Radiology in Obstetrics and Antenatal Paediatrics

G. B. Russell

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Editor's Foreword

In the seventy-five years or so of its life diagnostic radiology has grown from a scientific toy into a useful tool and from an occasional luxury into a diagnostic necessity. Today it performs an important role in clinical diagnosis. Radiologists are no longer isolated from their colleagues in dark basements. They now form an integral part of the team, comprising many specialties, whose object is successful patient management. Collaboration and mutual understanding between the various members and some appreciation of the value and limitations of their several disciplines is obviously necessary.

It is to this end that this book has been written and forms part of the series Radiology in Clinical Diagnosis. The purpose of the series is to give clinicians an up-to-date and comprehensive survey of the role of diagnostic radiology in different spheres of clinical practice and to provide radiologists in training with a hand-book from which they can quickly learn and to which they can readily refer. The books have been written and printed so that they will be comprehensive without being exhaustive. We very much hope they will prove a pleasure for the individual to own and to use as well as a standard text for the library shelf.

This book unashamedly and rightly begins with a detailed description of the technique necessary to produce informative radiographs. It goes on to describe all aspects of obstetric radiology and is illustrated with what must surely be a unique collection of cases. An 'atlas' of standards of skeletal development for the assessment of fetal age is given in Chapter 3. The complementary relationship between ultrasound and radiography is fully and helpfully described. In the last chapter radiography of the pregnant mother is given practical perspective.

Westminster Hospital, London DAVID H. TRAPNELL

Preface

Obstetrical radiology in the last two decades has been dominated by the names of Alice Stewart and Ian Donald. Radiologists owe a great debt to Dr. Stewart for drawing attention to the dangers of fetal irradiation. Whilst, fortunately, the hazard is not so great as she initially calculated, the radiogenic hazard to the fetus dominates the choice of radiographic technique and is an important factor in the list of indications for antenatal radiography.

Professor Ian Donald is the driving force behind the development of the science of medical ultrasonic scanning, the chief use of which is still the examination of the fetus. We are currently radiographing some 1,000 fetuses a year and carrying out about 5,000 obstetrical ultrasonic scans annually—clear indication of the growing importance of this new science in obstetrics.

Obstetrical radiology embraces both these forms of diagnostic radiation—x-rays and ultrasonics—and this book naturally considers both. It is in large part an account of the experience of the Department of Radiology of St. Mary's Hospital, Manchester. The book would have been written by my predecessor, the late Dr. J. Blair Hartley, had not illness near the time of his retirement dictated otherwise.

A radiological book depends largely on its illustrations. I am particularly lucky to have as Superintendent Radiographer Miss A. Stirling Fisher, whose skill in obstetrical radiography has given her an international reputation. In addition, Miss Fisher has a remarkable memory which enables her to recall from twenty or more years ago the name and details of a patient and her films; this is an invaluable gift when searching for illustrations of a rare disease. Her aid in the compilation of this work is gratefully acknowledged.

Dr. Robert Ollerenshaw, Director of the Department of Medical Illustration, United Manchester Hospitals, together with his staff, prepared the prints and diagrams. Dr. Ollerenshaw's skill is widely recognized and I am grateful for his assistance.

St. Mary's Hospital, Manchester J. G. B. RUSSELL

Contents

Chapter 1

Radiography

No branch of radiology demands a higher quality of radiography than does obstetrics. Second-rate radiography is often worse than useless; it can be positively misleading and dangerous. Yet observation of the standard of films from many centres in several countries on both sides of the Atlantic has shown that often obstetrical films are of second-rate quality. This is unfair to all concerned—mother, child, radiologist and clinician.

No apology is made for including this section at the beginning of this book. It is important for clinicians as well as radiologists to understand the radiographic techniques available. Obtaining good films requires no special apparatus and only careful application of standard radiographic skills. Because of the special hazards of radiation, it must be stressed that obstetrical radiography is not a field in which a trainee or junior radiographer may practice, except under the critical and close supervision of a senior experienced worker.

ESSENTIALS OF TECHNIQUE

Choice of Kilovoltage

There are two schools of thought in obstetrical radiography regarding this type of exposure.

One (Clark, 1964) uses a high kilovoltage and the other (Hartley and Fisher, 1953) recommends a lower kilovoltage.

X-rays generated at a high kilovoltage are more penetrating than low kilovoltage x-rays. A high kilovoltage thus allows a shorter period of exposure and hence less hazard of blurring from movement of the fetus. However, films taken with a high kilovoltage are 'greyer' or 'flatter' than low kilovoltage films, which with more contrast look 'crisper' and provide better detail. The greyness of a high kilovoltage radiograph is accentuated by the use of high speed screen and films, but a low kilovoltage radiograph allows the use of high speed screens and films without so much loss of 'crispness'. Generally speaking there is more information on the low kilovoltage films, so fewer repeat exposures are needed and more secondary information is generated (e.g., of unexpected fetal abnormalities).

