INTEGRATED SOFTWARE TOOLS FOR THE CALCULATION IN RADIOTHERAPY

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ABSTRACT

To enhance quality and readiness of treatment with radiation at division of radiation oncology , Chulalongkorn Hospital, we have invented the integrated software tools for various calculation in radiotherapy. The program was written on personal computer and Microsoft Access was chosen as a programming environment because of its powerful database management, calculation and graphic capabilities. There are several separated modules for each calculation. The modules consist of the radiation isoeffect dose module for radiobiological dose calculation , the monitor unit module for double-checking of monitor unit for a linear accelerator, the percentage depth dose module for quick finding of percentage depth dose of single field radiation treatment , the craniospinal technique calculation module, the gap between adjacent fields module, the body surface area module for quick calculation of body surface area, the activity of radioisotope module for calculation of residual activity of radioisotope after known time interval and tangential breast technique module for calculation in simulation of breast irradiation.

INTRODUCTION

Computer can be used in the field of radiation oncology in many ways. Radiotherapy treatment planning, information storage, interactive tutorial and clerical functions are frequently mentioned and sold by commercial company. Those systems are costly, inflexible, not widely used and typically based on mainframe or minicomputers. Because Powerful and relatively inexpensive microcomputers have been available for many years. With the development of icon-based windowing operating systems and hardware optimized for graphics, they have enable us to write a very complex program but easily to used. There have been prior published reports of microcomputer used for calculation in radiotherapy, a text-based system with limited scope, such as spreadsheets for dosimetric calculations.[6] So the graphical user interface calculation program has been developed at Chulalongkorn Hospital since August 1995.

METHODS AND MATERIALS

Hardware

The minimum requirements for hardware are :

1. A personal computer based upon the Intel 80486 or Intel Pentium processor series.
2. Hard disk which has at least 40 megabytes of free disk space.
3. RAM (Random Access Memory) which has at least 8 megabytes.
4. Color graphic display and color monitor.
5. Mouse and keyboard.

These hardwares are relatively inexpensive and widely available in Thailand.

Programming environment

We chose Microsoft Access version 7 that needs Microsoft Window 95 to run as a programming environment. Microsoft Window 95 is operating system that is widely used in the world and consists of many powerful tools. Microsoft Access version 7 was chosen as the programming environment because of its powerful database management, calculation and graphic capabilities. The written program has many tables, forms, macros and codes. Tables are collections of data about physic parameters for monitor unit and percentage depth dose calculation such as field size factors, tray factors, wedge factors,

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tissue maximum ratios (TMRs), equivalent areas of rectangular fields and percentage depth doses. Forms are used as data entry tools or switchboards. They contain text fields, calculation fields, graphics and various controls ("buttons, list box, combo box"). Macros are sets of actions and codes are sets of Visual Basic Programming Codes that do some tasks such as opening a form or printing a report. The macros or codes may be associated with any fields, forms or controls, and their actions will be activated so that a specific event is detected such as clicking left mouse button or double clicking left mouse button.

Data

Data for the program were obtained from both private and published sources. Raw data for monitor unit calculation such as field size factors, tray factors, wedge factors, TMRs, percentage depth doses measured by physicists during the installation of the linear accelerator are kept in spreadsheet format. They were changed to the database format for easy retrieve. Most of the equations in the program were abstracted from published sources.

