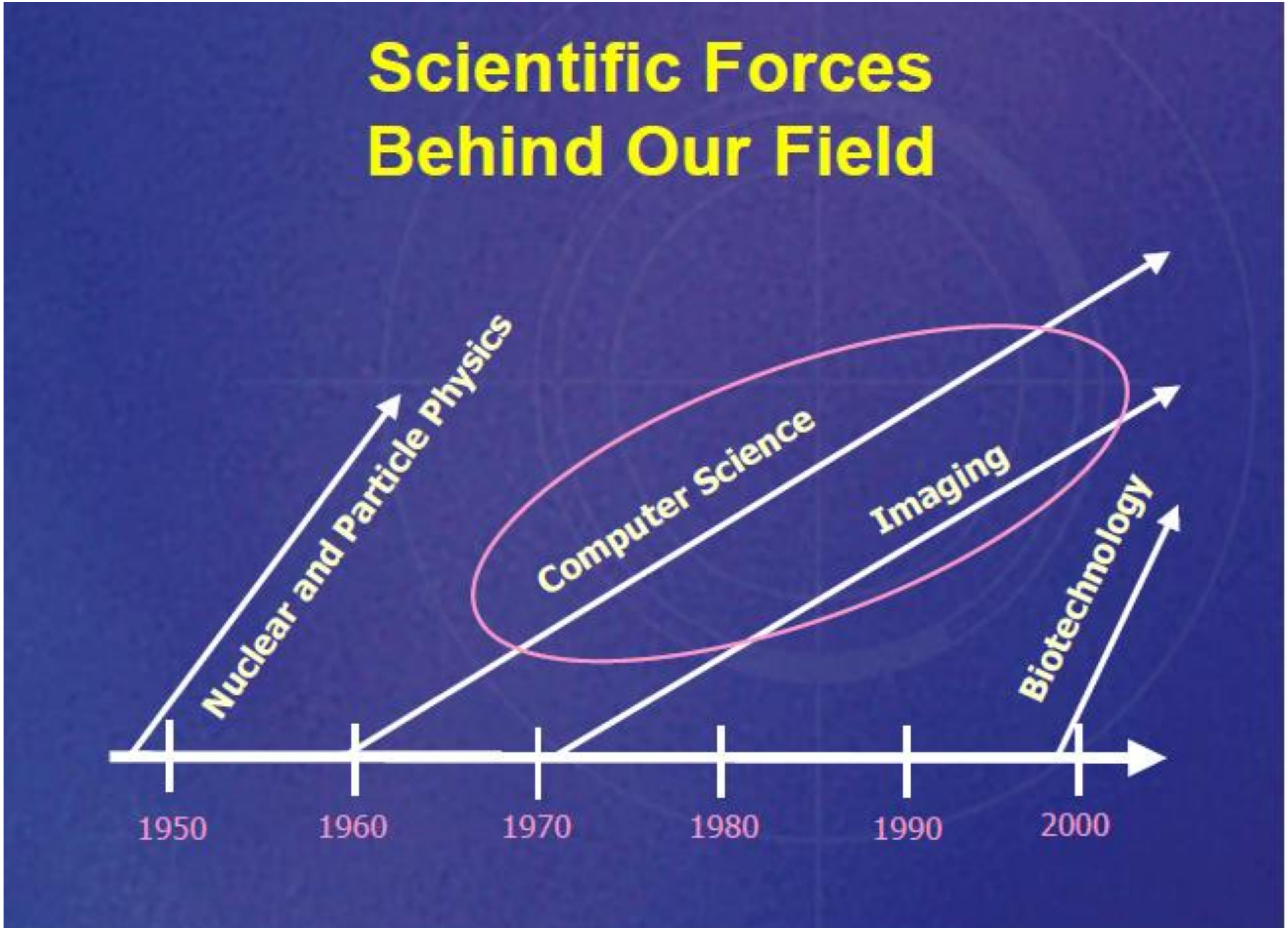
Use of Computers in External Beam Radiotherapy Procedures with High Energy Photons and Electrons

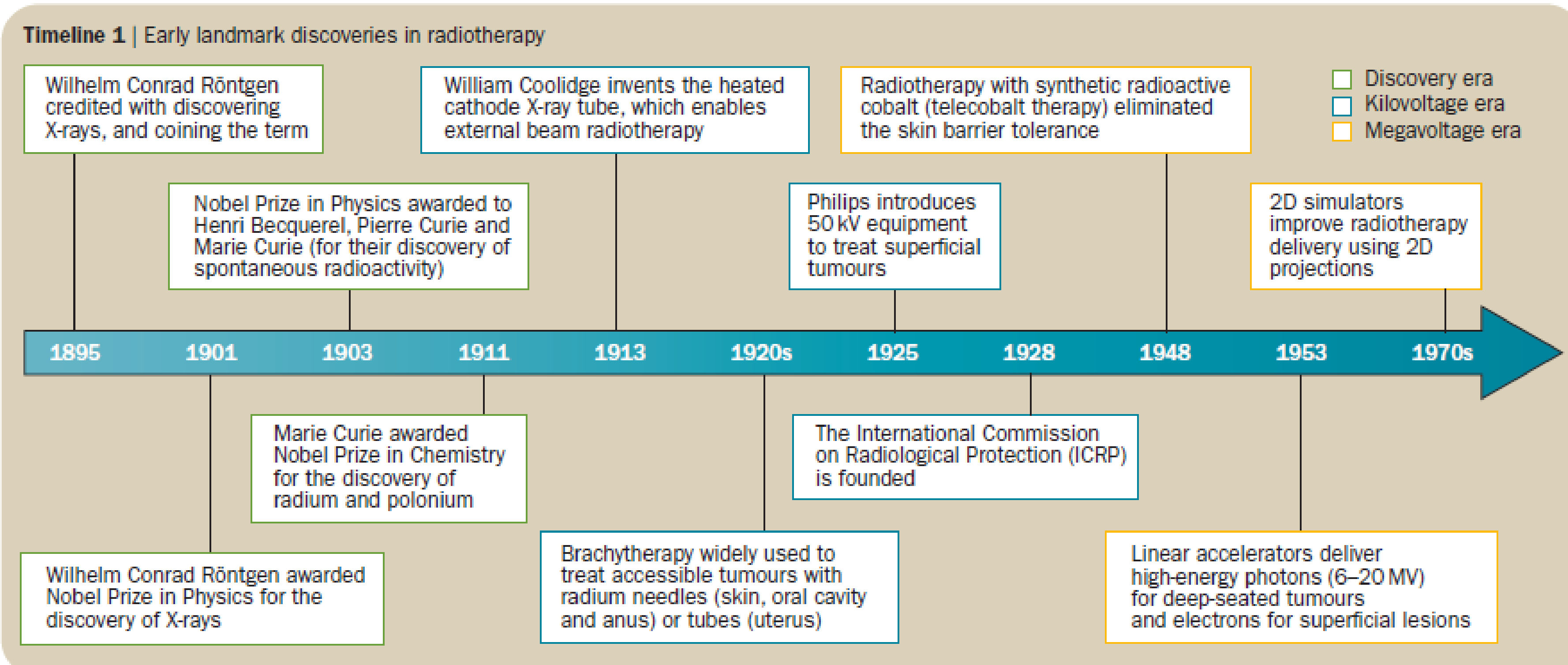
Dr Susovan Banerjee

Medanta The Medicity , Gurgaon.