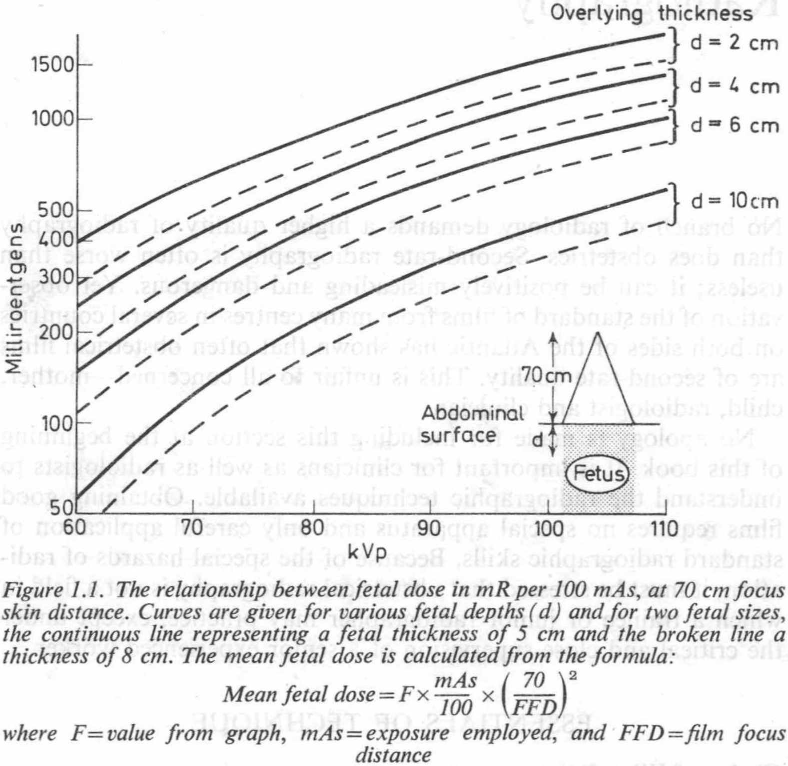

Figure 1.1. The relationship between fetal dose in mR per 100 mAs, at 70 cm focus skin distance. Curves are given for various fetal depths (d) and for two fetal sizes, the continuous line representing a fetal thickness of 5 cm and the broken line a thickness of 8 cm. The mean fetal dose is calculated from the formula:

$$\text{Mean fetal dose} = F \times \frac{mAs}{100} \times \left(\frac{70}{FFD}\right)^2$$

where F = value from graph, mAs = exposure employed, and FFD = film focus distance

(Reproduced by courtesy of Mr. J. B. Massey)

The extra information is provided because the range of intensity of radiation in the transmitted beam with the lower kilovoltage falls within the useful range (latitude) of the film—i.e., the pale and dark areas on the film are not using the toe and shoulder of the characteristic curve (Meredith and Massey, 1972).

The case for using a high kilovoltage rests on the premise that a lower fetal radiation dose is associated with a high kilovoltage.

The difference between high and low kilovoltage techniques is in fact quite small. The better range of contrast with the lower kilovoltage allows the use of high speed screens with these low kilovoltages, which is precluded at higher kilovoltages. The absence (until recently) of a film which was both of high speed and suitable for automatic processing has been regrettable, but we are hoping to introduce suitable high speed films into routine use in the near future. This would have the effect of reducing still further the fetal radiation dose at low kilovoltages.