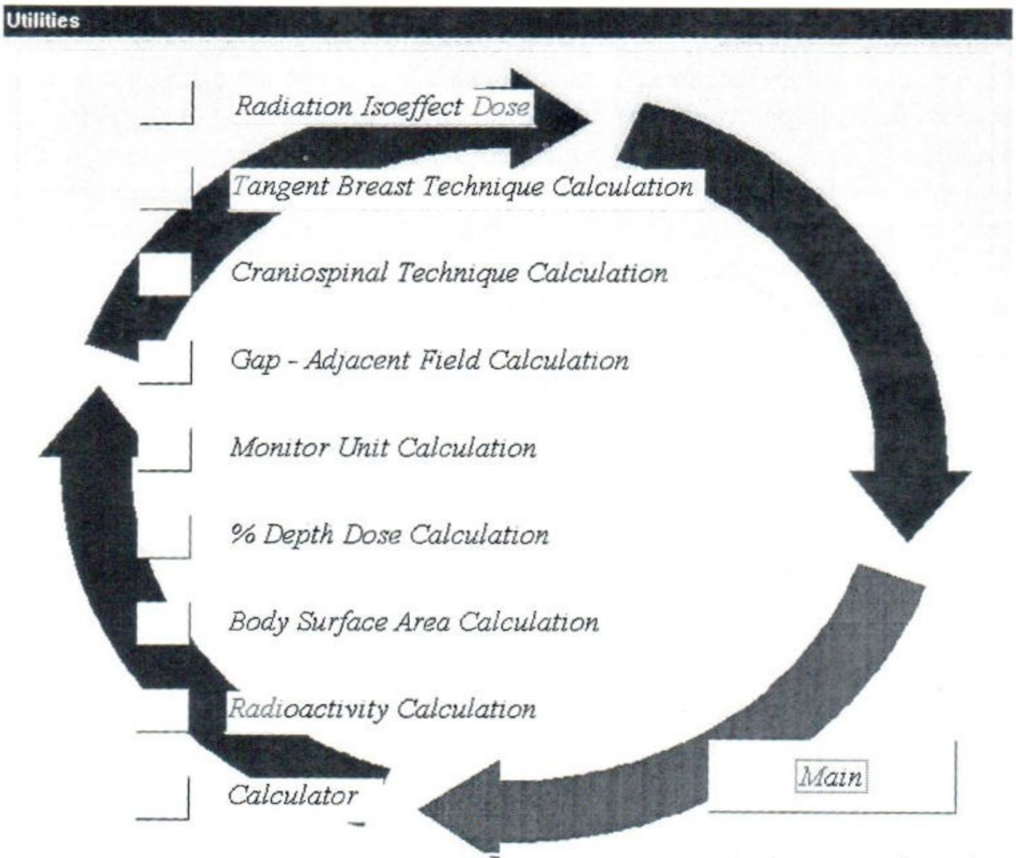

Fig. 1 Main menu screen.

RESULT

The modules, created to date, include the radiation isoeffect dose module, the monitor unit module , the percentage depth dose module, the craniospinal technique calculation module, gap between adjacent fields module, body surface area module , activity of radioisotope module and tangential breast technique module. Details of all modules are described below.

Because of graphic user interface of the operating system, the user just move the mouse over various areas of the screen and click the left mouse button that indicate the chosen module to be activated (Figure 1). This main menu is the form that include all the modules in the program. After finishing each module, it always goes back to the main menu automatically.

Radiation isoeffect dose module

Despite the increasing accumulation of radiobiological data, radiotherapy planning does not take into account the biologically effective dose of irradiated tissues. Altered fractionation regimens is a challenging treatment in modern radiotherapy. The radiation isoeffect dose module is designed for calculation of biologically effective dose in radiation treatment. The module can compute the different fractionation schemes based upon the same biologically effective dose. The module contains three equations as followings:

1. Linear-quadratic module (Fig. 2)

The calculation is based upon the extrapolated response dose model, as proposed by Barendsen (1982) and developed by Dale (1985).[1-2] This model is based on the linear-quadratic relationship between dose and bioeffect which is found on cell survival and microdosimetric theories. The ERD* equations for fractionated for high dose rate fractionated treatment and low dose ratre continuous treatments are shown in equation 1 and equation 2 respectively.

Equation 1

$$ERD = Nd\left[1 + \frac{d}{\alpha / \beta}\right]$$

ERD = *Extrapolated response dose (Gy)*
N = *Number of fractions*
d = *Dose per fraction (Gy)*
α/β *Tissue - specific parameter (Gy)*

Equation 2

$$ERD = RT\left\{1 + \frac{2R\left[1 - 1/(\mu T)\right]}{\mu(\alpha / \beta)}\right\}$$

ERD = *Extrapolated response dose (Gy)*
R = *Dose - rate (Gy/h)*
T = *Implant time : T > 10 h*
μ = *Tissue specific parameter* (h^{-1})

* ERD = Extrapolated response dose (Gy)

