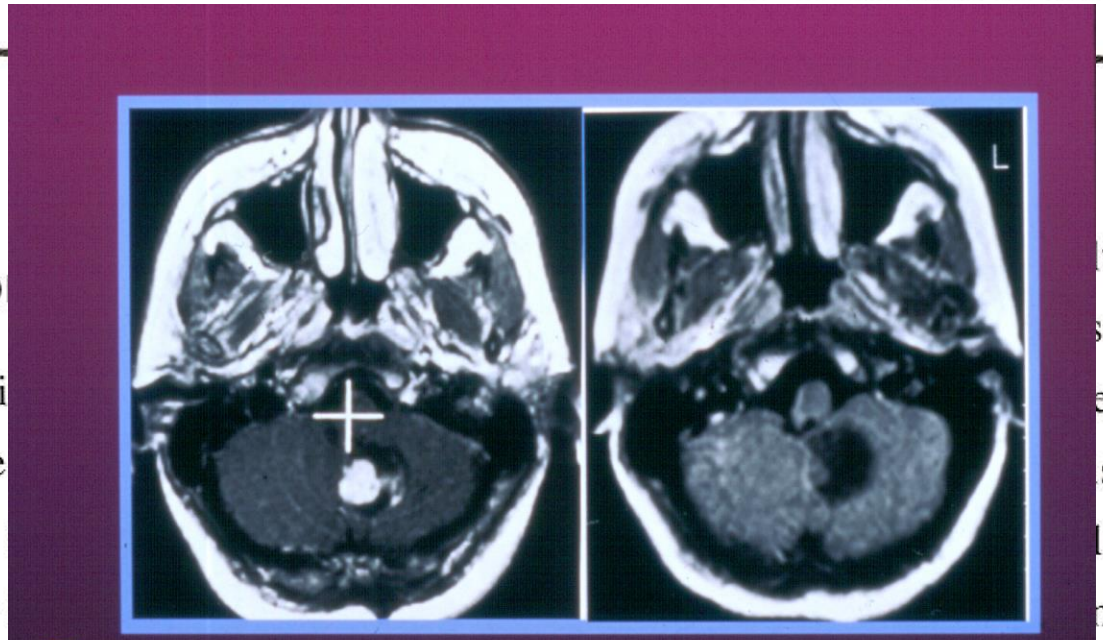
Craniopharyngeoma



〈教育講演〉

2. The Role of the Gamma Knife in the Treatment of Intracranial Astrocytomas

Lars Leksell Center for Gamma Knife Surgery, Department of Neurological Surgery,
The University of Virginia, U. S. A
György T. Szeifert, M.D., Ph.D., Dheerendra Prasad, M.D., Toshifumi Kamiryo, M.D.
Melita Steiner, M.D., Ladislau E. Steiner, M.D., Ph.D.

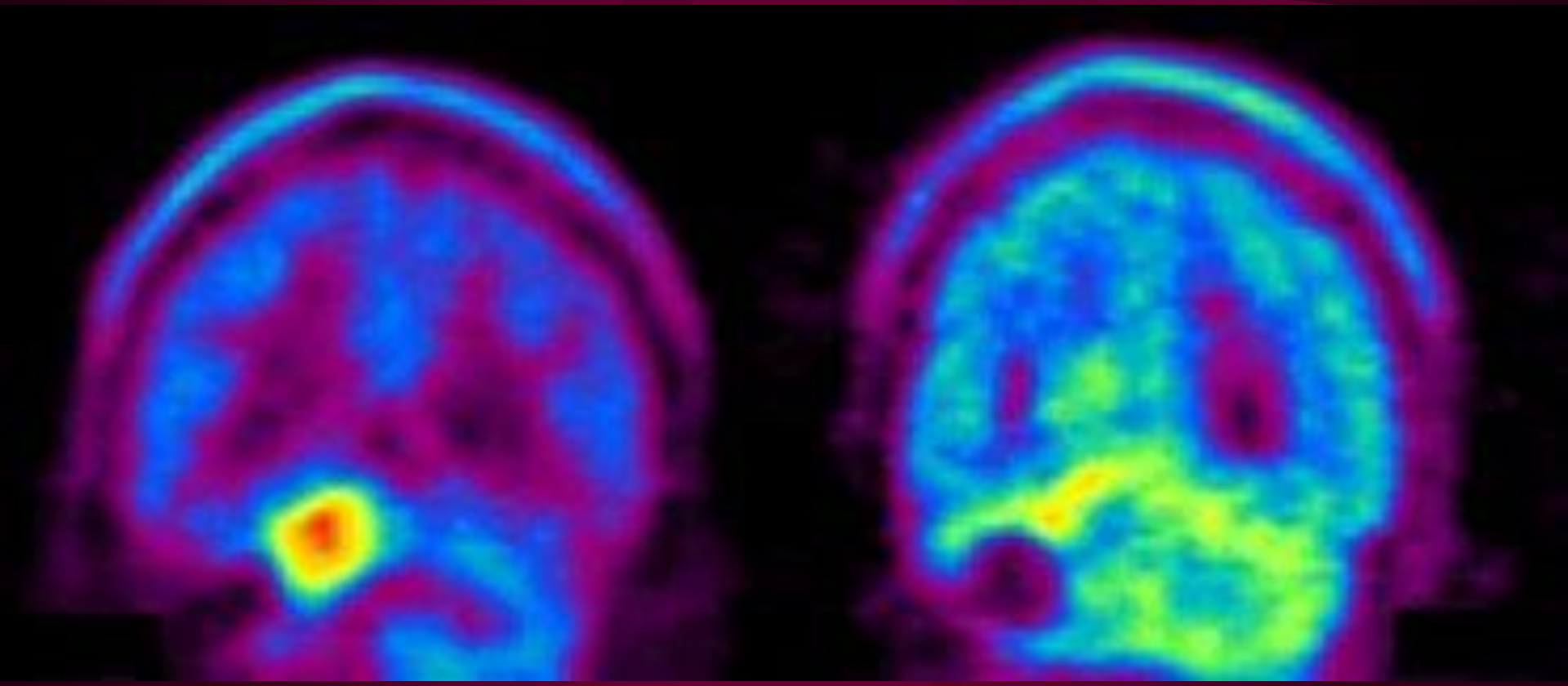


1. Introductio

The quest for the i
tomas is one of the
neurosurgeons and
fifty percent of the

trate the brain tissue
ss tumor margin. In
ectomy for glioblas-
solated in tissue cul-
lly normal part of the
mote migrating capa-

C-11 Methionine PET



What can we learn from pathology?

