FETAL DOSE ASSESSMENT FOR BREAST CANCER RADIATION THERAPY WITH COBALT-60 QUADRATE TECHNIQUE

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ABSTRACT

Objective There is no current information about the estimated fetal dose from an extensive breast cancer radiation treatment which include internal mammary chain (IMC), supraclavicular (SPC) and tangential chest wall. The aim of this work was to determine an appropriate irradiation technique and to build a fetal dose data set for the management of pregnant women needing breast irradiation.

Methods Measurements with thermoluminescent (TLD-100) dosimeters were performed in an anthromorphic phantom which was modified to simulate a pregnant patient at first month to sixth month of pregnancy: i.e., 4, 12 and 24 weeks of gestation. Two similar treatment plans, quadrate technique with the open and wedge tangential field, were delivered with a total dose of 50 Gy using Cobalt-60 gamma-ray. Abdominal shielding was constructed and its efficacy was verified. Results of the measured doses were analyzed and plotted as a function of depth and distance from the tangential field edge.

Results Minimum fetal doses in all three gestational periods were detected by the open tangential field quadrate technique with the shielding. With the total prescription dose of 50 Gy, the corresponding average measured doses at 4, 12 and 24 weeks gestation were found to be 5.4 ± 1.19, 11.0 ± 5.18 and 19.6 ± 17.3 cGy or 0.11%, 0.22% and 0.39 % of the total dose, respectively. The modification device, a wedge filter, was found out to yield more external scattered radiation dose to the fetus, about 17-27%, in comparison with the open tangential field technique. The measured dose in the shielding technique, both the open and wedge tangential field technique, was lower than the non-shielding technique approximately 50-60%. For all three periods in a simulated pregnant phantom, the fetal doses showed a small change with depth. But the fetal doses were likely to decrease exponentially with the distance from the primary beam edge. This observation was seen both in the second and third trimesters with correlation coefficients, $R^2 = 0.93$ and 0.94 respectively.

Conclusion A reliable and accurate data set to assess the doses to fetus for breast cancer pregnant patient receiving Cobalt-60 gamma ray with quadrate technique irradiation was obtained. Fetal doses presented in a graph, plotted as the function of depth and distances were found to be useful in the risk management for any individual pregnant patient requiring cobalt-60 quadrate technique radiation therapy at our institution.

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INTRODUCTION

Recently, recorded in our tumor registry, the most common malignancy in Thai women has been noted to have changed from carcinoma of the cervix to carcinoma of the breast.[1] There are some conditions for which radiation therapy may be required for pregnant woman with malignancy. However, irradiation may increase the risk of malformations in the conceptus with the threshold for this effect reported to be 10 cGy.[2] Ensuring that the radiation dose to the fetus over the treatment course will be kept below the threshold, is very crucial for the planning and management of the treatment. Several studies have been reported on the radiation therapy of breast cancer during pregnancy.[3-7] But the measurements were restricted to a limited number of techniques, e.g., photon energy, gestation periods and also the shielding designs. In our institution, Cobalt-60 gamma-ray with the quadrate irradiation technique is still used as the standard treatment for breast cancer. Since the anatomic site of the breast is quite near the fetus, dose reception is a key factor for a treatment decision. For a busy department, estimated fetal dose for any individual patient was occasionally performed with a one point measurement using an ionization chamber and square phantom. However, the accuracy for these simple measurements may not be adequate for the treatment management of that particular patient. Investigation of the fetal doses received from radiation therapy of the breast using an anthromorphic phantom, and numerous measuring points combined with the routine techniques used in the clinic will provide a much more confident assessment and prediction. In this study, the fetal dose at different gestation periods (4^{th}, 12^{th}, and 24^{th} week) with Cobalt-60 quadrate techniques irradiation were assessed. To determine which technique will be suitable for giving to the pregnant patients, two similar treatment plans, the open and the wedge tangential field, were compared. Shielding equipments were constructed and verified for their efficacy. Measurement doses from TLD were analyzed and plotted as graph information in correlation with depths and distances from the tangential field edges in all three gestational periods.