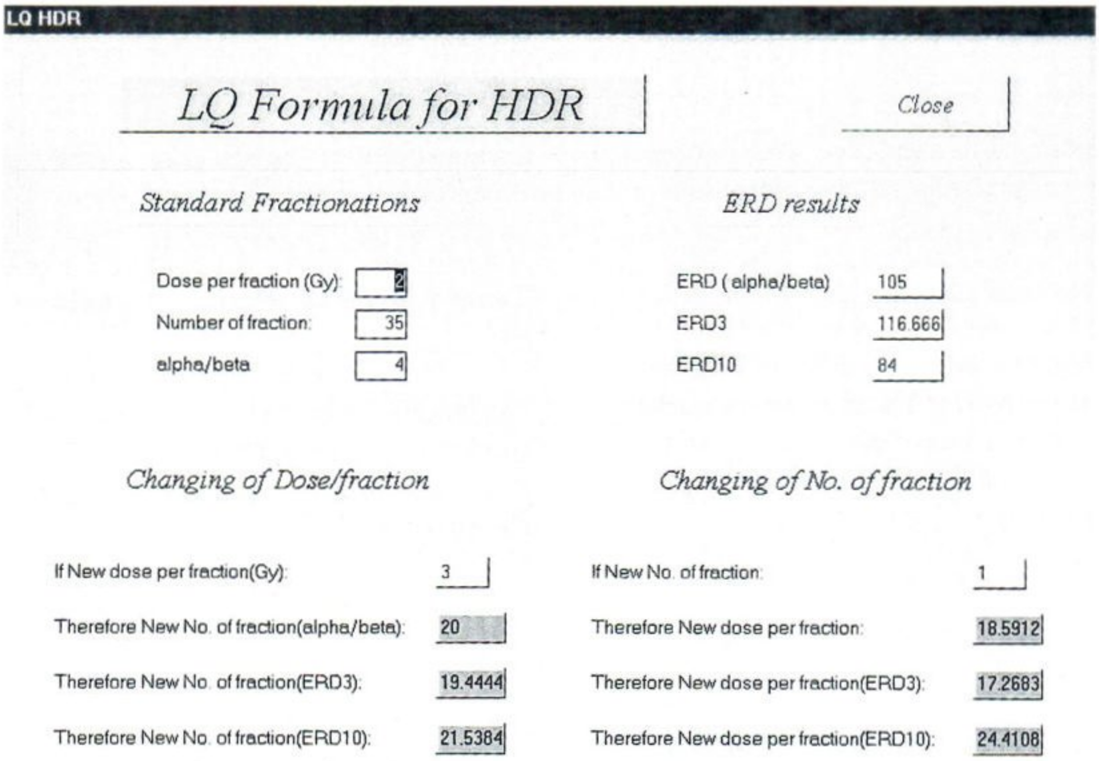

Fig. 2 LQ formula for HDR screen. This screen based on equation 1. After entering the standard fraction ation, the user can change dose per fraction or number of fraction, and the program will calculate the new number of fractions or the new dose per fraction correspondingly.