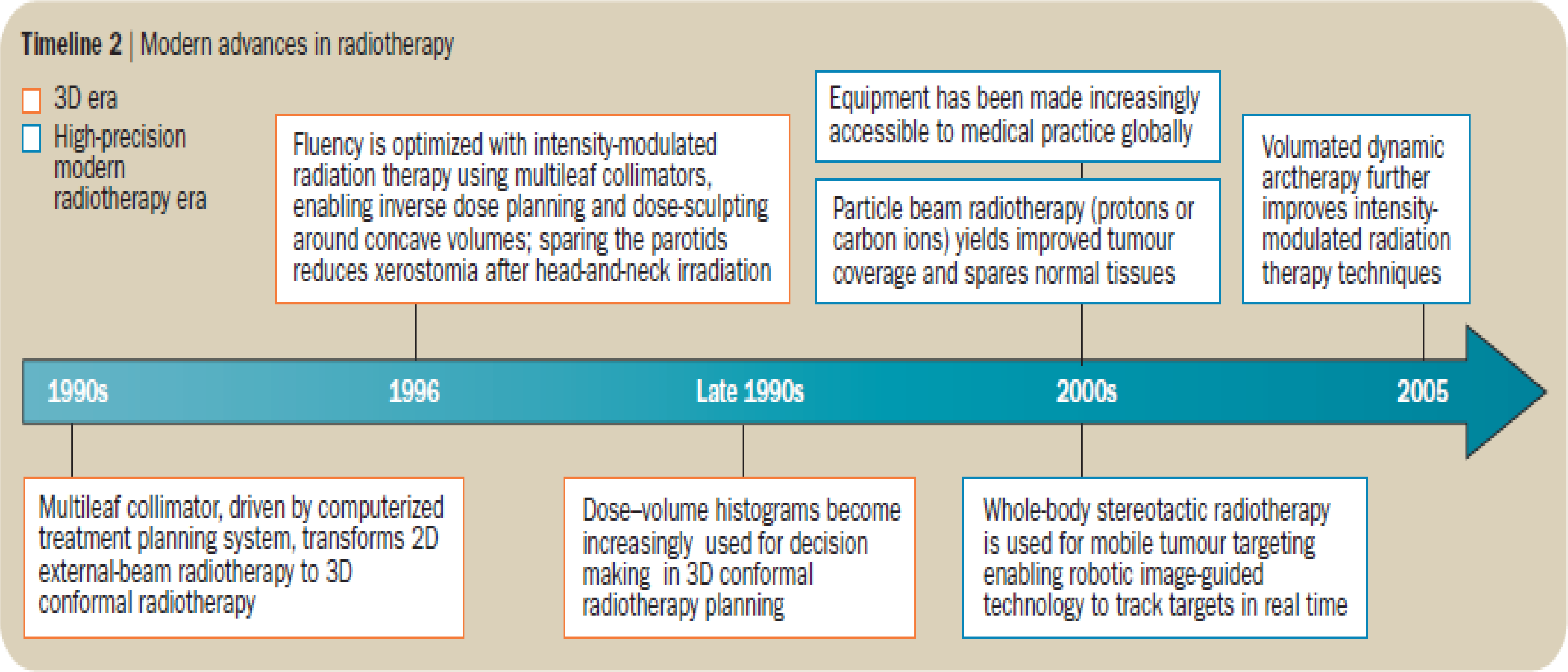
Slide from Prof **Thomas Rockwell Mackie(Advances in Radiotherapy)**

Advances in Radiotherapy(pre computer era)



Slide from Dr *Juliette Thariat*

Computer-assisted 1996–2012

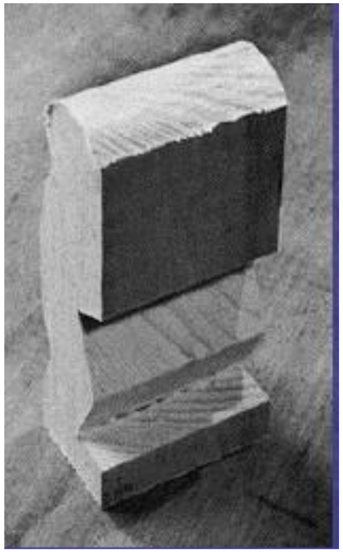


Advancements in Radiation therapy along with computers

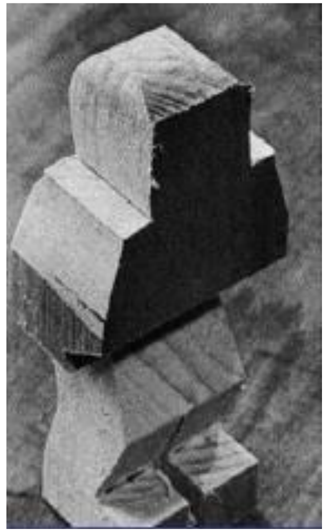
- 3D conformal radiotherapy.
- Hounsfield's invention of CT scans in 1971 .
- Use of computers in radiotherapy planning.
- Better radiation dose distributions.
- The introduction of multileaf collimators.
- Computerized algorithms and the new TPS.
- providing beam-eye-views, rapidly revolutionized radiotherapy.
- Delivery of radiotherapy dose accurately with dose sculpting in 3D onto target volumes and avoiding OAR.
- Cumulative data on clinical tolerance and dose–effect correlations.
- Allowed the definition of specific tolerance doses of OAR using dose–volume histograms.
-

The need of computers continues to grow in Radiotherapy………

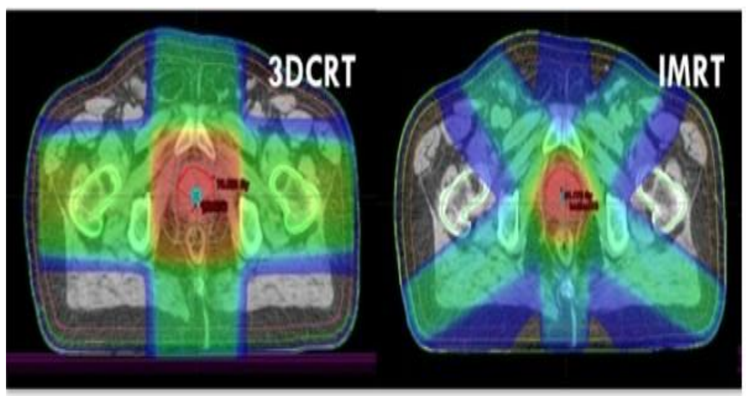
2 D planning

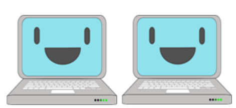


3 D planning

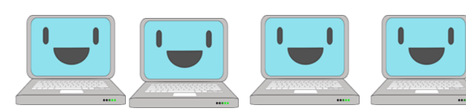


IMRT planning





4 D planning



Timeline of Computers in Radiotherapy

1960s-first use of computers for radiotherapy. Use of mainframe’ computers (probably at a university).
Used for calculating isodose distributions, replacing laborious manual calculations

Late 1970s- first use was made of CT data for RT planning.

Networking technology became available, computers connected directly together. However, CT scanners still used different file formats.

1980s-first record and verify systems appeared, transmit plans from the planning computer to the record and verify system

1985, the American College of Radiology and the National Electrical Manufacturers Association created a standard for medical images called ACR-NEMA.

1991, the standard was developed to specify how systems should communicate directly.- ‘Digital Imaging and Communication in Medicine’, or DICOM 3.0.

1990s- Computer driven of multileaf collimators , electronic portal imaging devices were developed.

At the turn of the millennium, radiotherapy centers were filled with computer systems transferring data- led to the recent development of radiotherapy, or oncology, information systems.

WHAT IS IT ALL ABOUT?

Data

The computer takes analogue data, converts them into digital bits (0 & 1), using *software programs* to provide speed and precision.
The computers role now includes Pervasive Computing and the new bride of the computing world, the Internet of Things(IoT, anything can be connected and communicate in an intelligent fashion)

Modified slide of **Victor EKPO, medical physics**

Computers help with:

- **Speed**
- **Automation**
- **Accuracy**

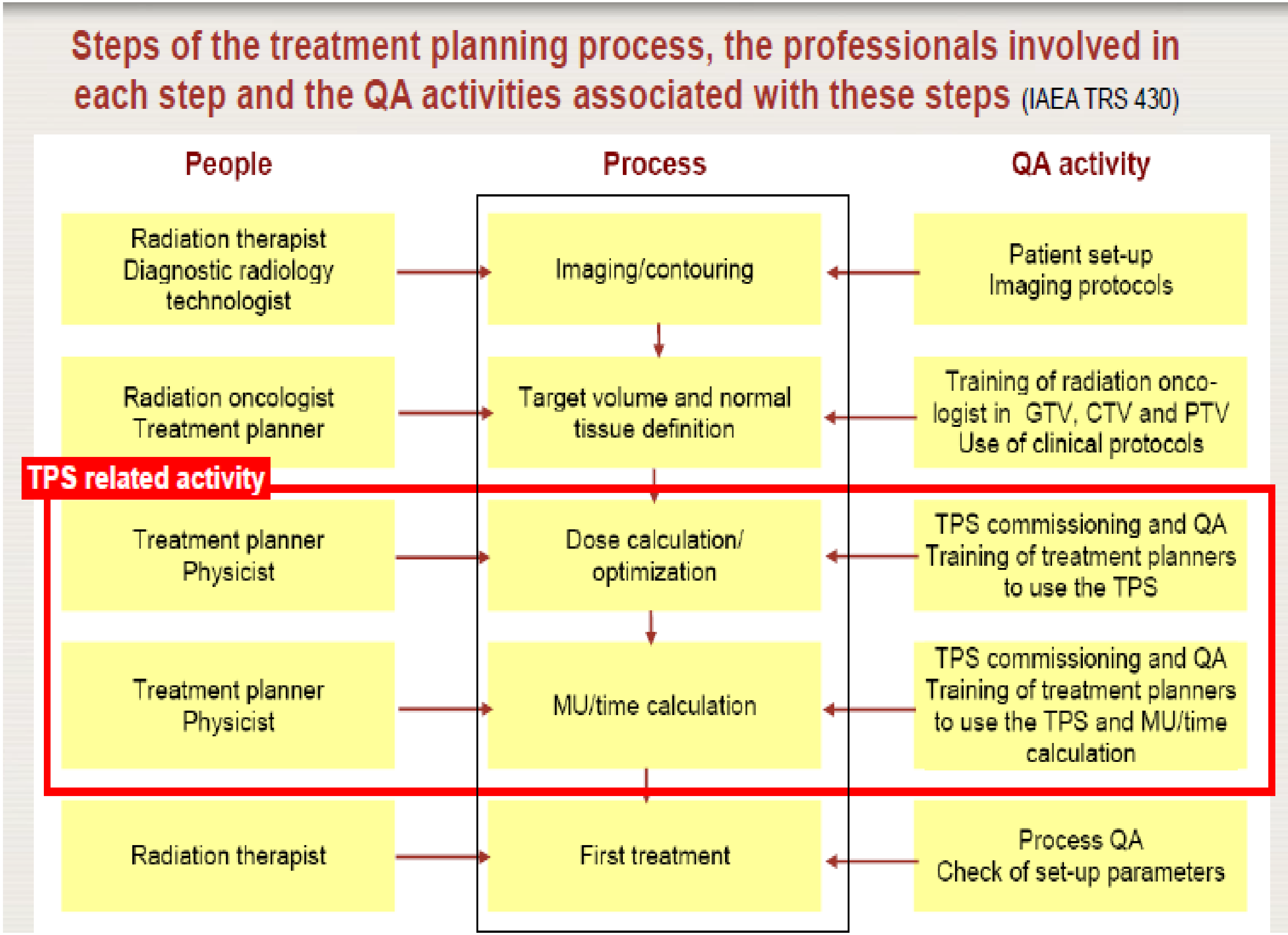
Computers in storing Data

The advantages of the computer include its ability to:

