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Radiographic Pelvimetry— Its Use and Possible Radiation Risk

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ABSTRACT

Radiographic pelvimetry is widely used in obstetrics. Every fourth primapara in Sweden is submitted to this radiographic examination. The frequency of the examination in the United States is estimated to a mean of 6% of all deliveries. The use of radiographic pelvimetry is now under intense debate and the missing argument in this discussion is a prospective study of an unselected group of parturients where progress and outcome of labour is referred to known pelvic dimension. Since the value of the method is questioned the frequent use of radiographic pelvimetry is justified only by an almost negligeable radiation risk to the mother and her baby. Such a low risk is also an indispensible condition to allow the correct scientific evaluation of radiographic pelvimetry mentioned above. This paper presents the measurement results of absorbed radiation dose with the only radiographic pelvimetry method used in Sweden. The estimated radiation risk of the method, based on these figures, is 1 case of childhood malignancy in 50 000 pelvimetries. This corresponds to 4 years routine use of radiographic pelvimetry in Sweden. The annual incidence of childhood malignancy in Sweden is 220. The maternal risk is estimated to one tenth of the fetal risk.

INTRODUCTION

Fetopelvic disproportion increases the hazard of vaginal delivery both for the mother and for the child. It may lead to protracted labour with fetal asphyxia or severe fetal damage due to pathological moulding of the fetal head or shoulder dystocia. The risk of rupture of the maternal vagina and the perineal soft tissue is increased.

For identification of women at risk, manual screening of the pelvic capacity is a widely used method. In women in whom narrow pelvic dimensions are suspected, radiographic pelvimetry is often employed. This latter method has still not been fully evaluated. Moreover, manual screening of the pelvic capacity has proved to be an unreliable way of estimating the pelvic dimensions (Lundh et al.: to be published).

Most obstetricians using radiographic pelvimetry base their choice between vaginal delivery and elective Caesarean section on exact pelvic dimensions. Thus their decision is founded on only one factor in a biological sequence in which a number of other factors are involved.

The pelvic dimensions accepted for vaginal delivery vary considerably between different delivery units in Sweden (18). In addition, the evaluation of pelvic diameters from radiographic images is subject to significant margins of error (16). In cases of small pelvic dimensions the clinical routines that are followed are based on different interpretations of the results of a retrospective study made in the late fifties (5), in which the probability of a successful vaginal delivery was estimated for different pelvic dimensions. Apart from the retrospective nature of that study, it was based on parturients among whom, for instance, 40 per cent of the pelvimetries were performed on indications usually associated with unsatisfactory progress of labour. Furthermore, breech presentations were not separated from cephalic ones, nor was any distinction made between primiparous and multiparous women.

Many authors have questioned the use of radiographic pelvimetry in the management of labour. O'Brian & Cefalo conclude in their review that "Data available to date have not demonstrated the decrease in perinatal mortality and morbidity associated with the use of intrapartum pelvimetry in a vertex presentation" (19). Furthermore, the American College of Obstetricians and Gynecologists state that "X-ray pelvimetry provides limited additional information to physicians involved in the management of labour and delivery. It should not be a prerequisite to clinical decisions..." (22).

In Sweden the clinical application of radiographic pelvimetry has been very extensive within the last two decades. In 1979-80 this examination was carried out at the Department of Diagnostic Radiology at Uppsala University in every fourth primapara in order to rule out a narrow pelvis (478 women in 1979 and 403 in 1980). Since a number of women also underwent radiographic pelvimetry in later pregnancies, it can be estimated that some 30 per cent of all parous women have been submitted to this examination. These figures are in good accordance with the figures for the whole of Sweden, where 12 149 pelvimetries were performed in 1980, that is in about 12 per cent of all deliveries. Some 10 000 of the pelvimetries concerned primiparae, whose total number was about 40 000 (25).

In the United States radiographic pelvimetry is performed in about 6 per cent of all deliveries; thus the frequency is about half of that in Sweden (1).

No investigation appears to have been reported in which the outcome of delivery has been studied prospectively in an unselected group of parturients with known pelvic dimensions. An important prerequisite for a prospective investigation is that the technique of radiographic pelvimetry be improved, with retention of a high image quality at the lowest possible radiation dose.