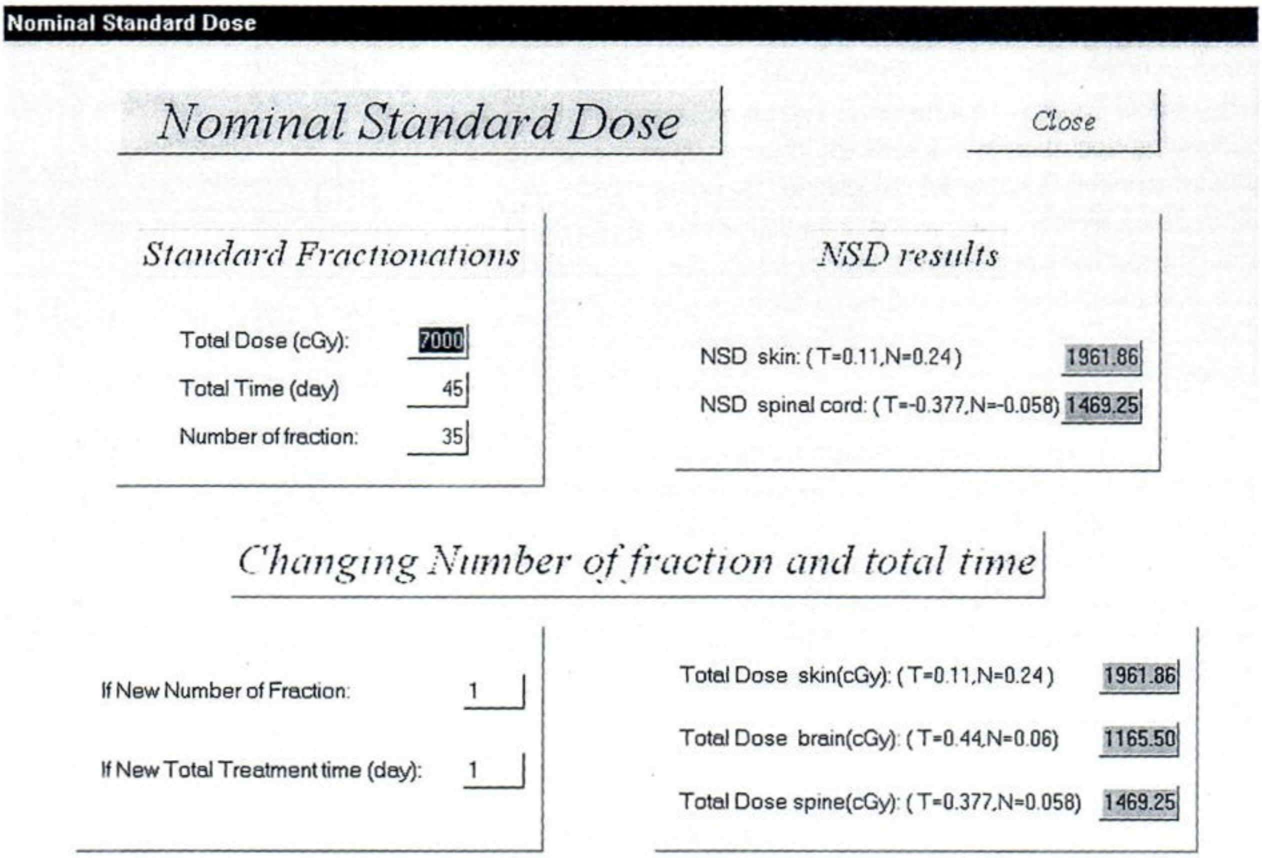

Fig.3 Nominal standard dose screen. After input the fractionation data, the NSDs are shown, and the user can change number of fractions or total treatment time that base upon the previous NSD.

2. Nominal Standard Dose Module (Fig.3)

The calculations are based upon the Ellis nominal standard dose (NSD).[3] The constant parameters for overall treatment time of days and number of fractions were changed according to specified tissues such as skin in equation 3.

Equation 3

$$D = (NSD)\, T^{0.11}\, N^{0.24}$$

D = *Total treatment dose (Gy)*
T = *Overall time (day)*
N = *Number of fractions*

Tangent Breast Technique Module

This is a graphic illustration one of methods of calculating the location of isocenter of tangential irradiating technique for breast carcinoma. The calculations based upon trigonometric functions as shown below.

$$D = \frac{1}{2}\left(sCOS(d)\right) - W\left(\sin(d)\right)$$

$$S = \frac{1}{2}\left(sSIN(d)\right) - W\left(\cos(d)\right)$$

D = *Depth of Isocenter (cm.)*
S = *Shift of Isocenter (cm.)*
s = *Separation of Tangent Field (cm.)*
d = *Degree of Tangent Field*
W = *Width of Tangent Field*

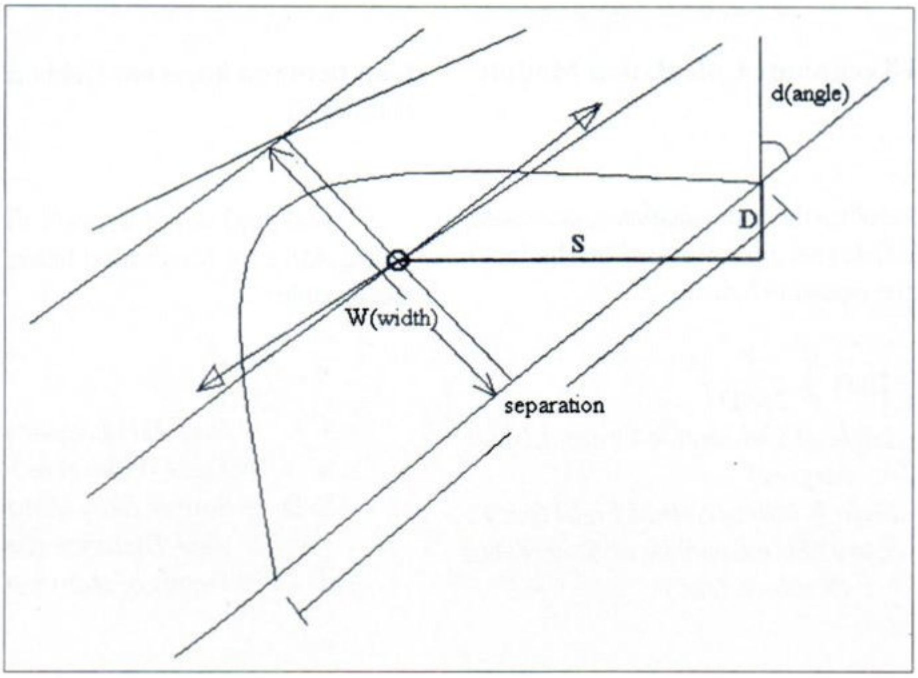

Fig.4 Illustration of tangent breast technique calculation.