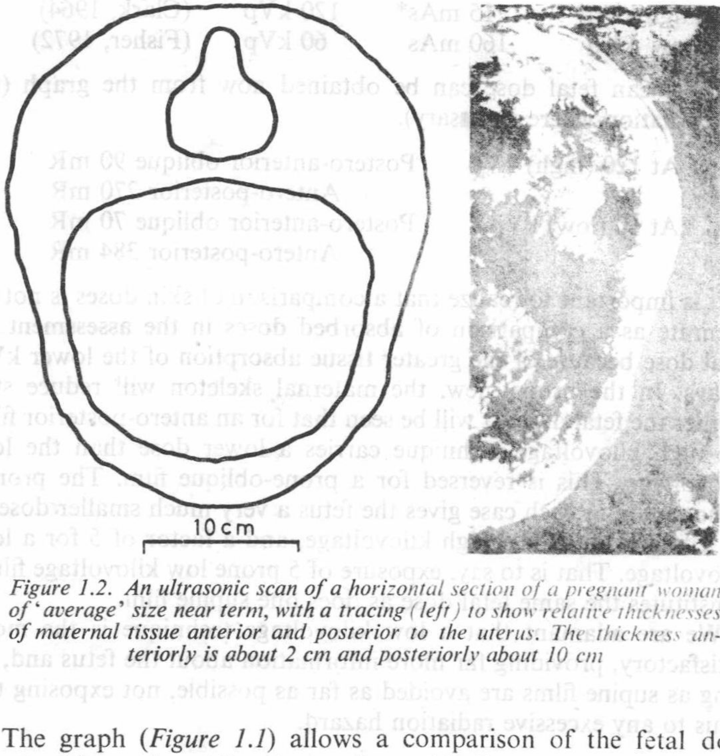

Figure 1.2. An ultrasonic scan of a horizontal section of a pregnant woman of 'average' size near term, with a tracing (left) to show relative thicknesses of maternal tissue anterior and posterior to the uterus. The thickness anteriorly is about 2 cm and posteriorly about 10 cm

The graph (*Figure 1.1*) allows a comparison of the fetal dose received for various kilovoltages. It was kindly prepared by Mr. J. B. Massey of the Physics Department, Christie Hospital, Manchester. In its preparation it was assumed that the fetus is ellipsoidal, that (for ease of calculation) the focal skin distance is 70 cm and that the maternal skin surface is flat and at right-angles to the axial x-ray beam. Obviously in every case approximations are thus introduced, but it does provide a method of comparing the fetal dose at various kVp. Care must be taken not to be misled by a curve showing an increase in fetal dose with the greater kVp. The graph represents the dose for a given mAs, and as the kVp increases so the mAs can be reduced.

An ultrasonic scan of an 'average' woman near term is shown in *Figure 1.2*. It will be seen that the anterior abdominal wall is relatively thin—about 2 cm in thickness—but posteriorly the tissues (loin muscles, bowel, kidney, spine etc.) are much thicker—some 10 cm.

We make some further assumptions—that the fetus near term approximates to an ellipsoid 8 cm thick, and that the following factors are in use:

High kVp*	15 mAs*	120 kVp	(Clark, 1964)
Low kVp	160 mAs	60 kVp	(Fisher, 1972)

The mean fetal dose can be obtained now from the graph (by extrapolation where necessary).

At 120 (high) kVp	Postero-anterior oblique 90 mR
	Antero-posterior 270 mR
At 60 (low) kVp	Postero-anterior oblique 70 mR
	Antero-posterior 384 mR

It is important to realize that a comparison of skin doses is not as accurate as a comparison of absorbed doses in the assessment of fetal dose because of the greater tissue absorption of the lower kVp x-rays. In the prone view, the maternal skeleton will reduce still further the fetal dose. It will be seen that for an antero-posterior film the high kilovoltage technique carries a lower dose than the low kilovoltage. This is reversed for a prone-oblique film. The prone-oblique film in each case gives the fetus a very much smaller dose—by a factor of 3 for a high kilovoltage, and a factor of 5 for a low kilovoltage. That is to say, exposure of 5 prone low kilovoltage films constitutes the same fetal dose as does one supine film.

We are adamant that a low kilovoltage technique is the more satisfactory, providing far more information about the fetus and, so long as supine films are avoided as far as possible, not exposing the fetus to any excessive radiation hazard.

Use of Compression Band

Mr. J. B. Massey has also kindly provided the graph shown in *Figure 1.3*. It shows the x-ray dose in soft tissues at various depths starting with an entry dose of 100 per cent on the skin surface. It will be seen that after an initial slight curve the lines are practically straight, and that, for example, at 60 kVp each 3 cm of tissue depth

* kVp = kilovoltage peak
mAs = milli-ampere-seconds

reduces the dose by 50 per cent. Thus for a given incident dose the exit dose will be doubled if we can reduce the thickness of tissue transversed by 3 cm or, more importantly, the incident dose can be halved for a given exit dose where the thickness is reduced by 3 cm. This can be done by using a compression band (the term 'compression band'—hallowed by time—is a misnomer since the tissue is not compressed but displaced). The band, which is a nylon cloth 35 cm wide, is applied across the mother by winding it on an axle fixed to the radiography table and controlled by a ratchet. It may be

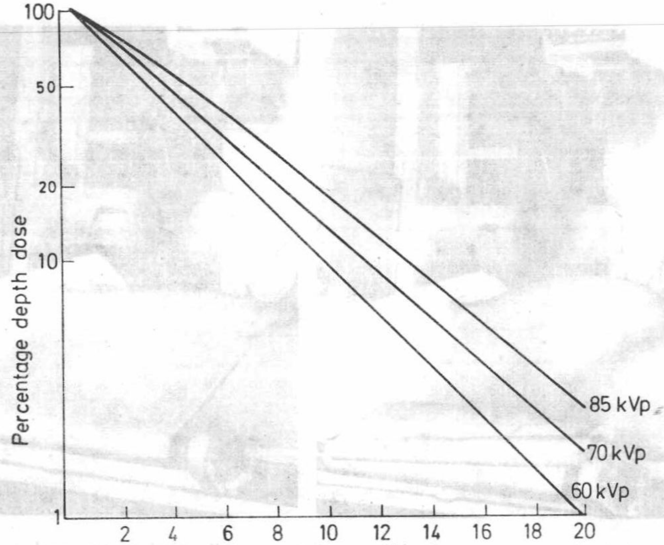

Figure 1.3. The dose–depth curves for various kilovoltages. Note that the dose scale is logarithmic