MATERIAL & METHODS

All treatment fields in the quadrate technique were defined on the left side of an anthromorphic phantom with 80 cm SSD under the simulator. According to the planning, the tangential field width in most patients were actually found to be 6-9 cm; the maximum field width 9 cm was selected to be used in the study. In the technique of wedge tangential field, a 30 degree wedge angle was used in the planning. Detail of the treatment fields and calculation is presented in Table 1.

The Alderson Rando phantom was modified to simulate pregnant women at different gestational ages. A slice corresponding to the position of the fetus was replaced by a slice made from molded paraffin wax, according to the report of conceptus size for Thai women.[8] Accuracy in the dose determination (within $\pm$ 5%) using paraffin wax was determined prior to use in the study.

To reduce the dose delivered to the fetus, a shielding device was designed and constructed. It was modified from a bridge over patient as described in AAPM report no. 50.[2] Each side and the top of the device were able to support a 2.5 cm thick lead sheet as shown in Fig 2.

Table 1 Quadrate treatment fields and calculation depth

Treatment field	Field size in cm (width x length)	Calculation depth (cm)
Internal Mammary Chain	6x15	4
Supraclavicular	16x9	6.8
Medial & Lateral Tangential	9x18	4.3

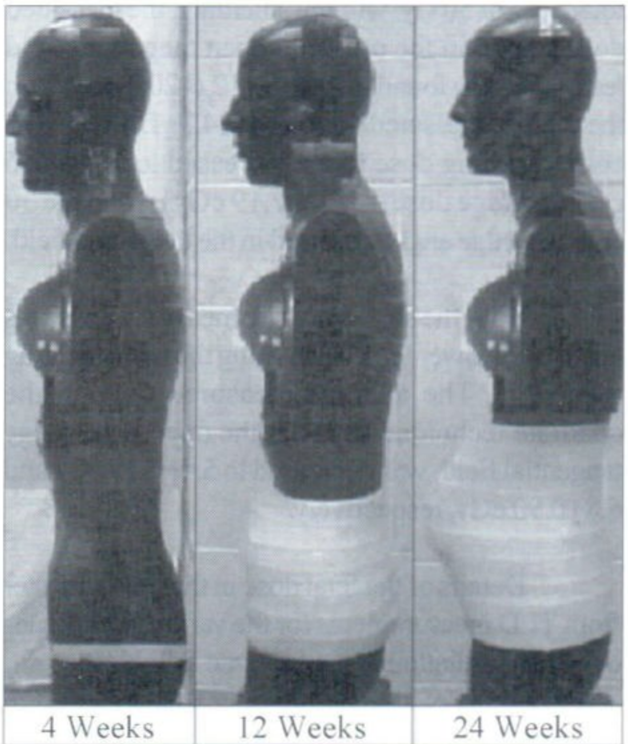

Fig.1 Three gestational age pregnant phantoms.

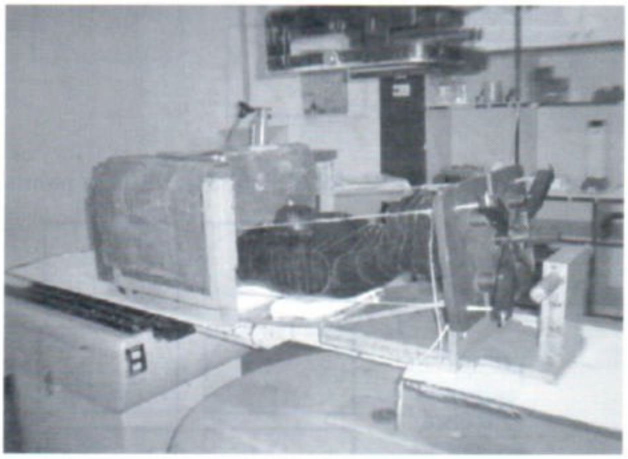

Fig.2 An abdominal shielding device design for a pregnant patient.

All TLD-100 dosimeters (1x1x6 mm. rod shaped) were then calibrated with the Cobalt-60 source. Points of measurement were determined based on the data of the fetal position and size from the past studies.[9-10] The phantom was irradiated with Cobalt-60 gamma-ray for each technique three times. To increase TLD reading sensitivity, we exposed the phantom with a radiation dose of 10 Gy. In anticipation, the linearity tests between the TLD scattered doses reading and the different amount of primary doses were performed and a 10 Gy primary doses was found to be practical for using in the study.