To find the location of the isocenter, the user must enter the parameters that can be measured by our special designed ruler, field width, separation of field and bridge angle of field (Figure 4). With this technique, it takes few minutes to simulate tangential field technique for breast irradiation.

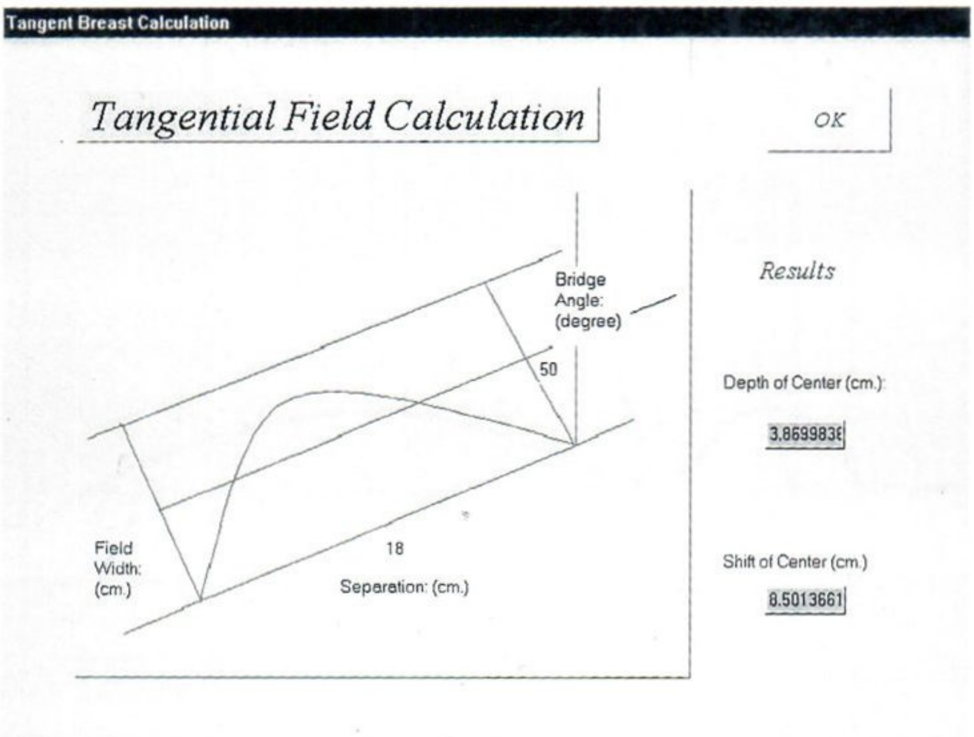

Fig.5 Tangential field calculation screen. After input three parameters, field width, separation and bridge angle, the program will show the location of the treatment isocenter. Depth of isocenter is the depth of isocenter at midline of patient, and shift of isocenter is the distance from midline of the patient to isocenter.

Craniospinal Technique Calculation Module
(Figure 6)

This is one of methods of calculating collimator angle of cranial field in the craniospinal irradiation. It is based upon the equation below.

$$Angle = \tan^{-1}\left(\frac{w}{2SSD}\right)$$

Angle = *Angle of Collimator Cranial Field (degree)*
w = *Field Width of Spinal Field (cm.)*
SSD = *Source Skin Distance or Source Axis Distance (cm.)*

Gap between adjacent fields module
(Figure 7)

This module has a simple illustration of calculating skin gaps for abutted fields. The equation for this module is:

$$S = \frac{w \times d}{2SSD}$$

S = *Half Field Separation (cm.)*
w = *Field Width (cm.)*
SSD = *Source Skin Distance or Source Axis Distance (cm.)*
d = *Depth of treatment (cm.)*