- Store large volumes of data.
- Retrieve data within the shortest possible time, with precision.
- Secure (confidential) data, using authentication and authorization.
- Share data faster and easily, to people of interest.

Role of computer in modern Radiotherapy includes but not limited to-

- Database Management
- Radiodiagnosis
- Image Display
- Image Processing
- Digital Radiography
- Computer – Aided Diagnosis
- Imaging Modalities (e.g. CT, MRI, SPECT, PET)
- Radiotherapy
- Computerised Treatment Planning
- Radiotherapy techniques
- Dosimetry
- Follow up and record keeping.


Steps of the treatment planning process, the professionals involved in each step and the QA activities associated with these steps (IAEA TRS 430)
People
Process
QA activity
Radiation therapist
Diagnostic radiology technologist
Imaging/contouring
Patient set-up
Imaging protocols
Radiation oncologist
Treatment planner
Target volume and normal tissue definition
Training of radiation onco-logist in GTV, CTV and PTV
Use of clinical protocols
TPS related activity
Treatment planner
Physicist
Dose calculation/ optimization
TPS commissioning and QA
Training of treatment planners to use the TPS
Treatment planner
Physicist
MU/time calculation
TPS commissioning and QA
Training of treatment planners to use the TPS and MU/time calculation
Radiation therapist
First treatment
Process QA
Check of set-up parameters

IAEA slide

Understanding the start of computers in Radiotherapy

- In the automatic dose calculation methods described by **TSIEN(1 955, 1958)-**methods were restricted to beams intersecting in one point, and to symmetrical beams.
- Cartesian systems are used-applicable to beams of any shape and asymmetrical beams.

COMPUTER METHOD FOR TREATMENT PLANNING IN EXTERNAL RADIOTHERAPY

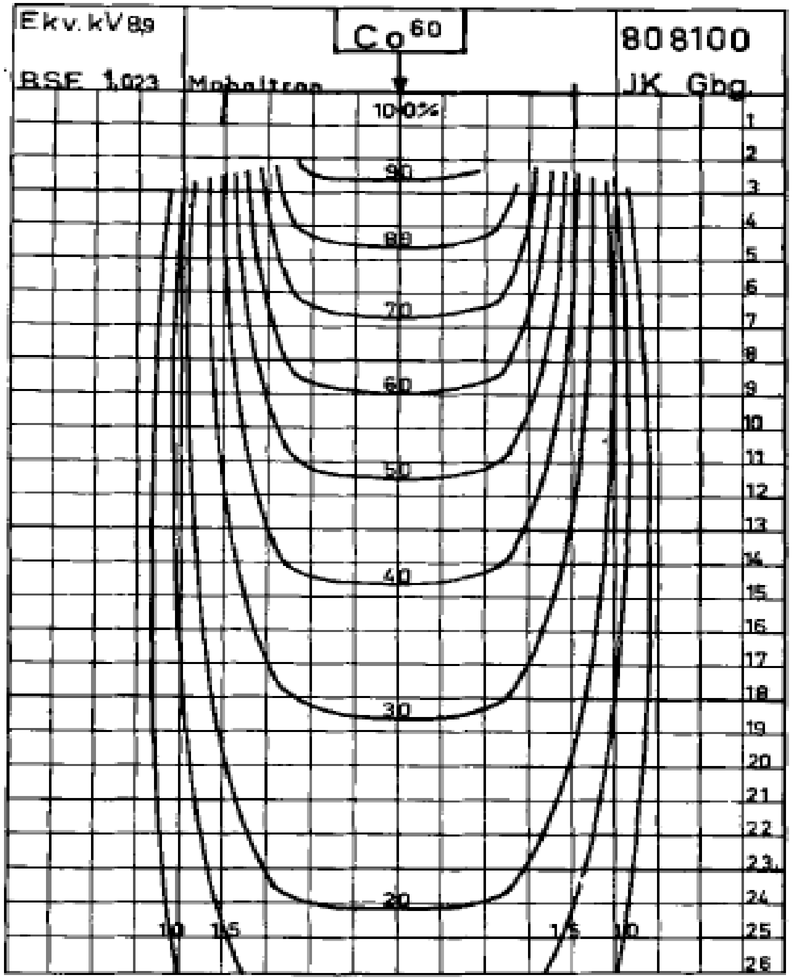
by

HANS HALLDÉN, INGER RAGNHULT and BENGT ROOS

Digital computers have proved to be very suitable for the calculation of dose distributions in radiotherapy with fixed or moving fields. In the automatic dose calculation methods described by TSIEN (1955, 1958) and STERLING, PERRY & BAHR (1961) polar co-ordinate systems were used, and the methods were restricted to beams intersecting in one point, and to symmetrical beams. SILER & LAUGHLIN (1962) schematically described a more generally applicable method. Cartesian systems are used in the computer method described below; it is not limited to symmetrical fields, but is applicable to beams of any shape. The method has been tried for different combinations of roentgen and cobalt 60 beams, and has been in practical use for about a year; it is now used mainly for the planning of cobalt treatments.

Hans Halldén, Inger Ragnhult & Bengt Roos (1963) Computer Method for Treatment Planning in External Radiotherapy, Acta Radiologica

Isodose charts and corresponding field metrics



Isodose diagrams for 80 cm SSD 'OCo, field size 8 x 10 cmz, angles of incidence: 0".