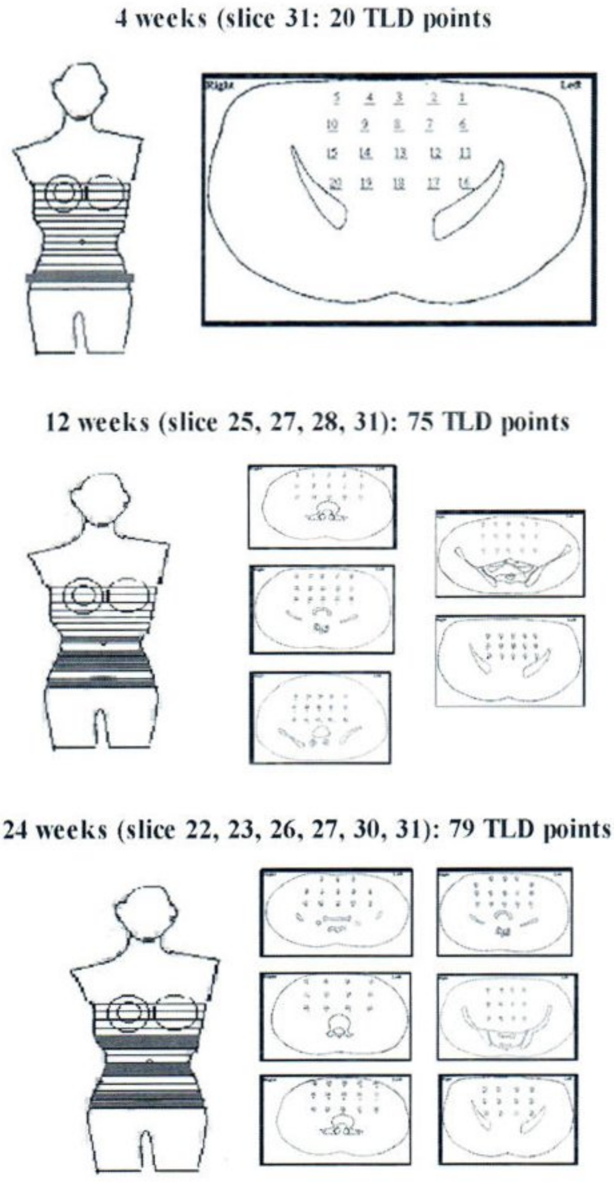

Fig.3 TLD measurement points in the slices representing fetus at different gestational phantom.

RESULTS

Fetal Doses at 4th Week Gestation

For the first trimester, the fetus was estimated to be located in slice 31. To measure the doses, 20 TLD points were distributed at the different depths from 5 to 12 cm below the skin. Distances between the estimated fetus and the primary beam (lower border of the tangential field) was 27.5 cm. With a total dose of 50 Gy, without shielding, the measured doses range in the quadrate open tangential field technique was found to be from 12.6-20.2 cGy, with the average measured dose being 14.3$\pm$1.70cGy. The corresponding dose range increased to 13.0-22.6 cGy (average dose = 16.7$\pm$2.19 cGy) when the 30 degree wedge angle was used in the tangential field.

With the shielding , the measured dose was about 60% lower than when using the non-shielding technique. The average measured dose in the quadrate technique for both the open and wedge tangential field, was decreased to 5.4$\pm$1.19 cGy and 6.8$\pm$0.90 cGy, respectively.

Details of the fetal dose in the first trimester from TLD measurements for the various techniques of breast irradiation is summarized in Table 2.

Table 2 Estimated fetal dose at a 4th week gestation period for various techniques of breast irradiation.

Technique	Dose range (cGy)	Avg ±SD (cGy)	% of Prescription dose	% Dose increase from wedge	% Dose decrease from shielding
Non- shielding					
Open Tangential	12.6-20.2	14.3±1.70	0.286	-	-
Wedge Tangential	13.0-22.6	16.7±2.19	0.334	16.8	-
Shielding					
Open Tangential	3.5-7.9	5.4±1.19	0.106	-	62.9
Wedge Tangential	5.2-8.2	6.8±0.90	0.134	26.5	59.9

Fetal Dose at 12th Week Gestation

For the second trimester, the pregnant phantom was inserted with 75 TLD positions at 5 distances: 12.5, 17.5, 20, 22.5, and 27.5 cm from the primary beam (slice no. 25-31). The average measured doses at each slice depended on the distance from the fetus to the primary field edge, as shown in Table 3.