Since radiographic pelvimetry also is an extensively used routine procedure, a series of precautionary measures have been taken to reduce the radiation dose and these are described in the present report. Standard equipment and a modern conventional radiographic technique was applied so that the results should be applicable to any clinic.

MATERIAL AND METHOD

Primiparae in whom radiographic pelvimetry was considered indicated were asked to take part in the study. Two hundred and fifty-four women gave their informed consent. Some 20 women were excluded for technical reasons.

The imaging technique applied was that introduced by Borell & Fernström (5) and modified by Borell & Rådberg (6). Radiography is carried out in a lateral view in the standing position and in an antero-posterior view in the supine position. In the lateral position a ruler is placed high up against the perineum in the patient's midline to permit reductions of direct measurement values from the radiograph to proper values. The radiograph taken in the antero-posterior view consists of two orthodiagraphic exposures, ready for direct measurement (Fig. 1).

This technique allows measurement of the pelvic inlet and outlet and also of the positional relationship of the fetus to the maternal pelvis. Proper coning of the radiation beam and the choice of high kilovaltages are essential for reduction of the radiation dose. Further reduction was achieved by the use of appropriate film-screen combinations. Five different screens were employed in combination with Medichrome film (Agfa-Gevaert), namely MR 400, MR 600, MR 800 (Agfa-Gavaert), Lanex Regular (Kodak) and Trimax Alfa 16 (3M).

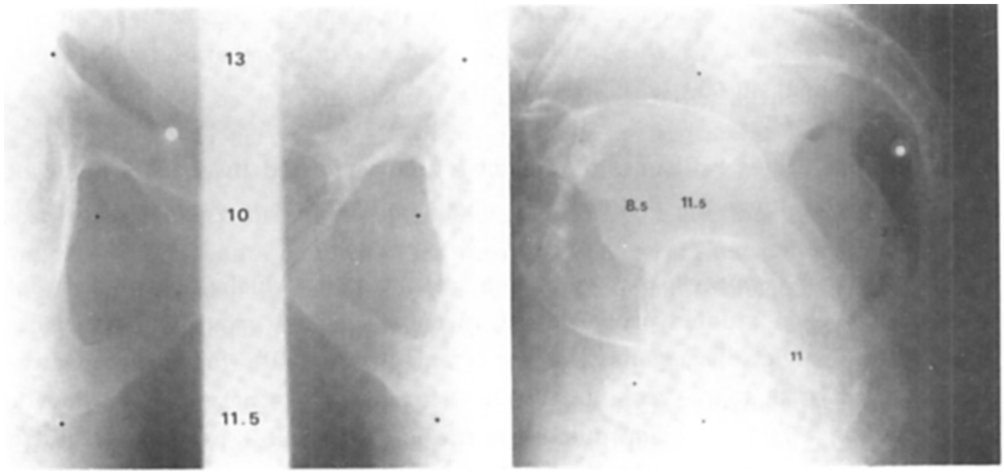

Fig. 1 Frontal and lateral projection illustrating the pelvic dimensions.
Black dots: Measurement points of pelvic diameters.
White dot: Lead pellet indicating dosimeter placement.
(The figures in the radiographs are not referred to in the text.)

The lateral view in the standing position was taken in a chest unit, REF Type Bucky (Siemens) and a ceiling-suspended, moveable tube (REF Type Bi 150/30/101 R RG 150/100). The focal size was 1.3 mm, total filtration 2 mm Al and film-focus distance (FFD) 150 cm.

The orthodiagraphic exposures were made with the subject in the supine position with the hips abduced on an X-ray table (Combi REF Type Siemens URT), with the tube angulated 25° cranially. The ceiling-suspended, moveable tube REF Type Bi 125/3/50 RG 100 G used for these exposures has a focal size of 1.0 mm; the total filtration was 2.5 mm Al and FFD 100 cm. A conventional standard coning device (Siemens) was used.

The exposure values for the examinations with the five different screens used in this study are given in Table 1.