808100

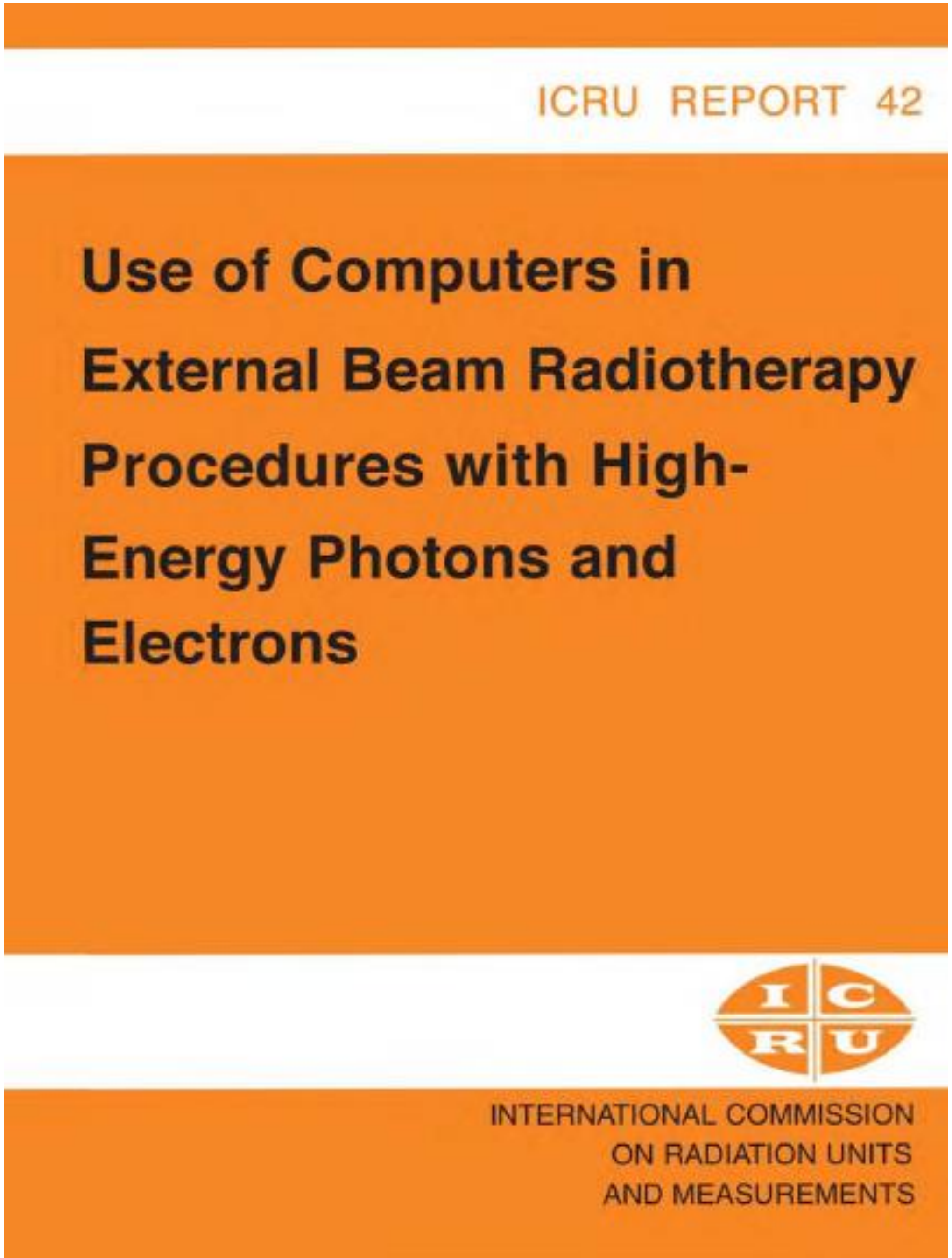
Symmetric YES

Max. width 13 units

Max. length 26 units

4	13	50	80	94	98	100						
5	14	45	79	94	98	98						
5	15	45	75	92	93	93						
6	15	44	72	85	88	88						
6	16	43	70	81	82	83						
7	17	42	65	75	77	78						
7	18	41	62	71	72	73						
8	19	40	59	66	68	68						
8	19	38	55	62	63	63						
8	19	36	51	58	59	59						
9	18	35	48	54	55	55						
9	18	33	45	50	51	51						
9	17	31	42	46	47	47						
9	17	29	40	43	44	44						
9	16	27	36	40	41	41						
9	16	26	34	38	38	38						
9	15	24	32	35	35	35						
8	15	23	30	33	33	33						
8	15	22	28	30	31	31						
8	14	21	25	28	29	29						
8	14	20	23	26	27	27						
8	13	18	22	24	25	25						
7	13	17	21	23	23	23						
7	12	16	20	21	21	21						
7	12	15	18	20	20	20						
7	11	14	17	18	19	19						

Field matrices obtained fom the isodose diagrams



Issued 15 December 1987
First Reprinting 15 January 1995
Second Reprinting 30 November 1998

Introduction from ICRU 42

- Computer techniques are extensive and diversified.
- To produce a report on treatment planning and recording and documentation procedures in external beam therapy.
- This report will be rapidly outdated; therefore, only the main concepts and basic methods are presented.

Steps in the radiotherapy procedure.

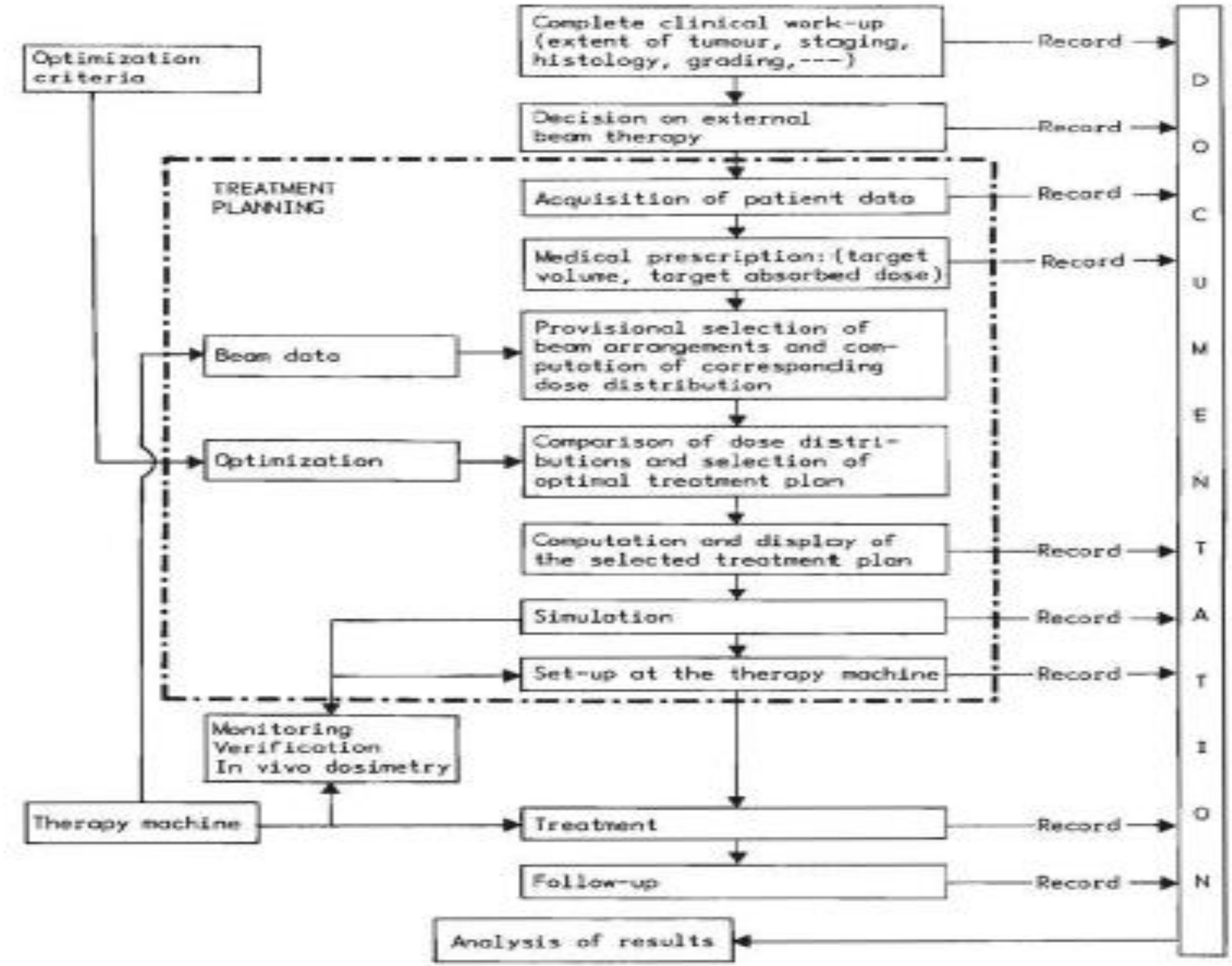
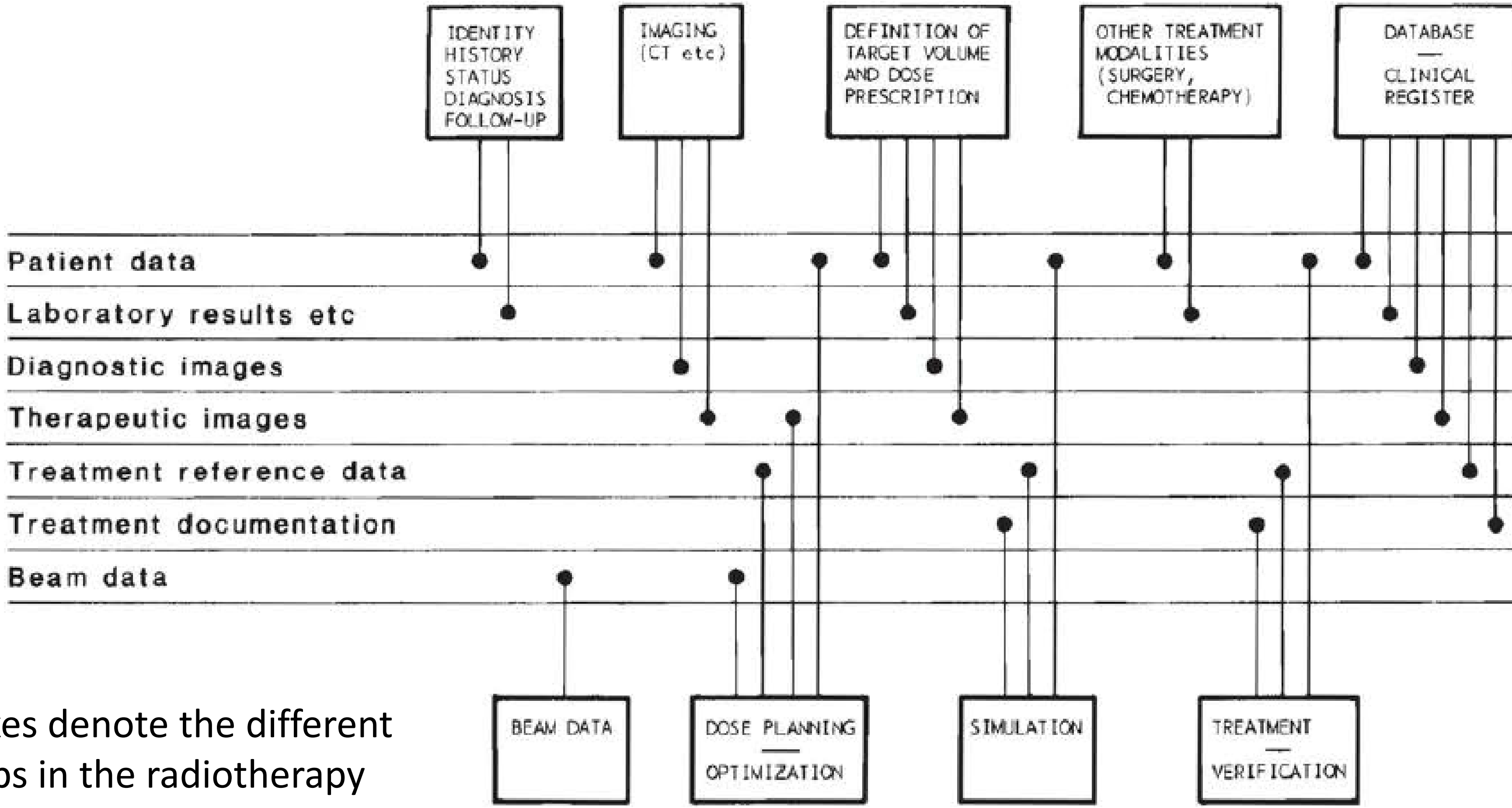