Table 3 Measured dose range and average measured dose (in parenthesis) in cGy at a 12th week gestation period at different slice levels for various techniques of breast irradiation (15 TLD positions per slice)

Technique	Slice 31 (27.5cm)	Slice 29 (22.5cm)	Slice 28 (20 cm)	Slice 27 (17.5cm)	Slice 25 (12.5cm)
Non-shielding					
Open Tangential	15.2-22.0 (18.8±2.10)	21.1-38.0 (29.5±4.75)	25.0-41.8 (30.6±8.90)	25.4-44.5 (35.0±5.55)	33.7-64.1 (46.1±8.66)
Wedge Tangential	19.0-23.1 (20.5±1.37)	22.3-46.3 (34.7±6.14)	27.9-52.5 (39.0±7.50)	30.0-49.2 (39.9±6.32)	43.4-77.5 (58.5±10.26)
Shielding					
Open Tangential	5.1-8.0 (6.3±0.85)	4.7-12.6 (7.7±2.25)	6.7-13.4 (10.2±1.99)	7.1-14.9 (11.2±2.19)	14.6-23.7 (19.8±2.94)
Wedge Tangential	6.2-10.7 (8.3±1.18)	6.0-14.2 (9.7±2.41)	8.9-16.9 (12.5±2.33)	10.8-22.0 (16.5±3.08)	17.4-28.7 (23.3±3.48)

Fetal Dose at 24th Week Gestation

79 positions of TLD were distributed at 6 slice levels (slice no.22-31)to predict the peripheral doses for the third trimester. In the technique of open tangential field with shielding, the maximum measured dose of 61.2 cGy, was found at the slice nearest the field edge at the left corner of the abdomen and the average dose was 49.9±7.25 cGy. Table 4 presented the measured dose range together with the average dose at each slice level for the 24th week gestation period.

Table 4 Measured doses range and average measured doses (in parenthesis)in cGy for a 24th week gestation at different slice levels for various techniques of breast irradiation.

Technique	Slice 31 (27.5cm)	Slice30 (25 cm)	Slice27 (17.5cm)	Slice26 (15 cm)	Slice23 (7.5cm)	Slice22 (5 cm)
Non-shielding						
Open	10.6-22.4	13.9-22.1	20.6-45.3	28.7-58.9	48.0-86.2	58.4-107.3
Tangential	(16.6±3.52)	(18.2±2.64)	(33.7±7.45)	(41.2±8.74)	(69.7±13.56)	(83.0±17.27)
Wedge	13.1-25.6	18.7-23.4	26.3-55.7	37.6-74.8	64.6-109.5	78.4-134.4
Tangential	(19.3±3.83)	(20.9±1.59)	(42.0±8.59)	(52.9±11.01)	(90.7±15.72)	(108.7±18.3)
Shielding						
Open	4.2-6.8	4.0-8.5	6.3-15.7	7.7-18.2	24.7-45.2	35.5-61.2
Tangential	(5.1±0.83)	(6.1±1.51)	(9.8±2.89)	(12.7±3.25)	(35.7±6.58)	(49.9±7.25)
Wedge	5.6-10.1	4.9-12.3	9.3-23.0	11.1-26.7	42.7-60.8	51.1-77.2
Tangential	(7.3±1.39)	(9.0±2.43)	(14.3±4.19)	(18.6±4.84)	(50.8±6.41)	(62.3±8.22)

DISCUSSION

Optimal irradiation technique for breast cancer pregnant patients

Radiation-related risks throughout pregnancy vary according to gestational ages. For a given radiation dose, the risk to the fetus is most significant during the first trimester, less in the second and least in the third trimester. Malformation of organs (3-8 week after conception) appears to have a threshold of 10 cGy. The fetal dose is considered to be negligible at less than 5 cGy. The risk of organ malformation will be significantly increased at dose level above 15 cGy.[11]

In this study, the results showed that the quadrate, open tangential fields, with shielding technique yielded the minimum peripheral doses in all three gestational ages as shown in Fig 4. However, in the first trimester the measured doses both in the open and wedge tangential fields were found to be lower than the threshold doses. This data ensured that the efficacy of our shielding was sufficient enough to be used in a clinic.