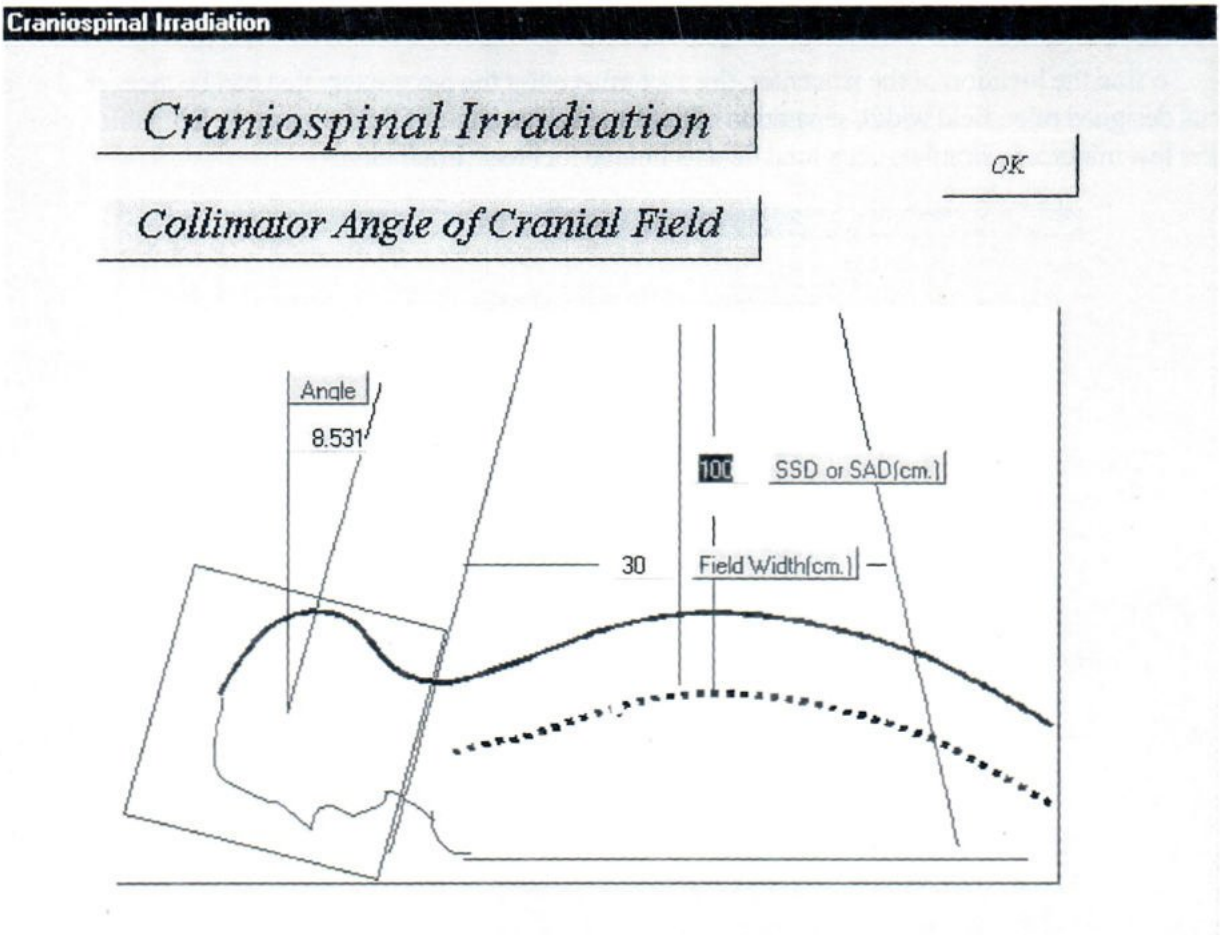

Fig.6 Craniospinal irradiation screen. After the user enters the SSD or SAD of the spinal field and the width of the spinal field, the collimator angle will be shown.