Fig. 1.1. Steps in the radiotherapy procedure.

Schematic representation of data flow within a department of radiotherapy.



- Boxes denote the different steps in the radiotherapy procedure.
- The horizontal bars indicate different channels of the logical network.
- A dot means that information exchange occurs with the respective box.

Representation and Modification of Photon Beams

Tabular or matrix format

- The most basic example would be a table of depth-dose data.
- Matrix format-presentation of the distribution of absorbed dose in a plane requires a two dimensional array of numbers.

➢ Cartesian coordinates

➢ Polar coordinates

➢ Fan-line system

- **Beam generating functions/formulas-** such functions are mathematical expressions which facilitate the direct calculation of the relative dose at a point.

Representation and Modification of Photon Beams- Cont

The Separation of Primary and Scattered Radiation.

- Primary radiation - design and construction of the gamma-ray source / x-ray target/ collimation system.
- Scattered radiation -beam size and shape and composition of the volume of material that is irradiated.

Photon Beam Modification

- Beam limiting devices-

Primary symmetric collimators- already accounted in reference situation.

Secondary shielding blocks needs to be considered..

- Beam attenuating devices-filters may be interposed in the beam in order to modify the dose distribution- flattening filters, wedge filters, compensators.

Beam data acquisition-it is important to provide adequate beam data or each machine and each type of representation

Representation and Modification of High-Energy Electron Beams

- Many similarities between the behavior of electron beams and that of photon beams, there are also many differences.
- Steep fall-off of the depth-dose curve.
- Broadening of the dose distribution with depth resulting in a bulged pattern in the penumbra region,
- Strongly affected by beam limiting and modifying devices .
- Complex behavior of electrons in and around tissue in homogeneities

All of this makes the calculation of dose distributions for electrons more difficult than for photons

Acquisition and Representation of Patient Data

Traditionally, anatomical data represented by a series of transverse parallel sections containing the target volume.

Image acquisition

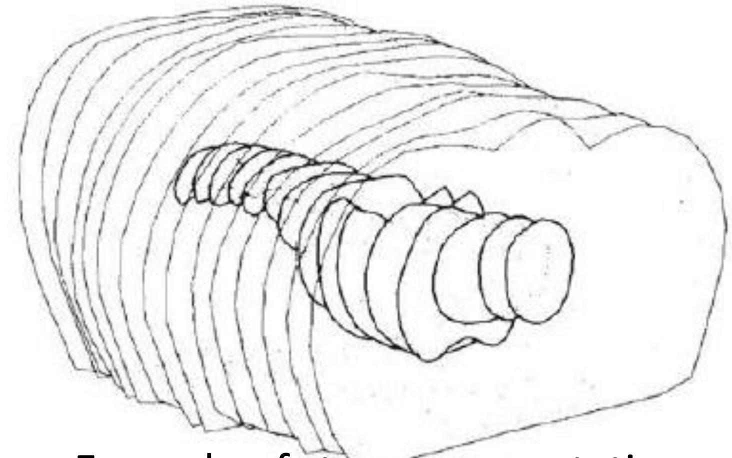
- Analog methods- external- calipers and lead wires,

For *internal topography,* orthogonal x-ray films and/or analog images from CT,MRI used in a computer.(care must be taken to avoid distortions).

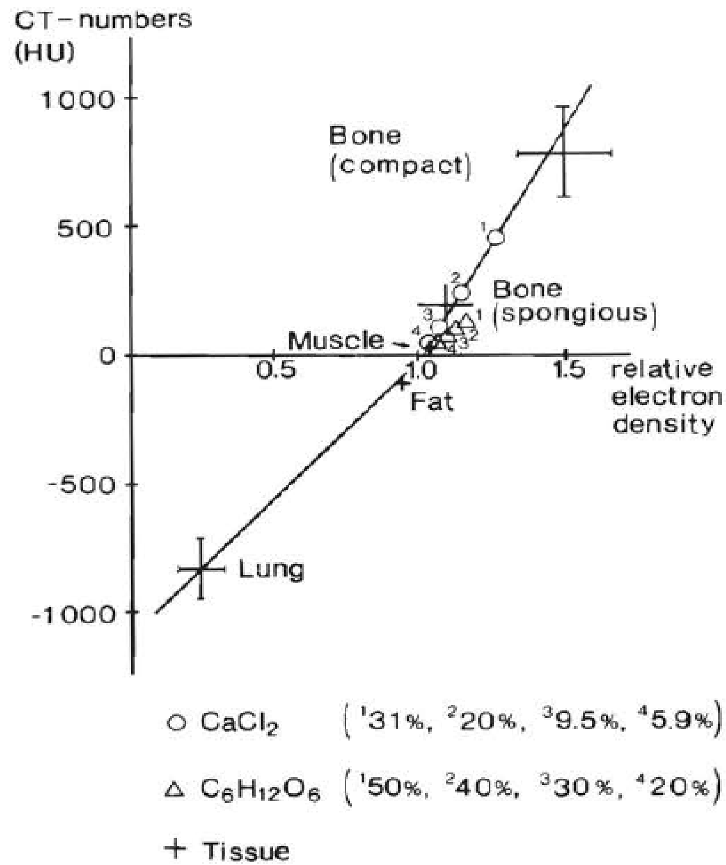
- Digital Methods- the digital matrices of images may be fed directly into the treatment planning computer for processing and display- contours of internal structures may be generated

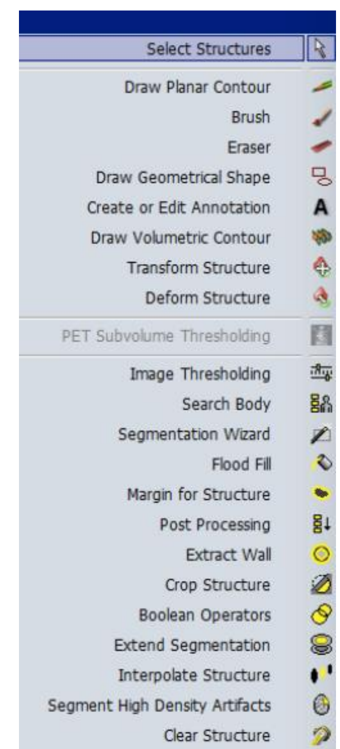
Representation of Patient Data-

- Representation of contours in a section.
- Representation of surfaces in a volume- three-dimensional structures are usually acquired and displayed as a series of parallel body sections.
- Representation of densities.