The pathological effect of radiosurgery on the CNS tissue

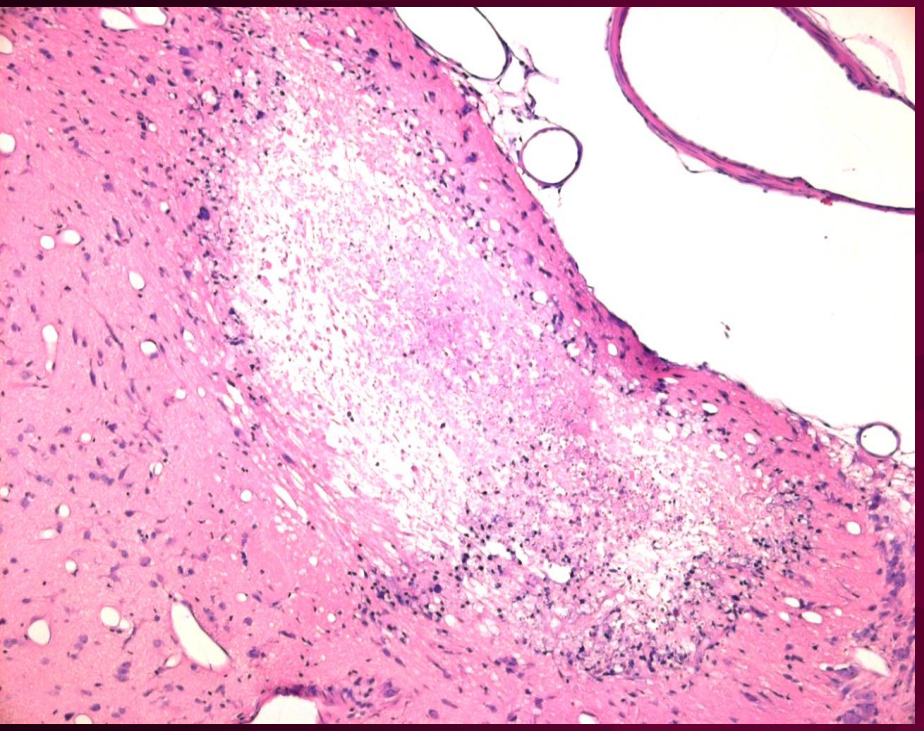
- Degenerative changes *(coagulation necrosis, hyaline degeneration, endothelial destruction, genetic modification, apoptosis,)*
- Proliferative changes *(granulation tissue formation, proliferation of glial cells, fibrocytes, fibroblasts, myofibroblasts, capillaries, inflammatory cells, collagen and glial fiber production)*

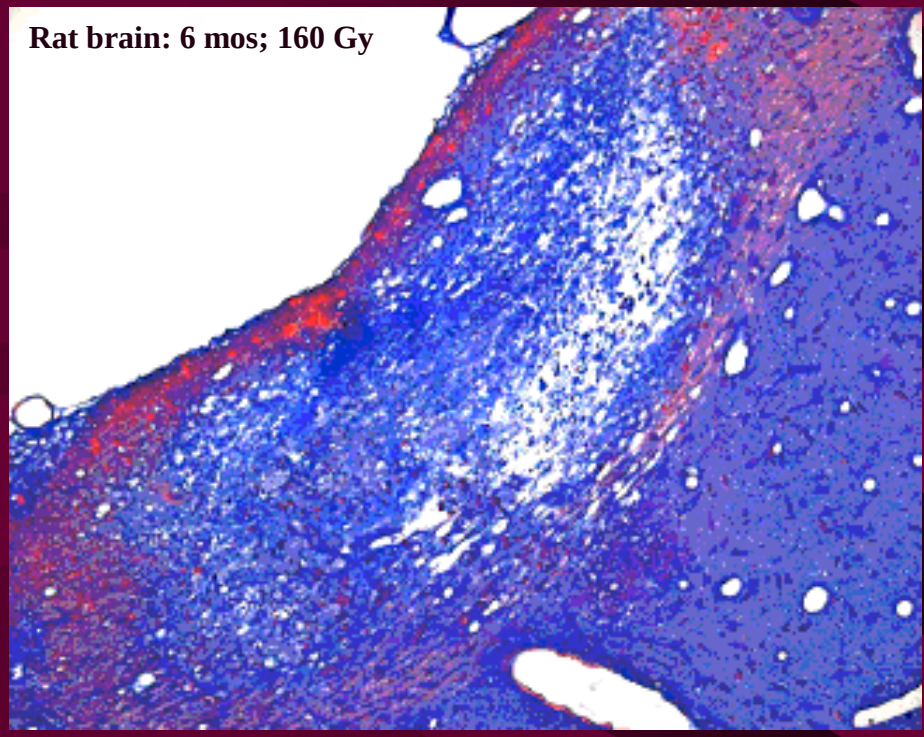
The basic histopathological lesion in radiosurgery

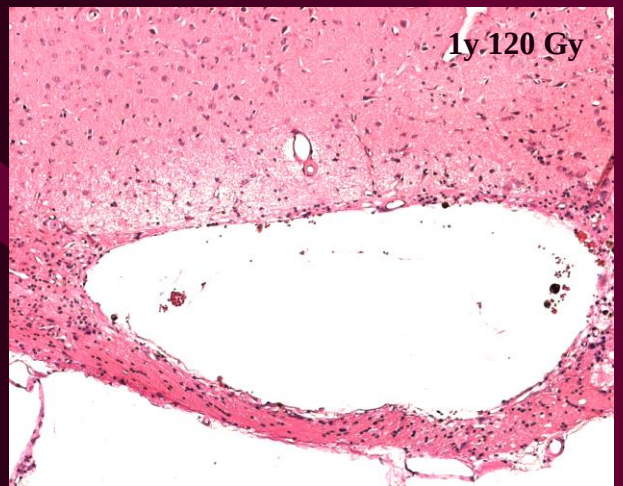
- **Larsson, Leksell** et al.: *The High-energy Proton Beam as a Neurosurgical Tool.* **Nature** 182; 1222-1223, **1958**.

- In animal experiments "*…with high-energy protons a sharply delimited lesion can be made at any desired site in the central nervous system.*"

Basic histopathological lesion in radiosurgery





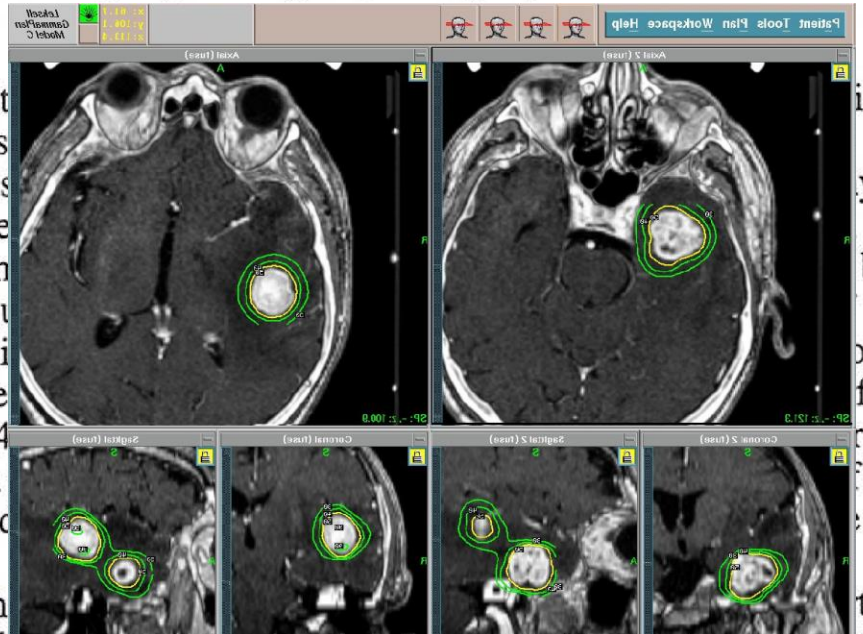


J Neurosurg (Suppl 5) 97:623–626, 2002

Observations of intracranial neoplasms treated with gamma knife radiosurgery

György T. Szeifert, M.D., Ph.D., Nicolas Massager, M.D., Daniel DeVriendt, M.D., Philippe David, M.D., Françoise De Smedt, M.S., Sandrine Rorive, M.D., Isabelle Salmon, M.D., Ph.D. Jacques Brotchi, M.D., Ph.D., and Marc Levivier, M.D., Ph.D.