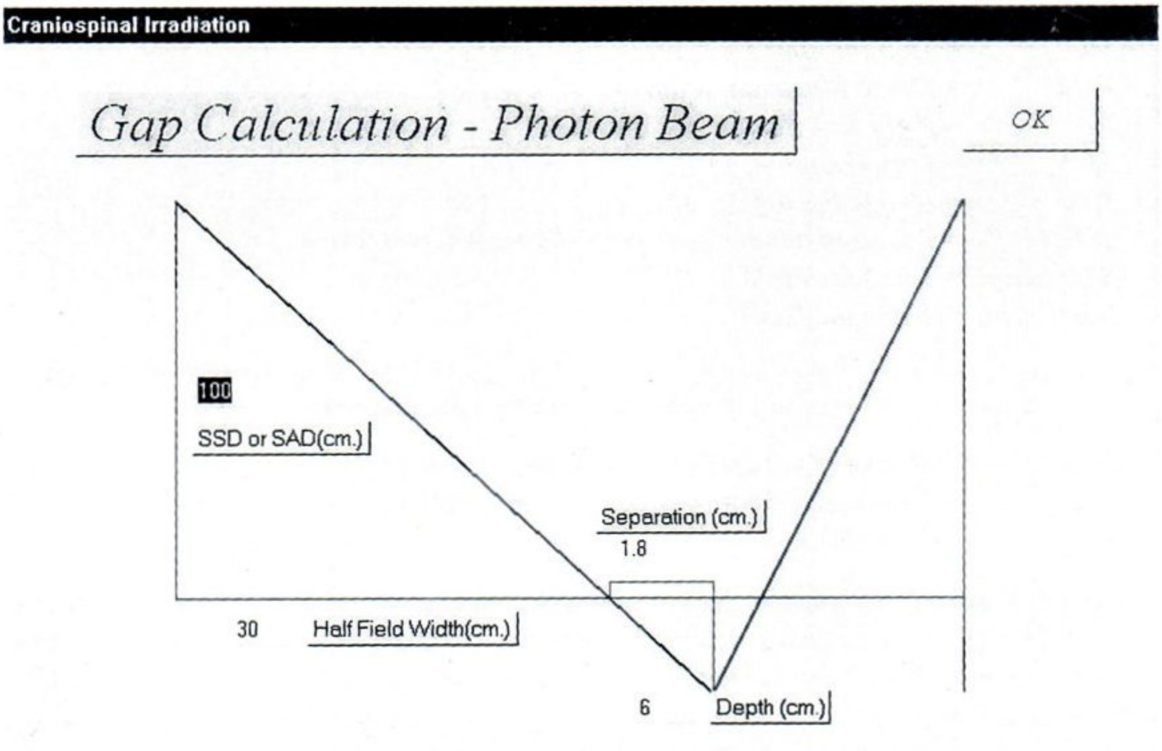

Fig.7 Gap calculation screen. To find out the half field separation, three parameters, SSD or SAD, half field width and depth of treatment.

Monitor unit module

This module is a sophisticated module, and can be used as an independent check for the consistency of radiation therapy dose calculations. It verifies the calculated monitor units(MU) required to deliver a prescribed dose to a certain point on an isodose line to the monitor units calculated manually by the technologist or by any commercial treatment planning system. There are many tables that contain numerous data about physics parameters for monitor unit and percentage depth dose calculation such as field size factors, tray factors, wedge factors, TMRs (Tissue Maximum Ratios), equivalent areas of rectangular fields and percentage depth doses. For photon monitor unit calculation, 6 and 10 MV modules are available. For electron monitor unit calculation, 6,9,12,16,20 MeV modules are available. The user can move the mouse over different areas of the form and click to indicate which of the input data items are to be changed. After the user specifies treatment parameters by easy clicking left mouse button within the list box of specific item or by entering number in some fields, the number of monitor unit will be shown immediately. The equation used in this module is:[4]

$$MU = \frac{TD}{TMR \times Fs \times Tf \times Wf \times SSDfactor}$$ For photon monitor unit calculation

MU = *Monitor Unit*
TMR = *Tissue Maximum Ratio*
Fs = *Field Size Factor*
Tf = *Tray Factor*
Wf = *Wedge Factor*
TD = *Required tumour dose per field per fraction (cGy)*
$SSDfactor$ = *1.030 for 6MV*
$SSDfactor$ = *1.051 for 10MV*

$$MU = \frac{TD}{0.8 \times CF}$$ For electron monitor unit calculation

MU = *Monitor Unit at 80% isodose line*
TD = *Required tumour dose per field per fraction (cGy)*
CF = *Cone Factor*

In the calculation of one treatment field, the user first enters the tumour dose in centigray and then selects type of tray and wedge. After the area is selected, the program will find out the field size factor for that area and display only various TMRs of the specified area according to depth of tumour. Finally, the user just selects depth of tumour and the program will show the monitor unit of the treatment in less than one second. It also has automatic recalculation feature updates the monitor units as each parameter is changed. (Fig. 8)