For the second and third trimester, the maximum doses found in using this technique were seen at the slice nearest to the primary beam. They were 23.7 cGy and 61.2 cGy respectively. From the T65DR dosimetry system, a significant excess in the risk of SHS (small head size) occurred between 0.1-0.19 Gy.[12] But this risk is evidently greatest during the embryonic period, smaller during the second trimester and even smaller during the third trimester of pregnancy. Also the risk of severe mental retardation (SMR) was observed at the threshold about 0.65 Gy at the gestational age of 16 to 25 weeks post conception.[13] These results clearly indicated that the quadrate open tangential field technique with shielding was the optimal radiation treatment for pregnant breast cancer patient undergoing Cobalt-60 radiation therapy.

Fetal dose as a function of depth

When depth of the measurement points perpendicular with the body surface were determined. Average TLD measured dose at a given depth in the open tangential field and shielding technique were plotted as presented in Fig.5. It was notably seen that at all gestational ages, changes of the fetal dose with depth were quite small. This finding agreed with previous studies performed with the megavoltage beams.[14-15] Graph information in Fig.5 will help in predicting the fetal doses at any given depth for the quadrate open tangential field technique used for the pregnant breast cancer patients during the entire pregnancy.

In addition, it was notable that at the first trimester, when the results in all techniques were analyzed as shown in Fig.6, fetal doses in the shielding technique ,in both the open and wedge tangential field, increased linearly with depth, while with the non -shielding condition, the results were shown to be in contrast. This evidence suggested that, at the shallow depth, the fetal dose was mostly influenced by the contribution of external scattered dose, such as from the collimator, head leakage and modification devices more than the internal scattered dose. The appropriate shielding thickness will play an important role in attenuating these unwanted external scattered doses.

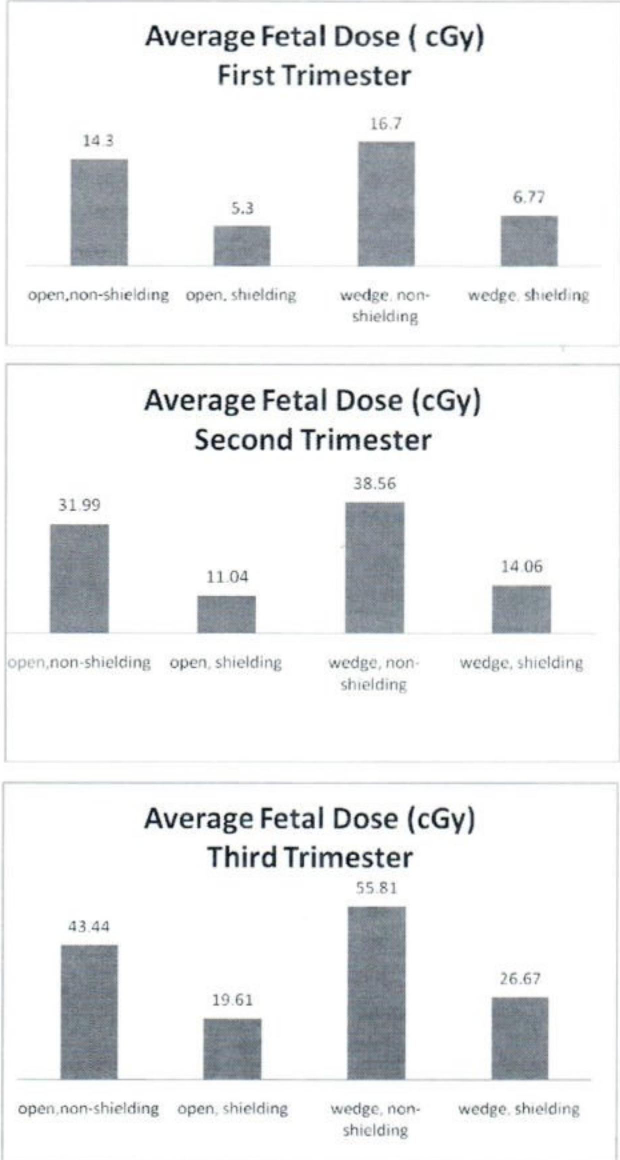

Fig.4 Average fetal doses in different techniques in all three gestational age.