Centre Gamma Knife, Hôpital Académique Erasme, Université Libre de Bruxelles, Brussels, Belgium; and National Institute of Neurosurgery, Budapest, Hungary



Object. The purpose of this st imaging findings in different tumors after gamma knife radios

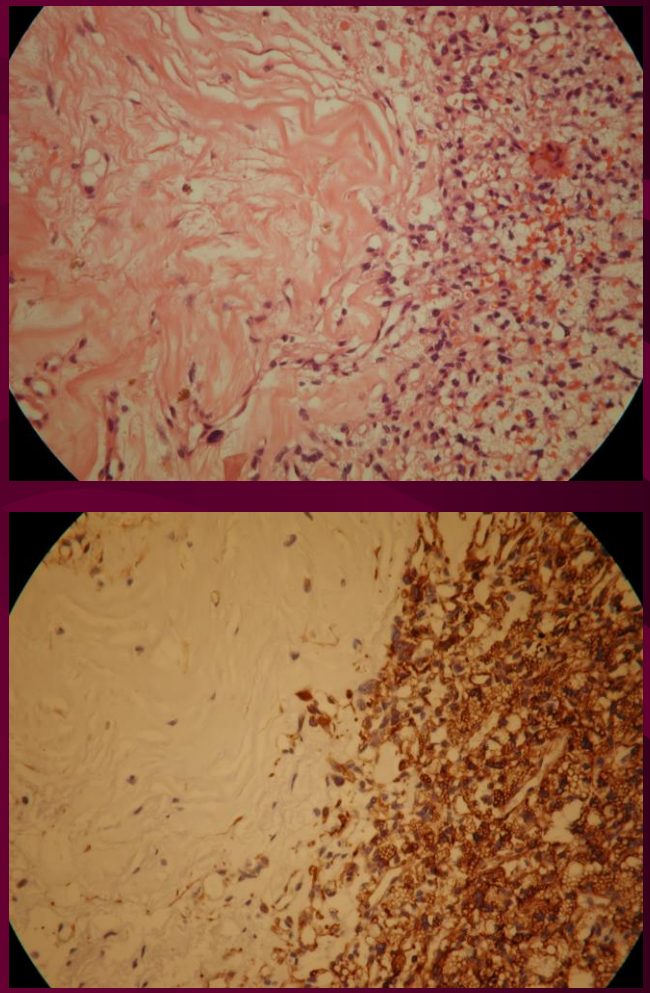
Methods. Five patients of a s y for tumor removal 3 to 12 months after radiosurgery. There one with vestibular schwannoma, one with malignant glion brain tissue outside the prescription dose volume was acqu the effects of radiosurgery. Histopathological and immunohi on to the routine hematoxylin and eosin and Mallory trichrome formed for Factor VIII–associated antigen (FVIII) and CD34 radiation.

Endothelial cells of vessels in the prescription isodose volume, expressed marked CD34 and samples, however, both reactions decreased remarkably.

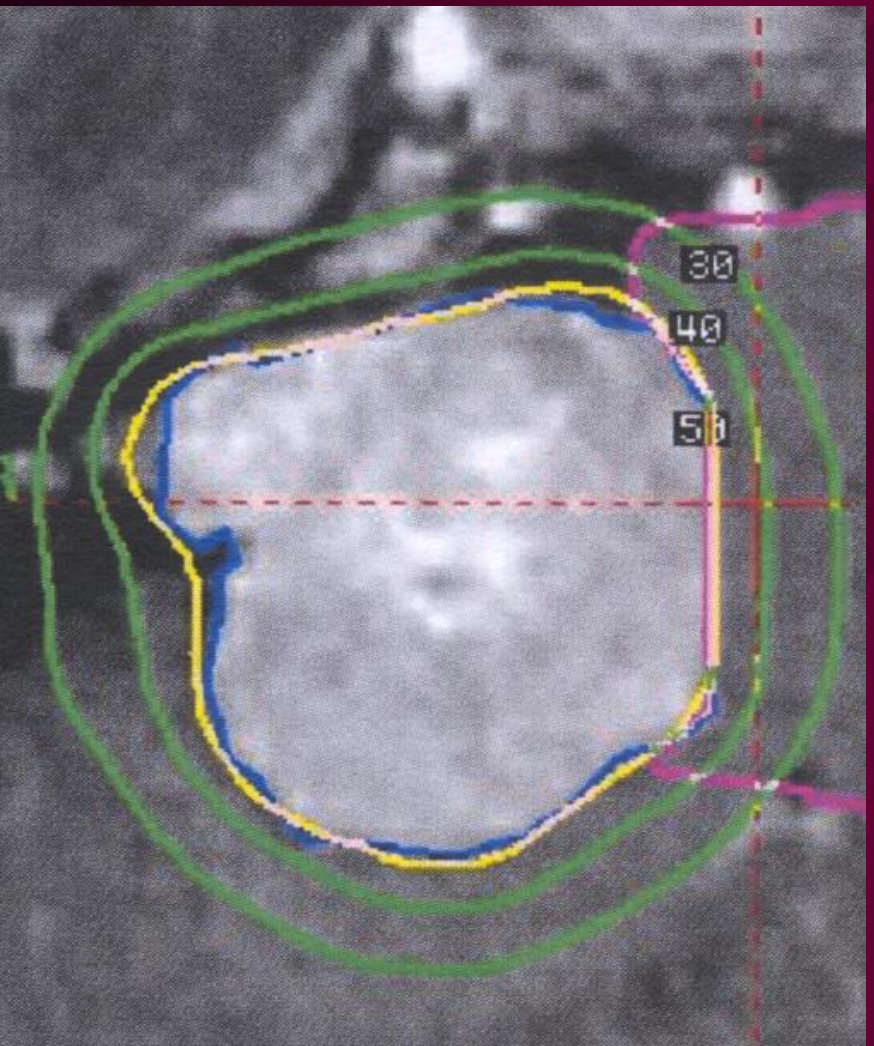
Conclusions. The results of th t to the experimental hypoth-