Measurements of absorbed doses in the subjects were made with high-sensitivity lithium fluoride thermoluminescent (TL) dosimeters with a dimension of 3.1 x 3.1 x 0.9 mm (Harshaw type TLD-100). The TL chips used in this study were selected for uniformity of response and were assigned individual calibration factors. All TL chips were calibrated before and after each measurement against a ^{60}Co-radiation source (Gammatron II, Siemens). The calibration factor was expressed as the number of readings per mGy absorbed dose ^{60}Co-radiation.

Table 1

Exposure values with five different screens

Screen	Frontal projection			Lateral projection		
	kV	mA	mAs	kV	mA	mAs
MR 400	70	200	8-22	120	200	150-250
MR 600	70	200	10-20	120	200	80-200
LANEX	70	200	10-20	120	200	64-200
MR 800	70	200	6-12	120	200	40-125
TRIMAX-16	70	200	6	120	200	50-120

^{60}Co-radiation is widely used in TL dosimetry and was therefore chosen as reference radiation. It offers the greatest possible stability during a relatively long period of measurement. All TL chips were annealed at 400°C for 30 min before being used for measuring procedures. After irradiation they were read-out in a reading unit (TLD-7300, Teledyne Isotopes). The read-out cycle of TL chips was always started with a preheating phase at a temperature of 135° for 8 s. The actual reading was then done at a temperature of up to 295°C.

Because of a slight energy dependence in the response for lithium fluoride dosimeters some correction has to be made when there is a difference in beam quality between reference radiation and measured radiation.

A correction factor of 0.8 was used at calculations of the absorbed dose for all TL chips (SSI-1976-037, Shuwert and Rudén). With the described method, the overall uncertainty in measuring the absorbed dose should not exceed 15 per cent.

Two TL chips were placed inside the tip of a teflon catheter, which was then placed in another catheter supplied with a lead pellet as an indicator. This device was then inserted high up into the patients rectum. In a few cases it was evident on the radiograph that the catheter had not been in a proper position during the radiographic exposure. These cases were excluded from further analysis.

In 8 subjects when using Lanex regular screens, two teflon catheters were used, one for radiography in the antero-posterior view and the other for the lateral view. By this arrangement the contribution of each of the two views to the total rectal dose could be calculated.

The average distance from the TL chips to the nearest point of the fetal head was calculated from measurements on all radiographs taken in the lateral view.

RESULTS

The results of the measurements of the absorbed dose in the rectum are presented in Table 2.

Table 2

Measured rectal doses with five different screens

Screen	Number of patients	Absorbed dose, mean (mGy)	Standard deviation	Range (mGy)
MR 400	24	1.9	0.8	1.0-3.6
MR 600	44	1.4	0.5	0.5-2.4
LANEX	51	1.4	0.5	0.5-2.9
MR 800	39	0.9	0.3	0.5-1.8
TRIMAX-16	76	0.7	0.4	0.2-2.2

The absorbed dose contribution from the two views to the total rectal dose are given in Table 3. From 113 radiographs taken in the lateral view the average distance between the TL chips and the fetal head was calculated to be 4 + 1 cm. (Fig. 1).

Table 3

Measured rectal dose at the two views with the Lanex regular screen

Frontal		Lateral	
mean (mGy)	range (mGy)	mean (mGy)	range (mGy)
0.1	0.1-0.2	1.3	1.0-2.4

DISCUSSION

The monochrome blue and white colour film has the advantage of a wide exposure range, with the effect that bone structures and soft tissues are both well reproduced simultaneously.

The tolerance of the Medichrome film to underexposure or overexposure is largely attributable to the wide latitude of its characteristic curve. The low granularity of the silver halogenide in the emulsion makes the medichrome film suitable for the use of high kilovoltages without generation of disturbing quantum mottle in the images.

With use of a blue monochrome colour film it is possible to raise the characteristic curve by using sodium fluorescent tubes when viewing the films at the negatoscope. The capability of the blue and white film to change its sensitometric properties to higher contrast at viewing with sodium fluorescent tubes favours detection in the process of visual perception.