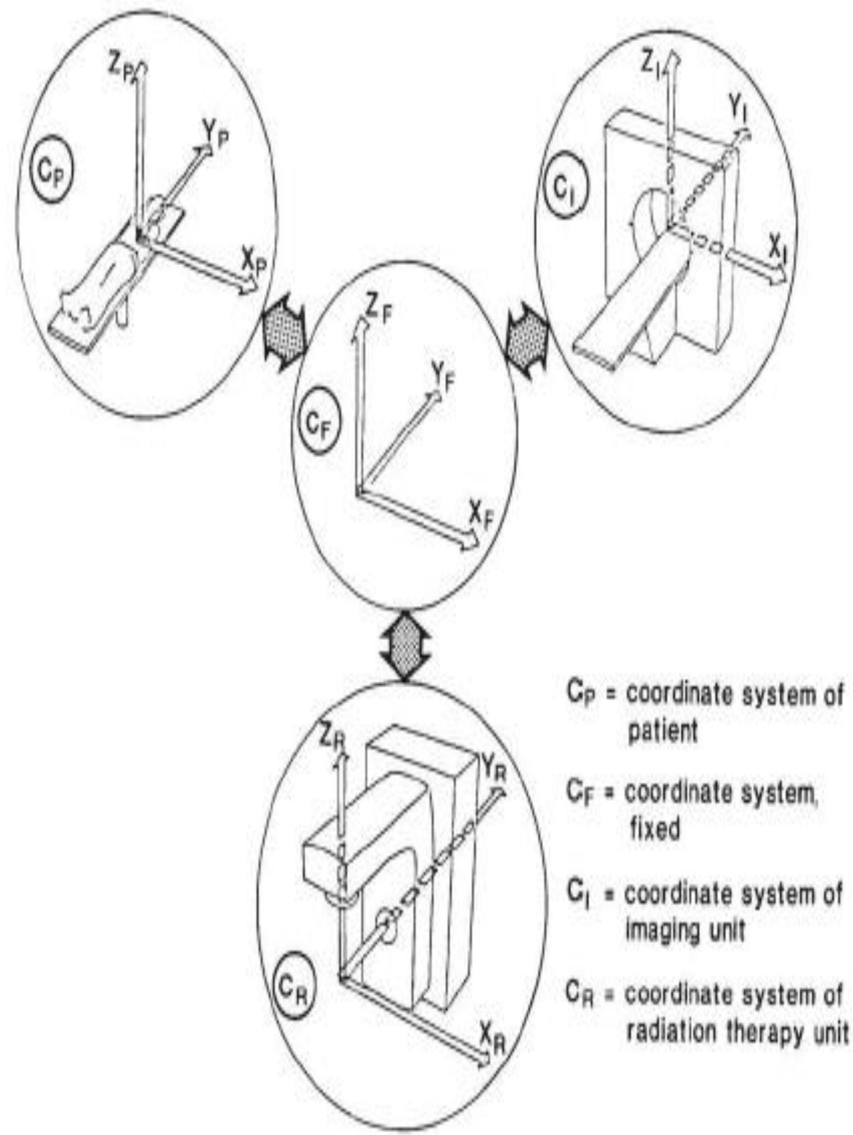
Example of step-representation





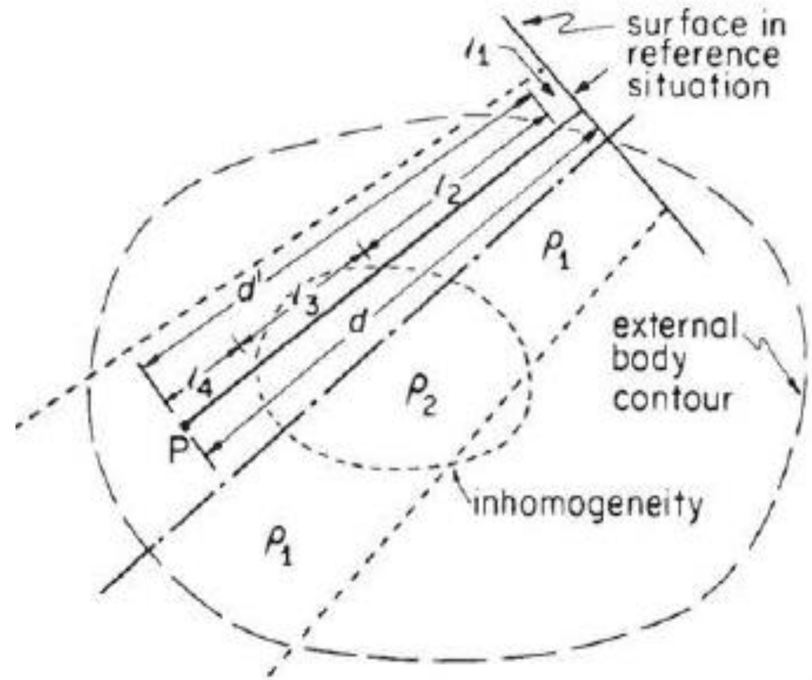
Computation of the Absorbed Dose Distribution in a Patient

- In practice patients are irregularly shaped, heterogeneous in composition, and irradiated in various positions.
- To relate the properties of the radiation beam to patient it is necessary to set up a coordinate system for each of them and to establish the relationship between the two systems.



Photon Beam Modification by the Patient

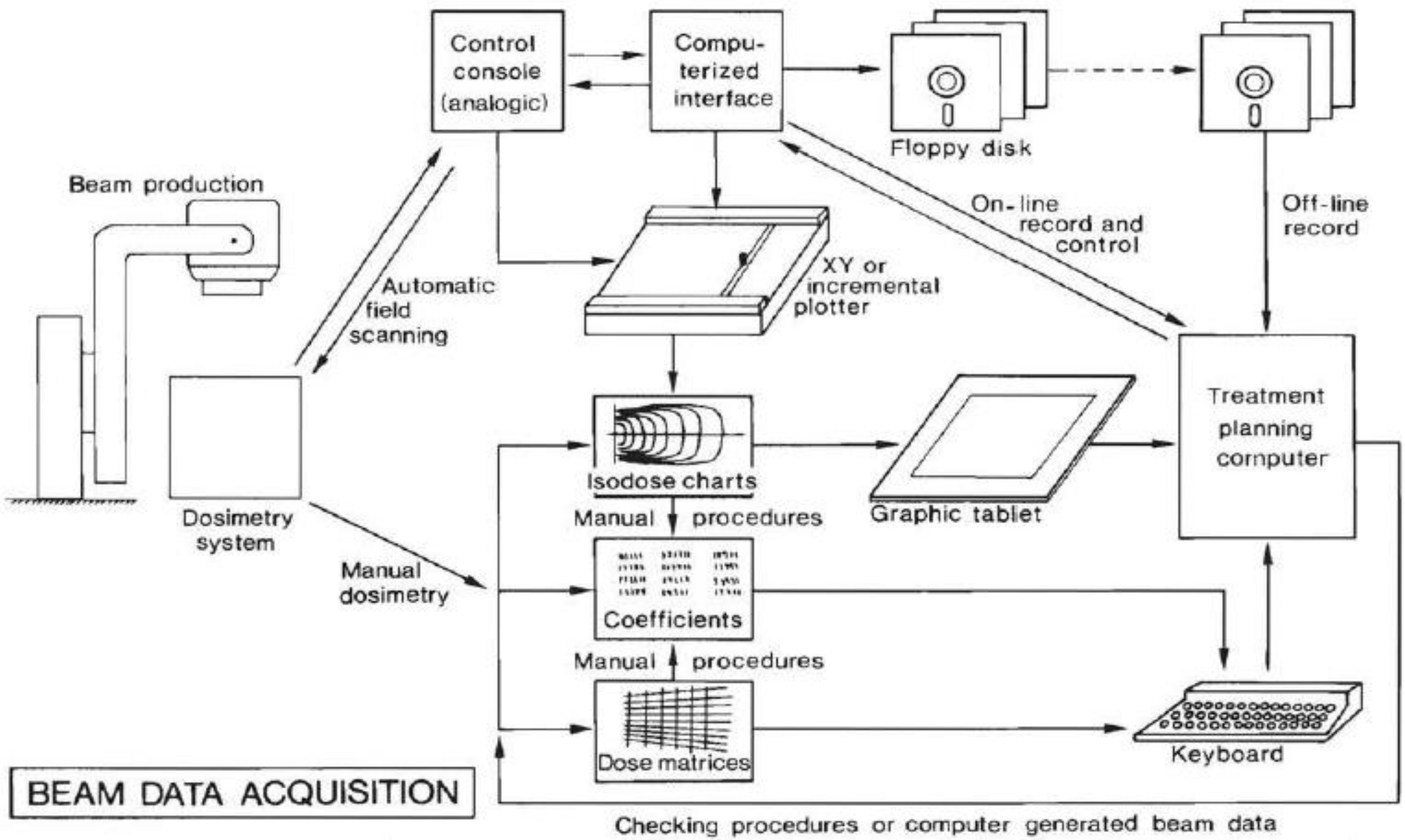
- Effect of source-surface distance (SSD).
- Effect of external shape – patients are not cylinders
- Effects of composition and density- patients are inhomogenous
- Volume irradiated- irradiated volume has a complicated shape and differs markedly from the reference situation