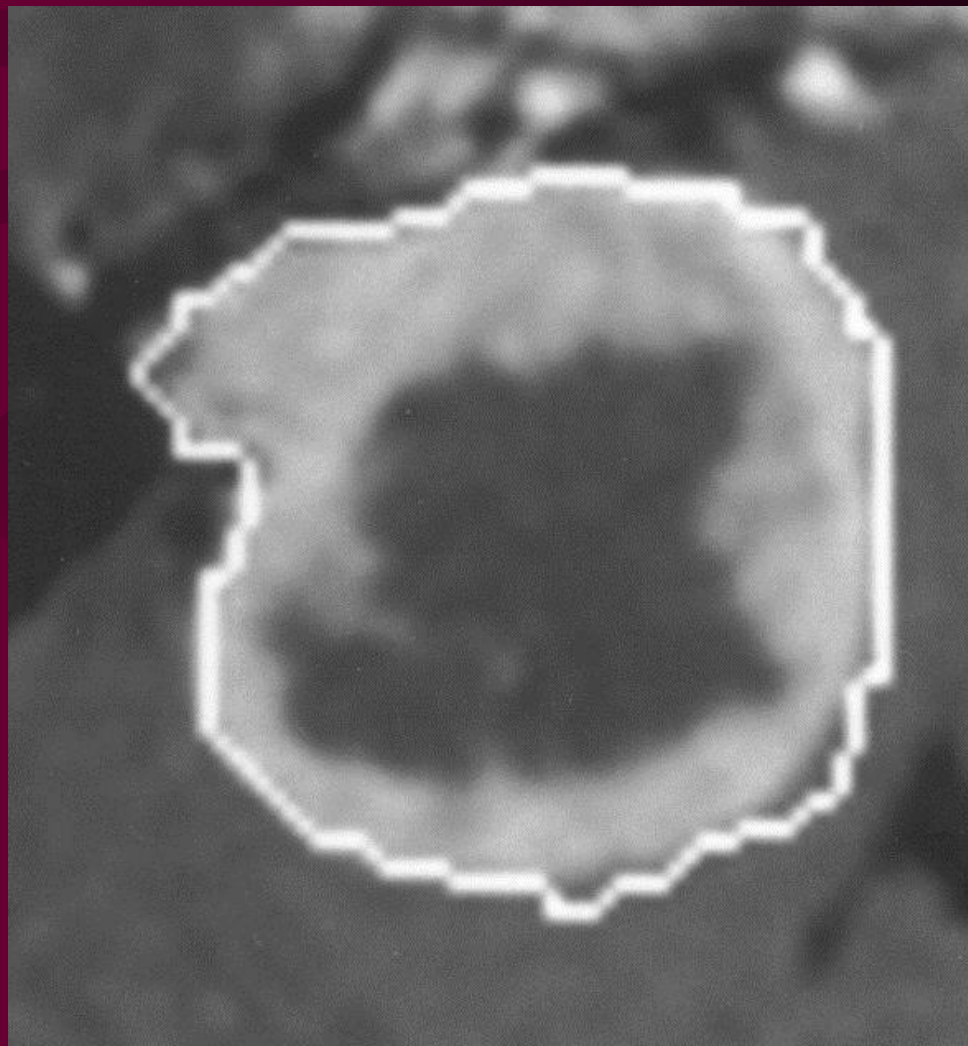
Coagulation necrosis created by high-dose irradiation

- Is within the target volume
- the boundary is distinct according to the sharp radiation fall- off
- does not change in time



Vestibular Schwannoma
(2,5 months after RS)



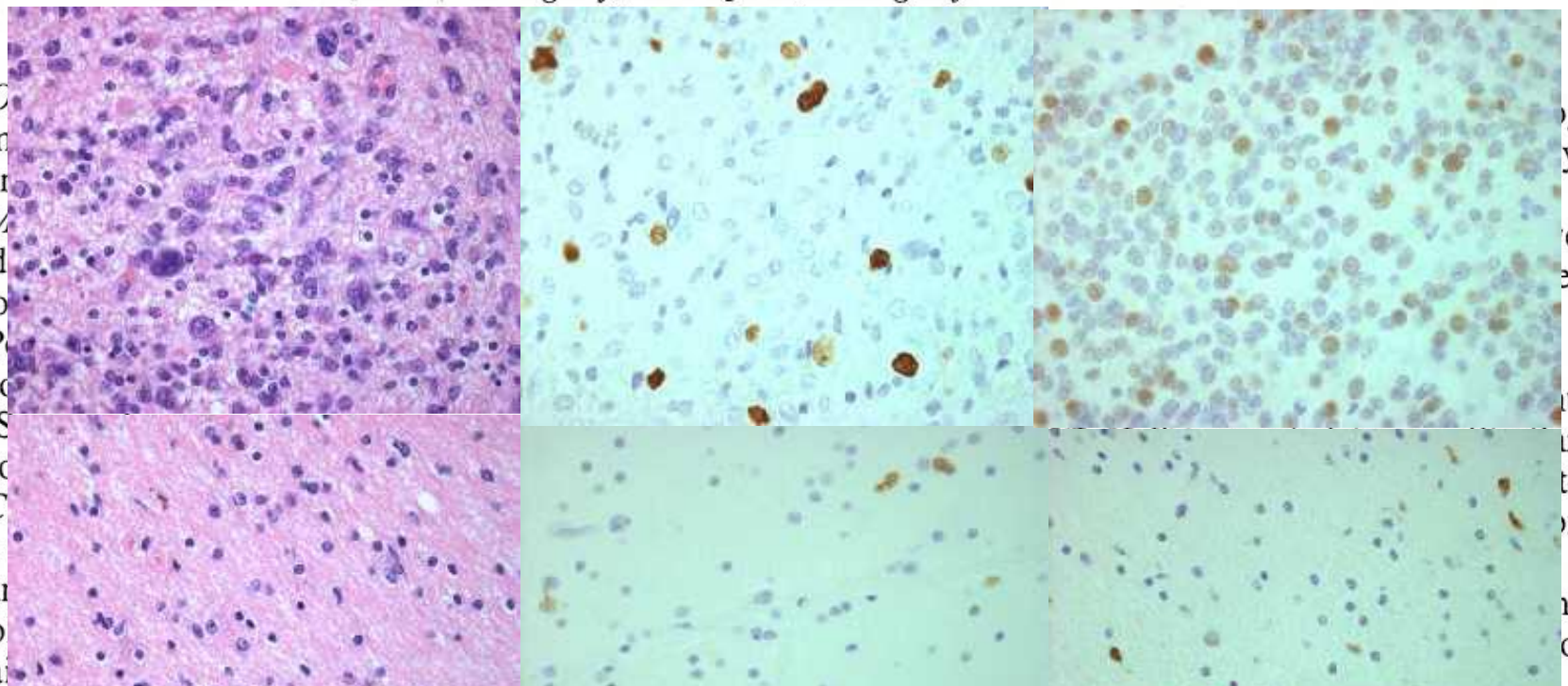


J Neurosurg (Suppl 5) 97:627–630, 2002

Morphological redifferentiation in a malignant astrocytic tumor after gamma knife radiosurgery

György T. Szeifert, M.D., Ph.D., Nicolas Massager, M.D., Jacques Brotchi, M.D., Ph.D., and Marc Levivier, M.D., Ph.D.