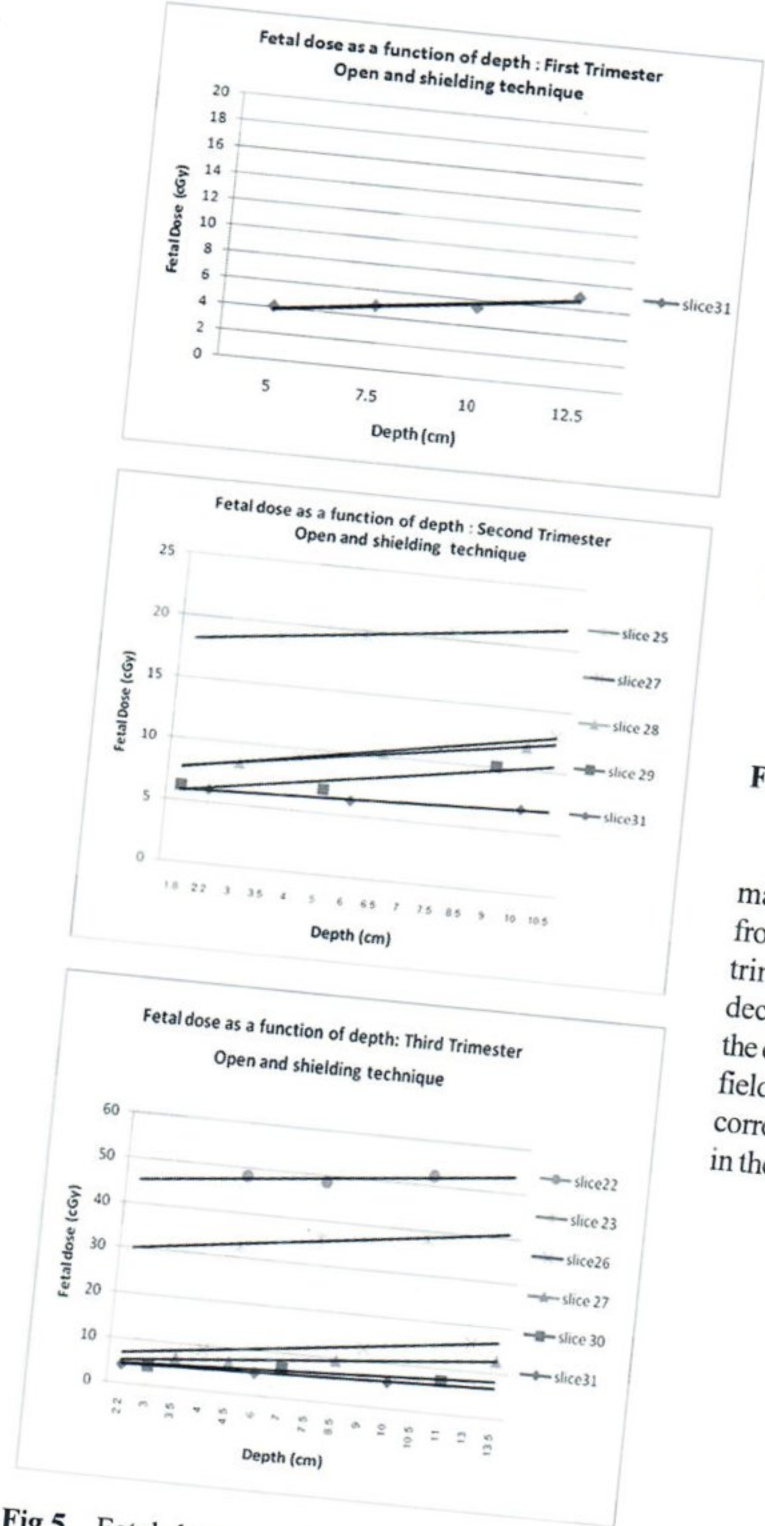

Fig.5 Fetal doses as a function of depth in the different gestational periods pregnancy