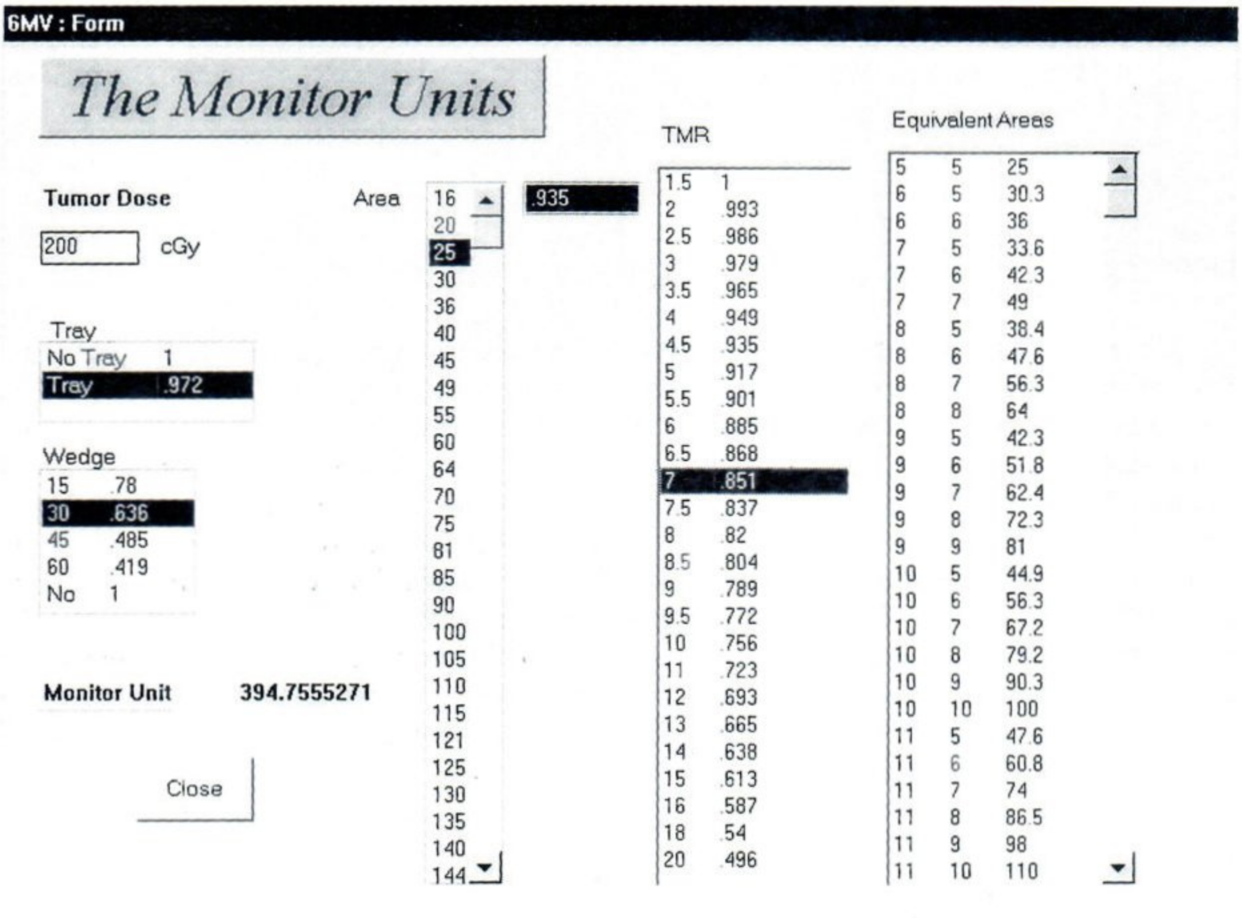

Fig. 8 Monitor unit screen for 6MV.

Body surface area module

Most of the radiation oncologists in Thailand treat their patients not only by radiation but also combined with chemotherapeutic drugs, so this module should be useful for our staffs. Two parameters, weight and height of a patient, have to be involved. The equation is shown below.

$$BSA = \sqrt{\frac{w \times h}{3600}}$$

BSA = *Body Surface Area*
w = *Weight (kg.)*
h = *Height (cm.)*

Activity of radioisotope module

This module shows the decay activity of radioactive material frequently used in radiotherapy. The equation for this module is:

$$A = A_0 e^{-\lambda t}$$

A = *Activity at time t (Ci.)*
A_0 = *Original Activity (Ci.)*
λ = *Transformation Constant*
t = *time (day)*

DISCUSSION

At the division of radiation oncology, Chulalongkorn Hospital, we need tools for calculation to help us in our routine work because of the overloaded number of patients. These tools should be easy to handle and should have quick calculation results and good database management. With windowing operating system, the users can use various programs without hard effort. Our program can be useful not only for radiation oncologist, but also for physicists and technologists. Fractionations of radiation treatment can be changed quickly based on the linear-quadratic relationship or Ellis nominal standard dose equation by using the radiation isoeffect module. During the simulation, the radiation oncologists can calculate various parameters by the tangent breast technique module, the craniospinal technique calculation module and the gap between adjacent fields module. Monitor unit calculation is very important in radiation treatment. Precise doses of radiation delivered to treat the patients come from the correct monitor unit calculation. In manual calculation, the physicist has to search for many parameters for the equation mentioned above from a big bunch of data file, and make calculation by calculator. With the monitor unit calculation module, the physicist just only enters number or click to select the parameters and rapidly get the answer. The body surface area module and the activity of radioisotope module are also used frequently as the others.

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