Centre Gamma Knife, Hôpital Académique Erasme, Université Libre de Bruxelles, Brussels, Belgium; and National Institute of Neurosurgery, Budapest, Hungary



C
imm
after
M
ined
befo
P
tumo
GKS
remo
C
tent
LI a
invo
repa

gical, and
ytic tumor

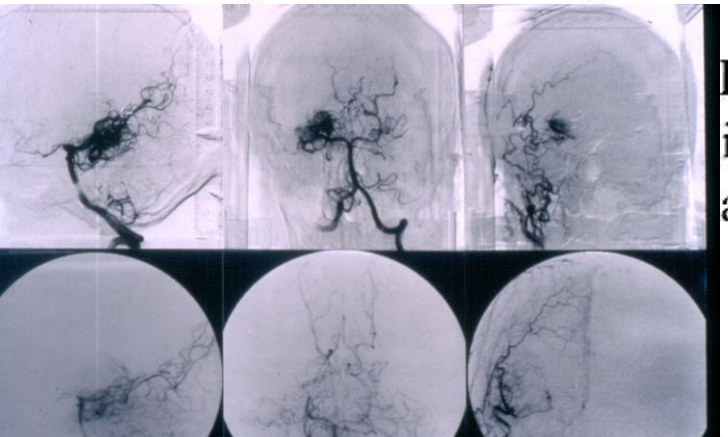
ere exam-
e obtained

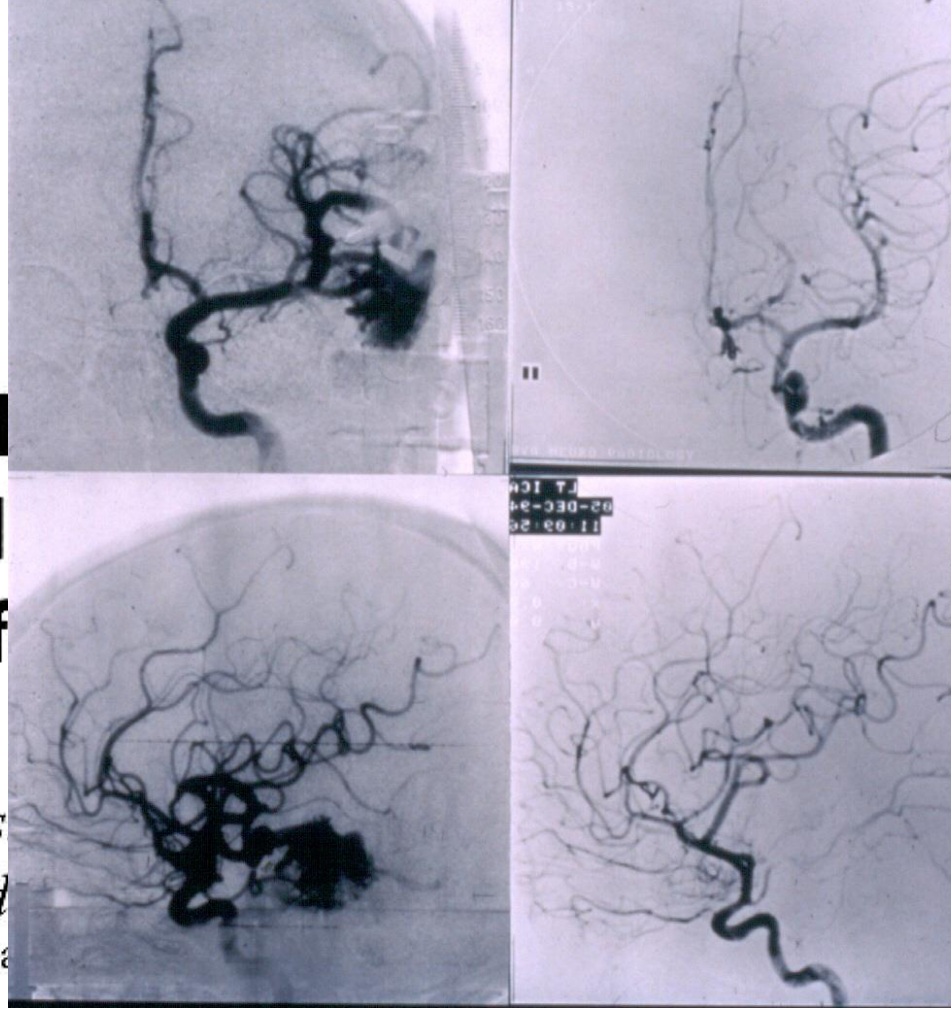
decreased
ths before
r material
ted tumor.
n) consis-
the Ki-67
ntial genes
ote partial

Kondziolka D (ed): Radiosurgery.
Basel, Karger, 2002, vol 4, pp 34–41

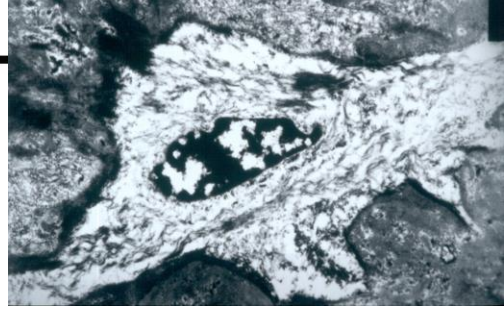
Recurrent Hemorrl
Radiosurgically Obl
Arteriovenous Malf

György T. Szeifert [a,e], *Bart Vanders*
Danielle Balériaux [c], *Georges Rod*
Jacques Brotchi [a,b], *Marc Levivier* [a]





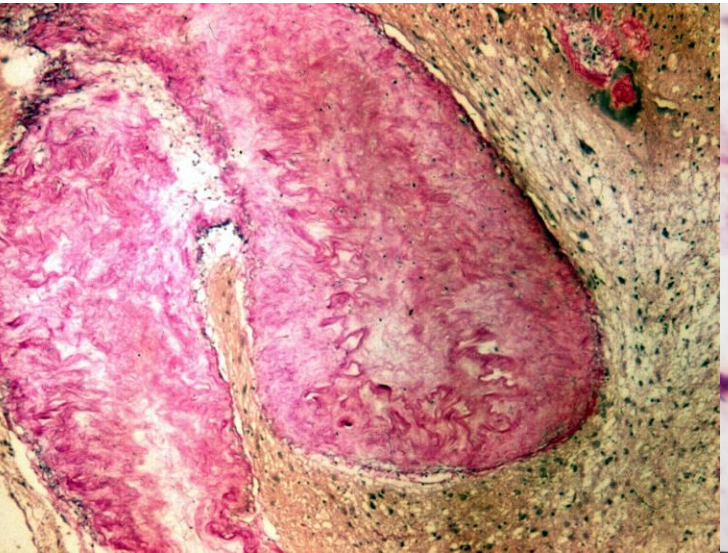
Departments of [b] Neurosurgery, [c] Neuroradiology and
iversité Libre de Bruxelles, Hôpital Académique Erasme,
al Institute of Neurosurgery, Budapest, Hungary