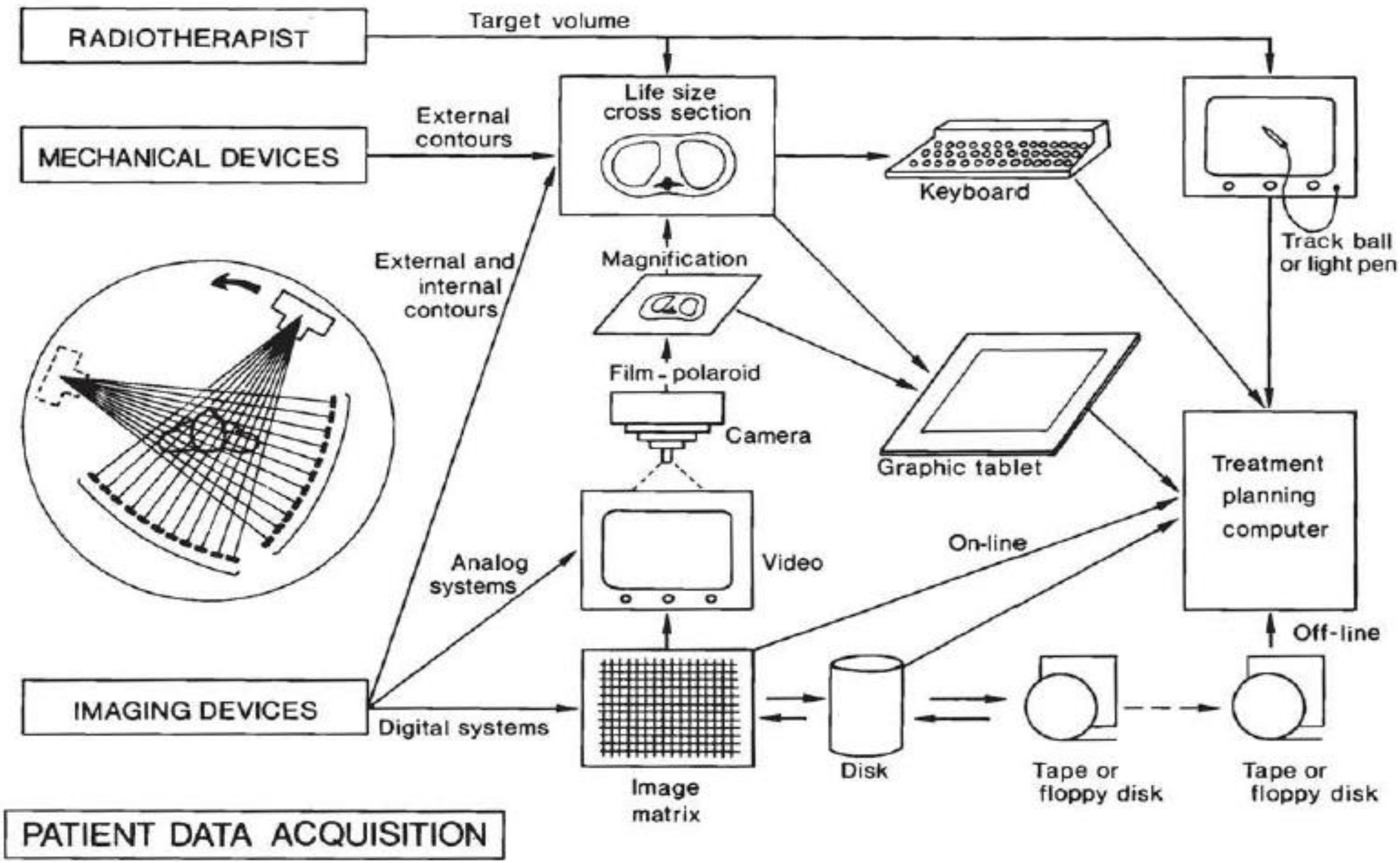
Schematic demonstration of the use of outlines (body outline indicated as surrounding an area with electron density, PI and outline surrounding an inhomogeneity with an electron density, *P2)* in the calculation of the dose to a point P in the body.

Practical Aspects of Treatment Planning by Computer

- Building a Beam Library.



Input of Patient Data



Practical aspects of treatment planning by computers

- Input of treatment parameters-

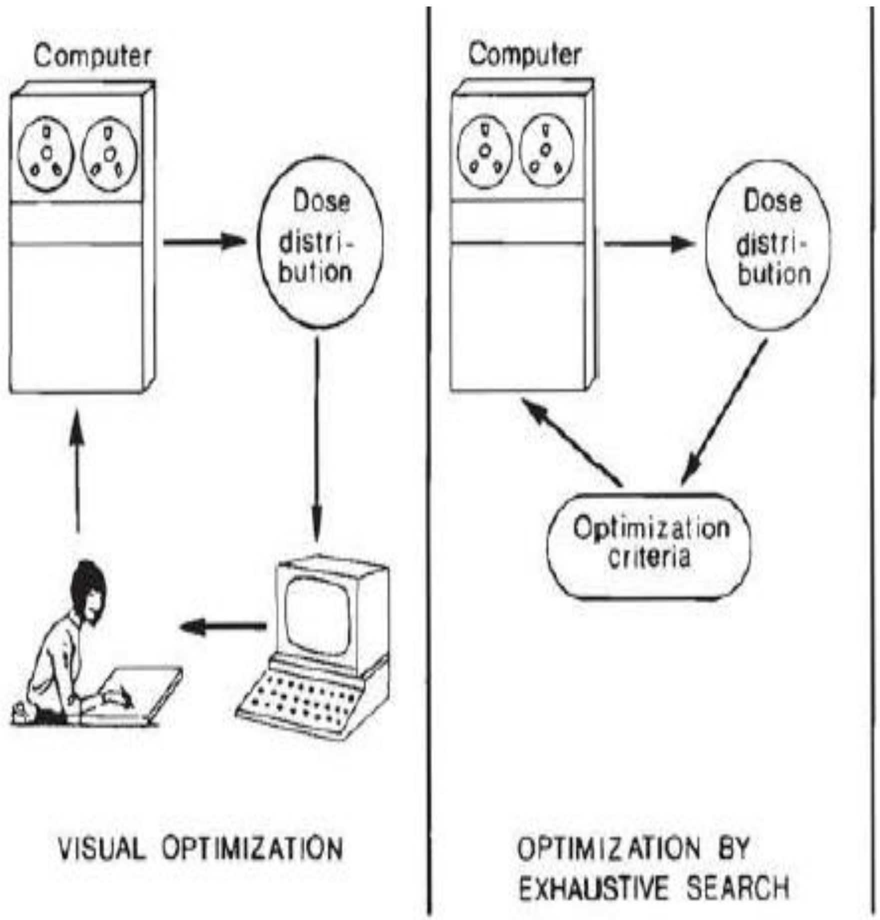
  Machine identification, SSD or SAD value,field size, beam direction, etc.).
- Absorbed dose computation time

- Treatment plan visualization and output.

  Interactive presentation- in a computer monitor

  Permanent output- as record in patient file.

Optimization



- Visual interactive and computer optimization procedures can be combined.
- A first choice is made of manually beam directions and field sizes) can be done and a subsequent adjustment is done.

Presentation of Results of Calculation

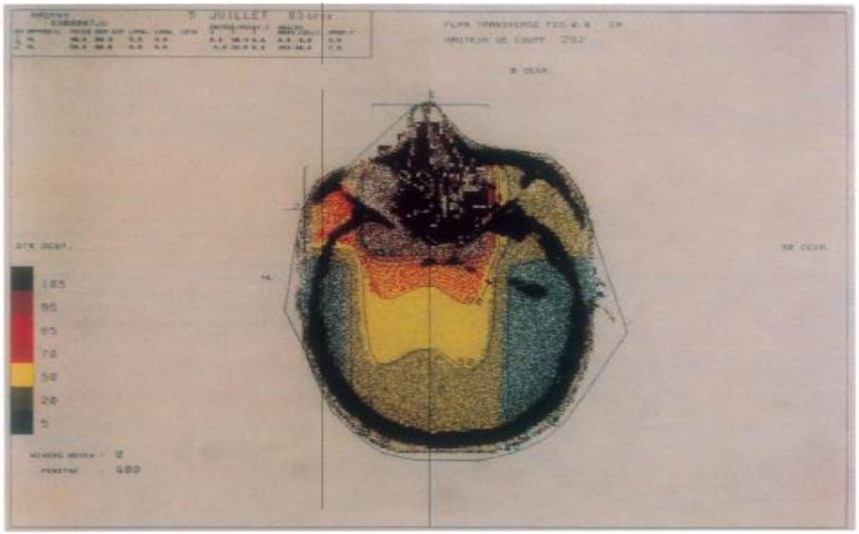
Information obtained from a treatment planning system consists of various treatment parameters, dose values and dose distributions related to the selected treatment plan.

Alphanumerical

- Identification of patient and dose plan.
- Description of technique.
- Single values of absorbed dose.
- Distribution of absorbed dose.
- Magnitude of areas and/or volumes

Graphic Information

- Identification information to be included.
- Isodose pattern-general remarks.
- Type of presentation-three-dimensional/two dimensional.



Treatment Preparation

- Automatic recording-of each session.
- Treatment monitoring(strict criteria's).
- Automatic set-up and dynamic treatment.
- System of documentation must permit a comprehensive description of a given treatment, both during actual treatment and for long-term follow-up.