The relation between the mean absorbed doses with the different film-screen combinations used equals the expected based on the relative speed of the respective combinations (Table 2). The contribution of the absorbed dose from the lateral projection was 80-95% of the total absorbed dose (Table 3). Concerning radiation protection the very low dose absorbed from the frontal projection favours the clinical application of radiographic pelvimetry advised by Ohlsén (20). The distance between the fetal presenting part and the TL chips used to estimate the absorbed dose was very constant and amounted to an avarage of 4 cm. Since in most of the lateral projection the TL chip is placed in an area of low attenuation and the fetal presenting part largely behind bones the measured value of absorbed dose represents a maximum value of the dose absorbed by the fetal presenting part (Fig. 1).

Radiographic pelvimetry has been the predominant source of ionizing radiation during late pregnancy for at least thirty years and still is today. Ragarding the risk of this examination, it is important to remember that the technique is continuously being improved. Bewley et al. presented data from Hammersmith Hospital in London in 1957 on the estimated fetal radiation dosage from obstetric radiographic examinations (4). By that time the antero-posterior projection of the pelvic inlet contributed to the largest part of the average fetal dose, which was about 13 mGy and thus almost 20 times higher than ours. Furthermore, one consequence of their pelvimetries including the antero-posterior projection was that almost the entire body of the fetus was in the primary beam. The authors' advice is to exclude the antero-posterior projection if there is no absolute need for information about the shape and dimensions of the pelvic inlet. With the technique used in our study only the fetal head or a part of it is in the primary beam when the fetus is in a vertex presentation. The contribution of the fetal head to the total body weight is about one fourth at the end of pregnancy, and thus, the total energy imparted to the fetus is much less today than it was 25 years ago.

The Swedish National Institute of Radiation Protection reports on a series of measurements performed during the years 1973-1975 in 13 Swedish hospitals (3). With radiographic pelvimetry they found an average dose to the maternal ovary of 4.6 mGy, which is approximately the same as the fetal head dose. A comparison with our present figures thus shows that within six years there has been a sixfold reduction in the absorbed dose of ionizing radiation at pelvimetry.

Axelsson & Olsén found a mean absorbed maternal ovary dose of 0.9 mGy They used essentially the same pelvimetric method as ours but instead of Medichrome blue film they used black and white. Also, for the lateral view they used specially made equipment to achieve the greatest possible coning of the radiation beam (2).

Ever since the first reports of the use of ionizing radiation during pregnancy and its possible ralationship to malignant disease in children, special efforts have been made to reduce the amount of radiation delivered in radiographic pelvimetry. By means of technical improvements and methodological modifications it has been possible to achieve a significant reduction in the absorbed dose of radiation while still retaining a high image quality, which in fact has even been improved.

COMMENTS

Ionizing radiation even in comparatively small amounts is commonly thougt to have injurious effects not only on the human embryo but also on the human fetus. For this reason the recommendations concerning medical exposure of pregnant women, proposed by the International Commission on Radiological Protection (14,15) have gained almost world-wide acceptance. Until recently there were no scientific methods for detecting the immediate microbiological effects of ionizing radiation at low doses, i.e. below 500 mGy. Nevertheless physicians all over the world have shown great respect for possible, though not yet evaluated effects of this radiation. Today we do have some insight into the deleterious effects at a microbiological level, but the present amount of knowledge regarding the hazards of X-rays is probably far less than the knowledge not yet available.

Roughly, the harmful effects of ionizing radiation can be divided into immediate and long-term types.

It is known today that ionizing radiation induces breaks in the DNA strands of the cells and that within a certain time interval a spontaneous repairing process is completed, the degree of healing depending on the amount of destruction (9). As a third step a process of postrepair DNA destruction ensues (8). The nature of this process is not known. The radiation dose used in Cerda's experiments (8) varied from 100 to 2 000 mGy and in the experiments dealing with cerebral and cerebellar structures the cells studied were predominantly neuroblasts under rapid proliferation, i.e. the kind of cells held to be exceptionally sensitive to ionizing radiation. The findings from these experiments are well in accordance with the results from investigations of the Japanese bomb survivors (17).

In late pregnancy, the developing visual system is a part of the human brain, still under rapid neuroblast proliferation. There are reports on the vulnerability of the visual system to irradiation during pregnancy. On the other hand, no reports have been published concerning damage to the visual system caused by irradiation - experimental or otherwise - in late pregnancy with doses at the level of those applied in diagnostic procedures, 1-20 mGy (21). The probable reason for this is that today's methods for detecting damage after ionizing radiation are not sufficiently sophisticated.