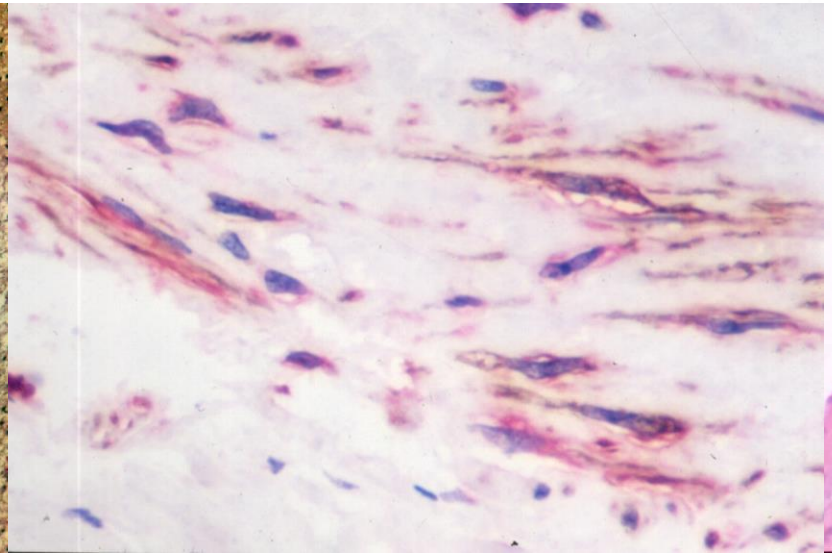


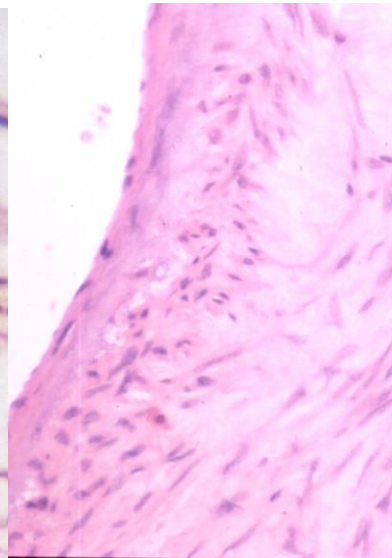
The Potential Role of Myofibroblasts in the Obliteration of Arteriovenous Malformations after Radiosurgery

György T. Szeifert, M.D., Andras A. Kemeny, M.D.,
Walter R. Timperley, M.A., D.M.,
David M.C. Forster, F.R.C.S.

Departments of Neurological Surgery (GTS, AAK, DMCF) and Neuropathology (WRT), Royal Hallamshire Hospital, Sheffield, England







Progress in Neurological Surgery
Vol. 20. Editor: L.D. Lunsford

Radiosurgery & Pathological Fundamentals

Editor
György T. Szeifert

Co-Editors
Douglas Kondziolka
Marc Levivier
L. Dade Lunsford

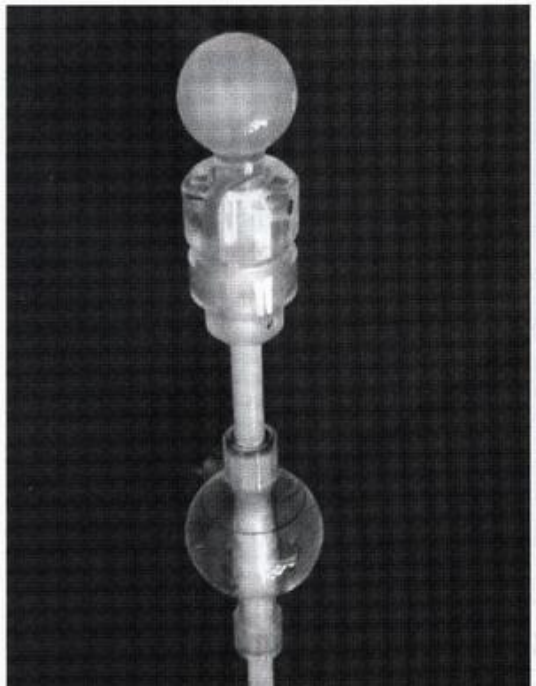
KARGER 2007

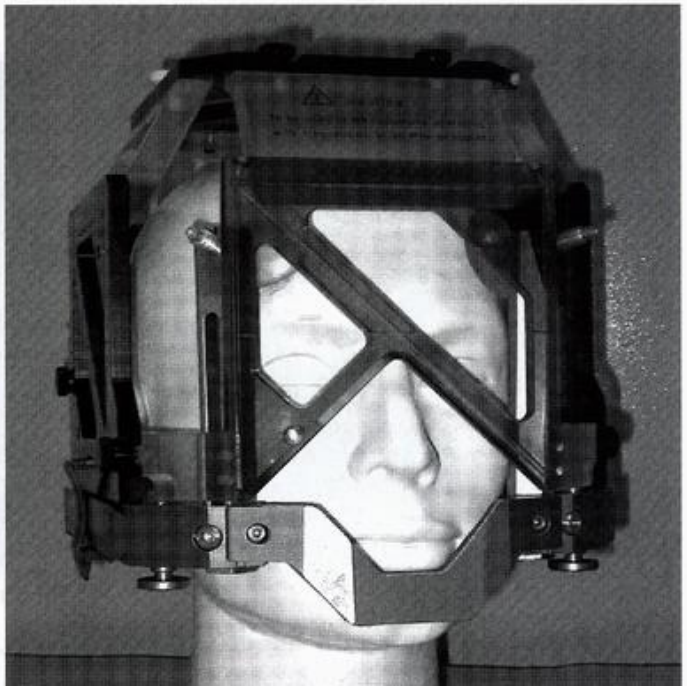
UPMC

- 3 Gamma Kés
- 1 CyberKnife
- 3 LINAC

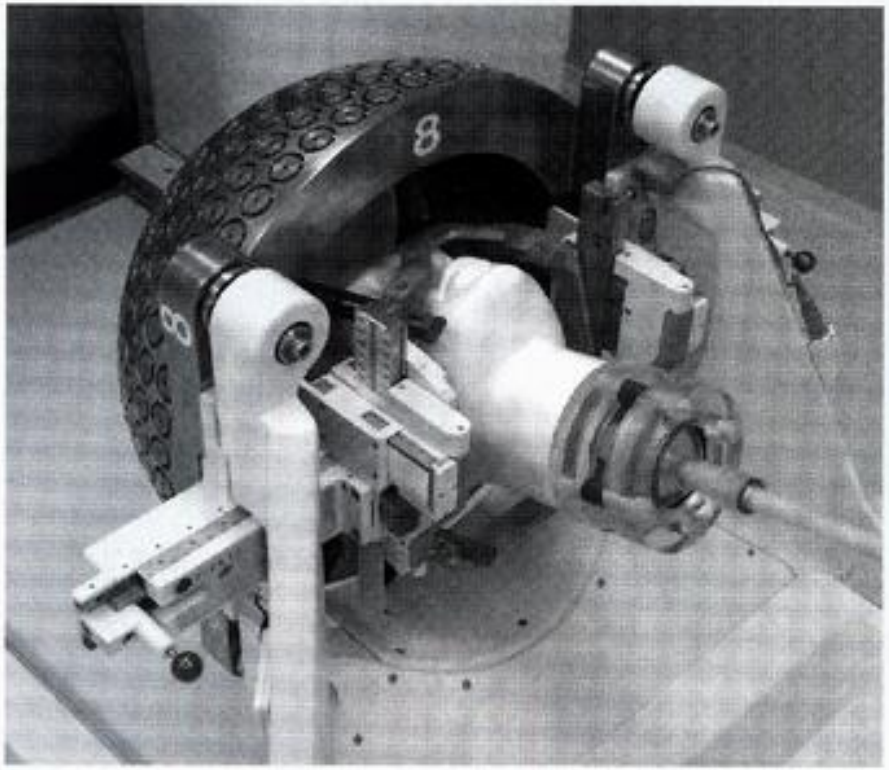
Dozimetria

Component	Formula	Weight fraction %
N,N′-methylene-bisacrylamide	$(CH_2CHCONH)_2CH_2$	3.0
Acrylic acid	$CH_2CHCOOH$	3.0
Sodium hydroxide	NaOH	0.3
Gelatin	$(C_{17}H_{32}N_5O_6)_X$	5.0
Water	H_2O	88.7