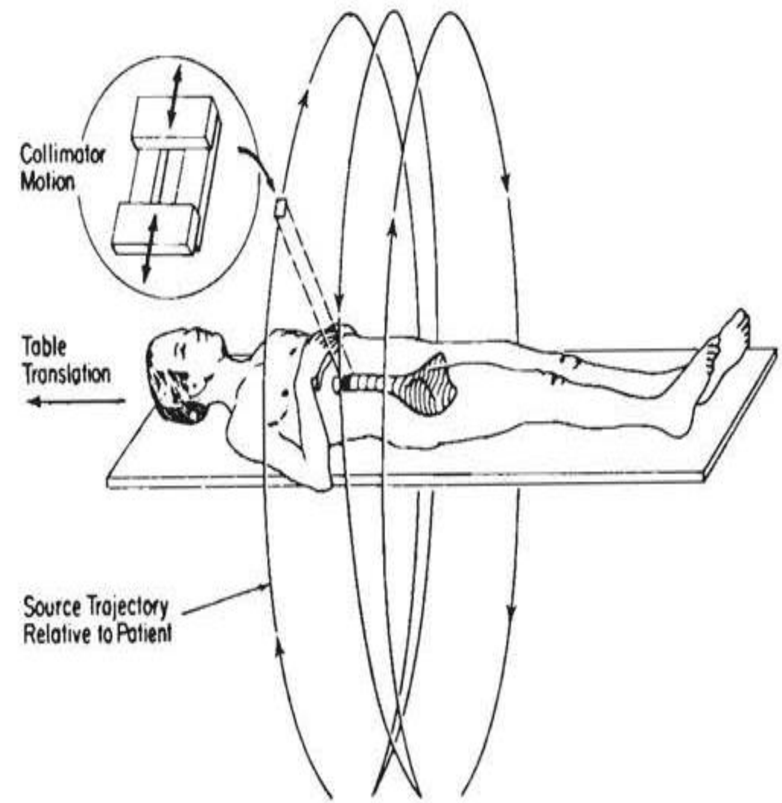


Fig. 8.1. Example of dynamic treatment of the paraaortic and iliac lymph nodes. The movements of the gantry, couch, and collimator blocks are controlled by a computer. (From Levene *et al.*, 1978.)

Quality Assurance

Introduction of computer technology will improve both the quality of a treatment plan (by permitting more sophisticated plans) and the dosimetric accuracy of the treatments.

- The use of computers will inevitably introduce new risks of error and responsibilities.
- Program and system(computer) documentation.
- Initial system checks.
- Repeated system checks.
- Quality assurance through manual procedures.
- *In Vivo* dosimetry if reqd.

Computers and radiotherapy how they match each other

- In 1965, Gordon Moore, co-founder of the computing giant Intel, predicted that microchip complexity would increase exponentially for at least 10 years.
- In the NHS, a lifetime of 5 years is used for IT equipment, compared to 10 years for a linear accelerator.
- Computer advancements has overtaken Radiation technology in terms of newer developments.
- The results are now seen as an extremely complicated computer network controlling our radiotherapy machines.

Benefits and hazards of computerization

- Modern era of radiotherapy is totally unfeasible without computers or data communication.
- Less chance of human error.

- Computers and networks do fail.
- Systems become more complicated, they are harder to check for errors.
- Computers do not remove the risk of human error altogether

Reverse the assumption that the computer is infallible- Key checks

- Is the isocentre correct?
- Is the reference position correct?
- Has the correct dataset been used for the treatment?
- Now that the treatment can be delivered at the touch of a button, that level of understanding is critical to detect errors.

high-performance computing (HPC) in radiotherapy.

- Real-time requirement of performing three computationally intensive tasks:

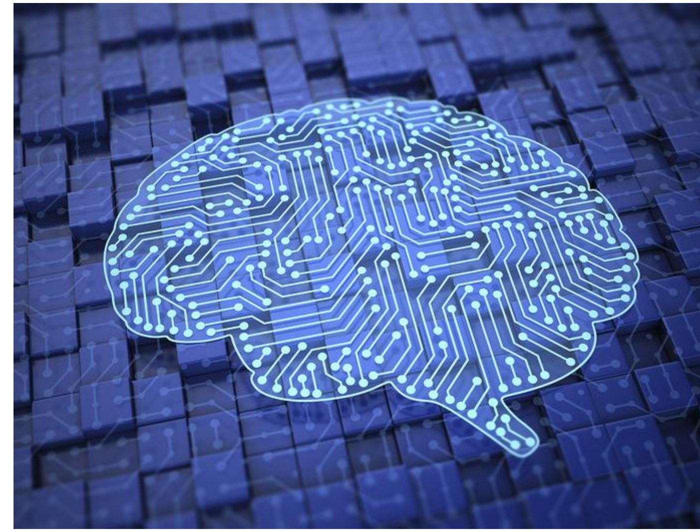
➢ patient modeling based on deformable image registration.

➢ simulation dose calculation using Monte Carlo methods

➢ Treatment optimization as a large scale optimization problem.

- A re-planning procedure within 10 seconds, while the current state of the art takes dozens of minutes.

Future of computers in Radiotherapy



Artificial intelligence. **Artificial intelligence** (AI) is the ability of a **computer** program or a machine to think and learn. It is also a field of study which tries to make **computers**"smart". John McCarthy came up with the name "**artificial intelligence**" in 1955.

Received: 1 December 2017 | Revised: 1 December 2017 | Accepted: 4 December 2017

DOI: 10.1002/acm2.12264

WILEY

PARALLEL OPPOSED EDITORIAL

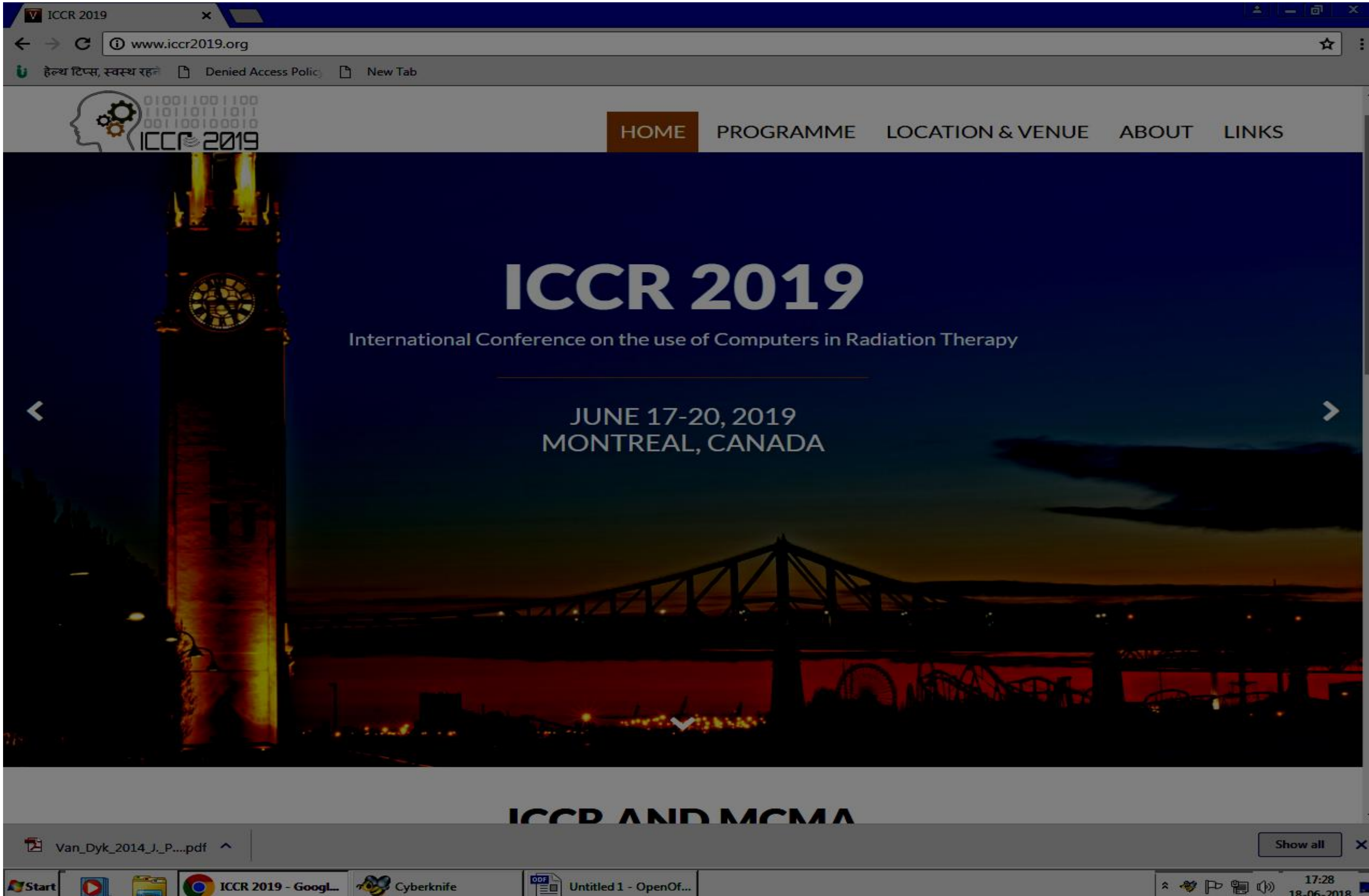
Artificial intelligence will reduce the need for clinical medical physicists

Xiaoli Tang[1,*] | Brian Wang[2,*] | Yi Rong[3]

Google DeepMind and UCLH collaborate on AI-based radiotherapy treatment

Google's AI research arm is partnering with the hospital to improve the scans available for radiotherapists by using machine learning

People interested in more knowledge



Thank You