Accepting the idea of a linear correlation between dose and damage, we may assume, however, that even doses below 10 mGy will cause some damage. This low-dose radiation, however, destroys only a few out of billions of proliferating cells in a process in which far more cells die as a natural consequence of the proliferative event. The additional destruction does not seem to cause any structural change to the tissue as such. When the destruction is limited, the process of repair apparently becomes almost complete and there is no reason to expect any functional alterations when the cells are finally differentiated.

The reports on long-term effects of ionizing radiation, i.e. induction of malignancy, are predominantly epidemiological. The mechanism whereby ionizing radiation exerts its influence and induces malignancy after years of latency is not known. It is evident from the experience of accidental ionizing radiation as well as from its experimental and medical use, that a causative relationship cannot be questioned. The increased incidence of leukaemia among the survivors of the atomic bomb explosions in Hiroshima and Nagasaki (7) and among patients who have had X-ray treatment for ankylosing spondylitis are tragic examples (10).

Among epidemiological studies concerned with the problem of induction of malignancy, many have been undertaken with the special purpose of clarifying the association between medical X-ray during pregnancy and childhood malignancy. One such study is often discussed, as the authors claim from the findings that there is a clear connection between diagnostic X-ray procedures and childhood malignancy. The study is based on material from the Oxford survey on childhood cancers (23,24). The authors estimated that in a group of children with malignant conditions who had been exposed to diagnostic radiation in utero (1946-1962) some 5 per cent of these cases of malignancy might have been caused by the X-ray examinations. The study has been criticized on the grounds that it was retrospective and that information concerning radiographic examinations performed during pregnancy derived only from interviews with the mohers. Furthermore, no consideration was paid to the indications for maternal radiographic examination and their possible contribution to the malignancy in the offspring. In a prospective study Court Brown et al. (11) obtained results which did not verify those of Stewart and Kneale. Their study was too small, however, to permit any firm conclusions concerning a disease as relatively uncommon as leukemia.

Although critized, the Steward and Kneale study instigated considerable interest in the question of possible harmful effects of diagnostic radiographic procedures. Several studies followed, but all of them had one or several of the scientific drawbacks mentioned above. Usually the materials were too small.

However, accepting the concept of linearity, the ICRP report of 1966 and the UNSCEAR report of 1977 estimate the risk that the fetus irradiated in utero will develop malignancy at 1/5 000 per 10 mGy of irradiation (13,26). Applying these estimates to our average radiation dose at pelvimetry, the examinations imply a risk of less than one childhood malignancy in 50 000 pelvimetries. The annual incidence of childhood malignancy in Sweden today is about 220 (12). The maternal risk is likewise estimated to 1/10 of the fetal risk (13).

At present the common opinion among obstetricians in Sweden is that the use of radiographic pelvimetry contributes to a large extent to the low perinatal morbidity and mortality in this country. Regarding the risk figures no good reason has emerged so far for omitting radiographic pelvimtery from the management of pregnancy and deliveries.

Since radiographic pelvimetry has not yet been properly evaluated either as a method for estimating pelvic dimension or as a contribution to clinical obstetric management, it is of greatest importance that a prospective clinical study be undertaken in which every primigravida is submitted to radiographic pelvimetry and the outcome of labour recorded. With the extremely low radiation risk as estimated at our pelvimetric examinations we consider such a study to be within ethically justifiable limits.

REFERENCES

1 Arcarese, J.D. & Morrison, J.L.: The utilization of X-ray pelvimetry in the United States. Clin Obstet Gynecol 25:165, 1982.

2 Axelsson, B. & Ohlsén, H.: Radiation doses in low-dose pelvimetry using rare-earth screens. Acta Radiol (Oncol) 18:470, 1979.

3 Bengtsson, G., Blomgren, P.-G., Bergman, K., & Åsberg, L.: Patient exposure and radiation risks in Swedish diagnostic radiology. SSI:1977-027, table 5.