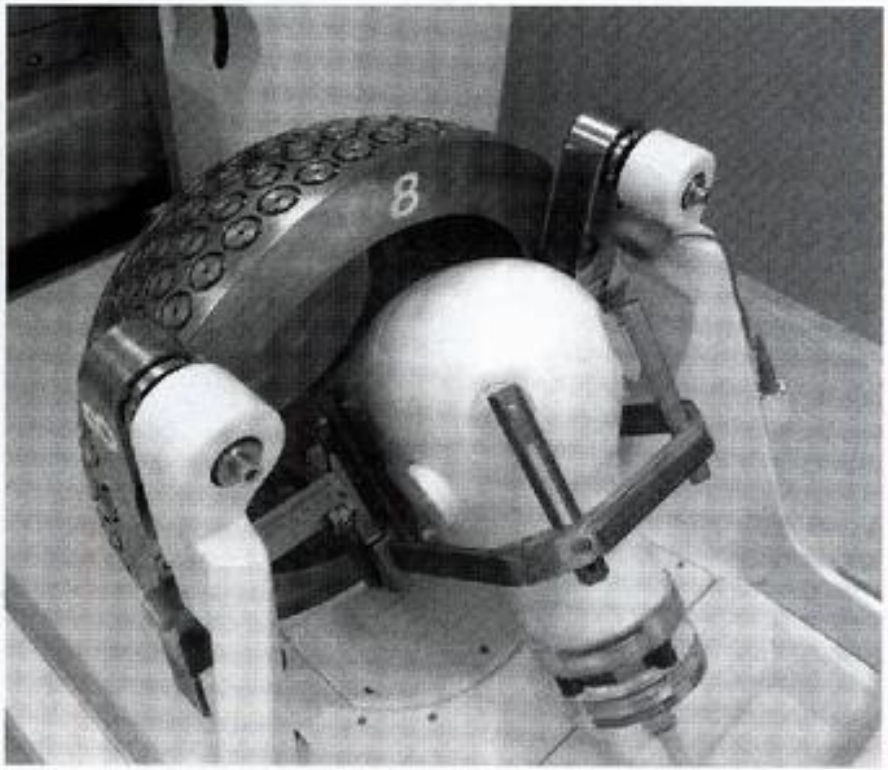




Dozimetria

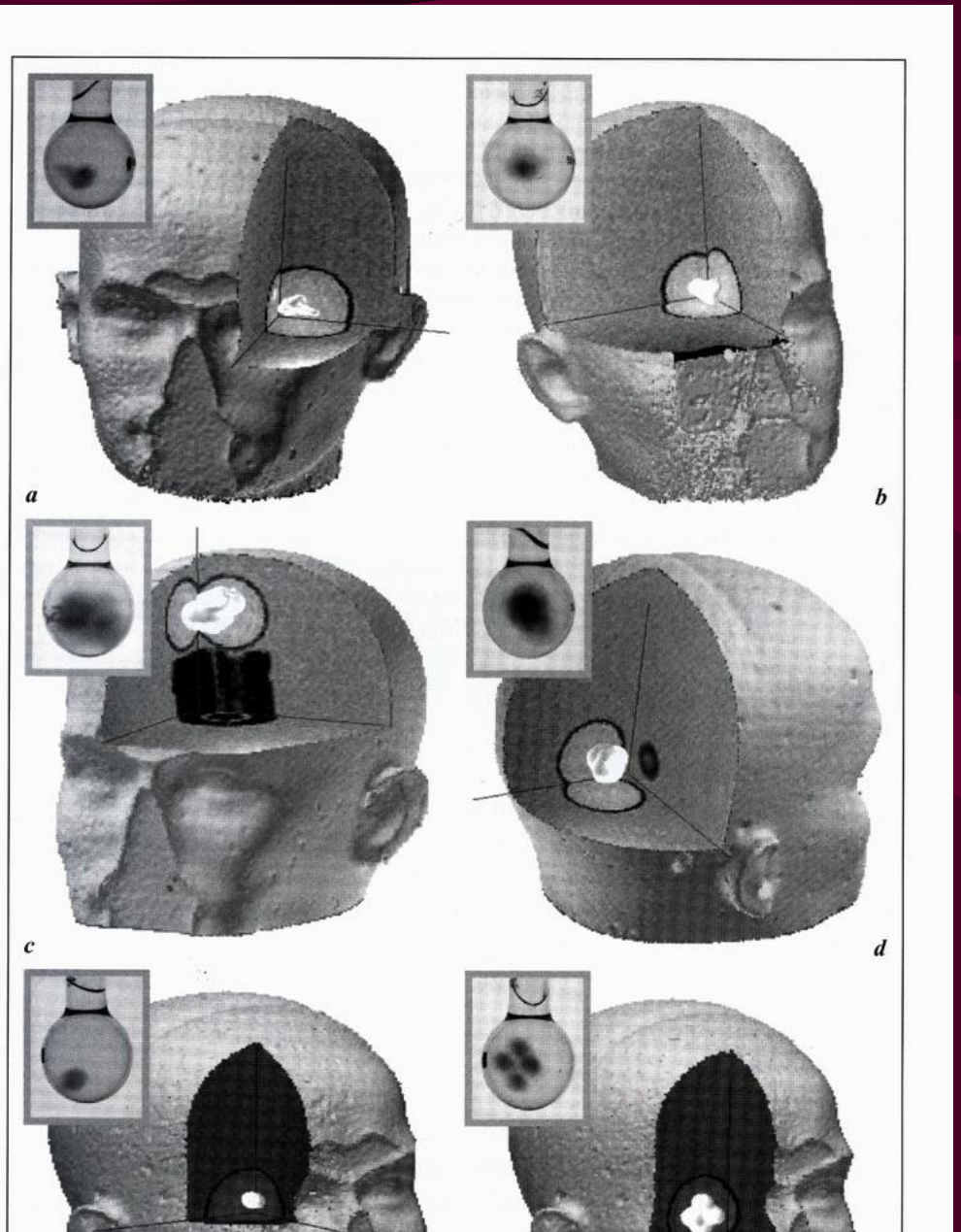


a



b

Dozimetria



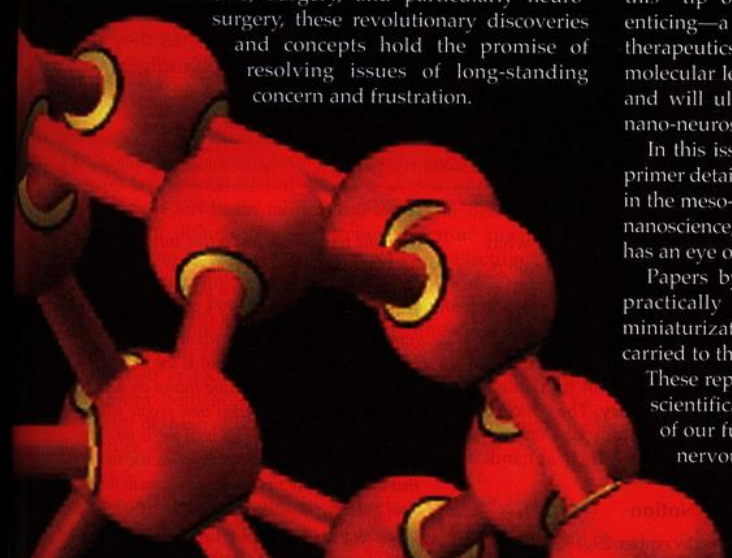
Nanotechnológia – nanoidegsebészet XXI. század

EDITOR'S LETTER

NANONEUROSURGERY: "THERE'S PLENTY OF ROOM AT THE BOTTOM."

nano- [fr. Gk *nanos*, dwarf]: one billionth (10^{-9}) part of. Merriam-Webster Dictionary.

Since its original conception in 1959 from the brilliant mind of Nobel Laureate and Caltech physicist Richard Feynman the idea of nanotechnology and its potential ramifications have held great fascination for many and has generated intense scrutiny in the scientific world (1, 2). Currently, what has been termed a "nanotechnology gold rush" is evident globally in the scientific, academic, and industrial sectors with thousands of laboratories generating data that hold great promise to initiate paradigm shifts in numerous important areas that will affect the lives of all individuals on our planet. For medicine, surgery, and particularly neurosurgery, these revolutionary discoveries and concepts hold the promise of resolving issues of long-standing concern and frustration.



Nanotechnology, with its implications for molecular manufacturing, and the utilization of nanomachines at the atomic level, in a practical sense, is clearly a vision for the future, but nanoscience is a robust field today. Advances are emerging daily which are creating a solid foundation for the later realizations of the "impossible." The definition of possibilities and physical/chemical events in the mesoscale world between the atomic and macro realms of every day existence are being realized. Currently it is apparent that much if not most of the body of knowledge that will allow practical application is in our future. But this "tip of the iceberg" is undeniably fabulous and enticing—a new world of possibilities for diagnostics, therapeutics and preventative interventions at atomic and molecular levels are clearly within the realm of possibility and will ultimately be a practical reality in the lives of nano-neurosurgeons.

In this issue of **NEUROSURGERY,** Leary et al. present a primer detailing principle information that has been accrued in the meso- and nanoscale realms that relate to the topic of nanoscience, an important area for each neurosurgeon who has an eye on the future of our specialty (2).

Papers by Muldoon et al. and Stretavan et al. detail practically relevant issues in this same theme of miniaturization, as the concept of minimal invasion is carried to the ultimate (3, 4).