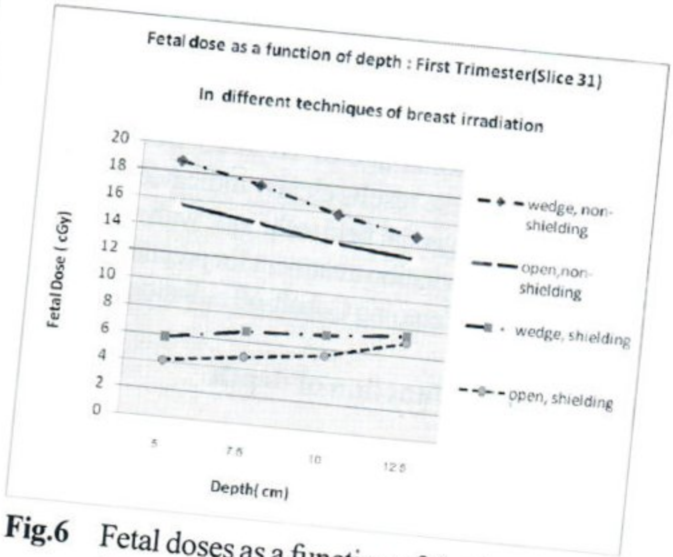

Fig.6 Fetal doses as a function of depth at slice 31 in the first trimester phantom with the different techniques of breast irradiation.

Fetal doses as a function of distances.

The most important factor for judging the magnitude of the peripheral dose was the distance from the field edge. Our data in the second and third trimester in Fig.7 showed that the fetal doses were decreased nearly exponentially in accordance with the distance from the field edge. In the open tangential field with shielding, this relationship was found with correlation coefficients (R^2) equal to 0.931 and 0.946 in the second and third trimester, respectively.

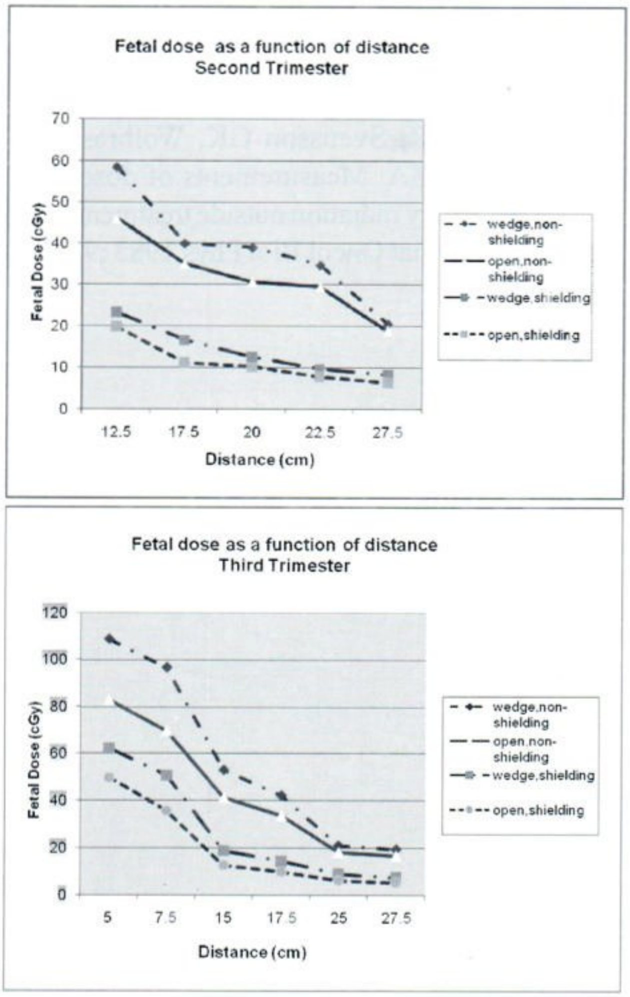

Fig.7 Fetal doses as a function of the distance from the field edge at the second and third trimester.

CONCLUSION

Anticipated fetal dose reception from Cobalt-60 gamma-ray quadrate technique irradiation with abdominal shielding by phantom dosimetry was obtained. Estimated fetal doses for any individual patient whose anatomy was similar to the measurement geometry can be easily predicted from this data set. Risk evaluation and optimal treatment management can be performed with no time delay, as opposed to the cumbersome measurement conditions usually used for each pregnant patient.

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