4 Bewley, D.K., Laws, J.W. & Myddleton, C.J.: Maternal and fetal radiation dosage during obstetric radiographic examinations. Br J Radiol 30:286, 1957.

5 Borell, U. & Fernström, I.: Radiologic pelvimetry. Acta Radiol Suppl 191, 1960.

6 Borell, U. & Rådberg, C.: Orthodiagraphic pelvimetry with special reference to capacity of distal part of pelvis and pelvic outlet. Acta Radiol (Diagn) 2:273, 1964.

7 Brill, A.B., Tomonaga, M. & Heyssel, R.M.: Leukemia in man following exposure to ionizing radiation. Ann Med Interne 56:590, 1962.

8 Cerda, H.: Radiation induced DNA strands breaks and cell pyknosis in the developing rat cerebellum. Int J Radiat Biol 44: 113, 1983.

9 Cerda, H., Johansson, K.J. & Rosander, K.: Radiation induced DNA strand breaks. Their repair in the developing rat brain. Int J Radiat Biol 36:65, 1979.

10 Court Brown, W.N. & Doll, R.: Leukemia and aplastic anaemia in patients irradiated for ankylosing spondylitis. Medical Research Council special Report 295, London: HMSO 1957.

11 Court Brown, W.N., Doll, R. & Bradford Hill, A.: Incidence of leukemia after exposure to diagnostic radiation in utero. Br Med J 2:1539, 1960.

12 Ericsson, J. L.-E., Karnström, L. & Mattsson, B.: Childhood cancer in Sweden, 1958-1974. Acta Paediatr Scand 67:425, 1978.

13 ICRP (International Commission on Radilogical Protection). Report of Committee 1, Hlth Phys 12:291, 1966.

14 ICRP (International Commission on Radiological Protection): Recommendations. ICRP publication 9:paras 4, 27, 63, 73 (Pergamon Press, Oxford), 1966.

15 ICRP (International Commission on Radiological Protection): Recommendations. ICRP publication 27:paras 65, 116 (Pergamon Press, Oxford), 1977.

16 Lundh, C., Lindmark, G. & Wilbrand, H.: Reliability of radiographic pelvimetry. A methodological study. (Submitted for publication) 1984.

17 Mole, R.H.: Consequences of prenatal radiation exposure for postnatal development. In: Developmental effects of prenatal irradiation. (eds. H. Kriegel, W. Schmal, G. Kistner & F.-E. Stieve), Gustav Fisher, New York and Stuttgart, 1982.

18 Nielsen, T.F.: Obstetrics and gynecology 35 (Swe). Acta Societatis Medicorum Suecanae, Hygiea 89:5, 1980.

19 O'Brien, W.F. & Cefalo, R.C.: Evaluation of X-ray pelvimetry and abnormal labor. Clin Obstet Gynecol 25:157, 1982.

20 Ohlsén, H.: Radiologic low-dose pelvimetry. Acta Radiol. (Diagn) 21, 747, 1980.

21 Ordy, J.M., Brizzee, K.R. & Young, R.: Prenatal Co^{60}-irradiation on visual acuity, maturation of the fovea in the retina and the strate cortex of Squirrel monkey offspring. In: Developmental effects of prenatal irradiation. (eds H. Kriegel, W. Schmal, G. Kistner & F.-E. Stieve, Gustav Fisher, New York and Stuttgart, 1982.

22 Quality assurance in obstetrics and gynecology. The American College of Obstetricians and Gynecologists 1981.

23 Stewart, A., Webb, J. & Hewitt, D.: A survey of childhood malignancies. Br Med J 1:1495, 1958.

24 Stewart, A. & Kneale, G.W.: Changes in the cancer risk associated with obstetric radiography. The Lancet I:104, 1968.

25 Studier över vårdkonsumtion: Radiologi, Röntgen - Ultraljud - Isotoper. Socialstyrelsens PM 41/1983, 65. (Studies of medical care consumption; Radiology, Roentgen-Ultrasound-Isotopes. Memorandum of the National Swedish Board of Health and Welfare 41/1983).

26 UNSCEAR (United Nations Scientific Committee on the Effect of Atomic Radiation): Report 1977. Sources and effects of ionizing radiation: 414 para 319. United Nations, New York 1977.

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