These represent an emerging foundation of concept and scientifically relevant data that will eventually shape all of our futures in dealing with surgical disorders of the nervous system.

Michael L.J. Apuzzo
Los Angeles, CA

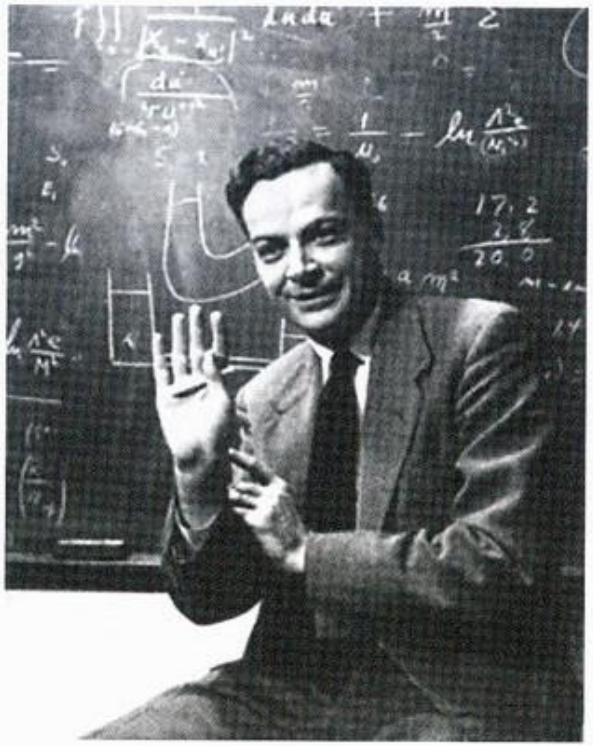


FIGURE 1. *Physicist Richard Feynman.*

Nanoidegsebészet

TOPIC REVIEW

TOWARD THE EMERGENCE OF NANONEUROSURGERY: PART I—PROGRESS IN NANOSCIENCE, NANOTECHNOLOGY, AND THE COMPREHENSION OF EVENTS IN THE MESOSCALE REALM

Scott P. Leary, M.D.
Department of Neurological Surgery,
Keck School of Medicine,
University of Southern California,
Los Angeles, California

Charles Y. Liu, M.D., Ph.D.
Department of Neurological Surgery,
Keck School of Medicine,
University of Southern California,
Los Angeles, California
Division of Chemistry and Chemical Engineering,
California Institute of Technology,
Pasadena, California

Cheng Yu, Ph.D.
Department of Radiation Oncology,
Keck School of Medicine,
University of Southern California,
Los Angeles, California

Michael L.J. Apuzzo, M.D.

Since its original conception in 1959, the notion of nanotechnology and its potential ramifications have not only created fascination, but also intense scientific effort and scrutiny. Currently, research activities are being principally conducted in mesoscale, the realm between nanoscale and macroscale, with the rudiments of nanoscience being defined in realities and principles that will determine activities and discoveries in the future. This paper reviews and discusses the evolution of nanoscience, its contemporary status, and the discoveries that currently constitute the main components of the body of knowledge from a neurosurgical perspective. Specific attention is given to the developments in imaging, fabrication, nanostructures, nanoelectromechanical systems, molecular manufacturing, nanocomputation, and emerging physical and chemical concepts in mesoscale, as they will establish foundations for the realization of nanomedicine and nanoneurosurgery.

KEY WORDS: Nanoscience, Nanotechnology, Mesoscale, Nanofabrication, Nanoelectromechanical systems, Molecular manufacturing, Nanocomputation, Nanomedicine, Nanoneurosurgery

Neurosurgery 57:606-634, 2005 DOI: 10.1227/01.neu.0000181533.17956.f9 www.neurosurgery-online.com

A paradigm shift is occurring with what has been termed the "nanotechnology

it might tell us much of great interest about the strange phenomena that occur in complex

Köszönöm a figyelmüket!

- *“The reasonable man adapts himself to the world, the unreasonable one persists in trying to adapt the world to himself. Therefore all progress depends on the unreasonable man.”*

  George Bernard Shaw (1856-1950)