(Reproduced by courtesy of Mr. J. B. Massey)

momentarily uncomfortable as it is applied, and so it is tightened immediately prior to exposure of a film, and gently released a second or two later after the exposure has been made.

Some alarm has been expressed regarding the hazard of applying a compression band. However, the uterus is an organ designed to sustain high pressures. In 25 years use we have had no instance of injury caused by the use of the band in pregnancy. Maternal co-operation is essential, and it should be carefully explained to the mother what is to happen to her. Besides reducing the incident dose a band will also reduce scatter (providing better pictures) and help keep mother and fetus still—thus lessening the need for repeat films.

Using a compression band a reduction of 3 cm in thickness of the maternal abdomen is easily obtained in an antero-posterior film (*Figure 1.4*). In a prone film the weight of the mother acts in the same way in reducing her thickness making the advantage less, but a band can still be applied considerately with advantage, both further to reduce the thickness of tissue slightly and to aid in immobilization. The exposure is made on full arrested inspiration.

A radiographer must never, in any circumstances, use a compression band on an abdomen swollen by masses other than a pregnant

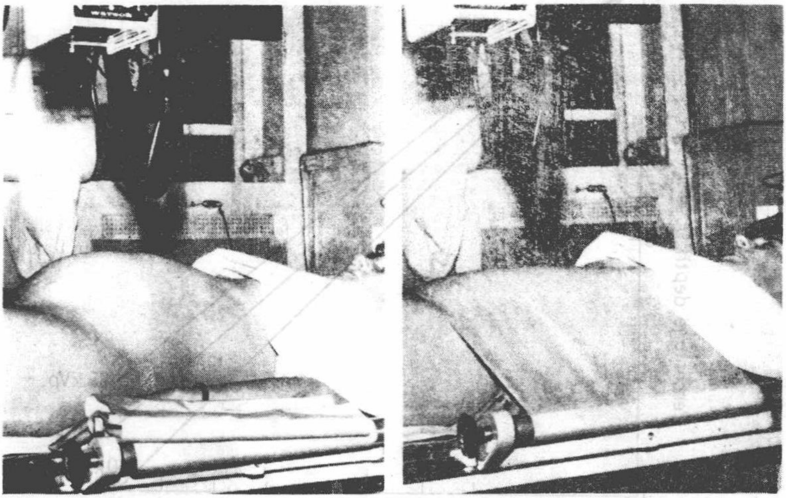

Figure 1.4. A pregnant woman lying supine on a radiography table, with and without a compression band. Note the significant reduction in maternal thickness with the compression band, which allows substantial reduction in the fetal dose

uterus. If, for instance, an ovarian cyst is compressed it may well rupture with possibly disastrous results.

Film Size

Reducing the film size will reduce the fetal radiation dose. If one views a full size film 35 × 40 cm (17 × 14 in)—of a pregnancy and covers the fetus with a small film—e.g., 25 × 20 cm (10 × 8 in)—it will be seen that the greater proportion of the fetus is still in the primary beam, and practically all the blood-forming tissues are primarily irradiated. Parts of the fetus not seen will include much of the fetal skull vault, which is the most important area when fetal abnormalities are sought. It is felt that the use of small films necessitates repeat exposures when areas of interest—e.g., the fetal knee—are not included on the film and that the fetal marrow dose as a whole will not be reduced by the use of small films. We prefer large films—35 × 40 cm (17 × 14 in)—for most purposes, although smaller films—30 × 25 cm (12 × 10 in)—should be used for specific purposes.

Polaroid x-ray films are claimed to be of higher speed compared with ordinary x-ray film. We have tried them, and find the film speed the same as par-speed film, and the detail poorer.

Use of Filters

Appreciable reductions in fetal dose can be obtained by using additional filters. The two we employ were constructed with the help of

Figure 1.5. Lateral view of the pelvis 25 × 30 cm (12 × 10 in). Note the lead cut-out filter which reduces the fetal x-ray dose without obscuring the maternal landmarks

Mr. J. B. Massey. Both fit into the cone holder of the light-beam diaphragm casing.

The first is used for the erect lateral pelvis film. This view requires a large exposure, and the filter is designed to protect the fetus as far as possible from primary irradiation by means of a lead insert (*Figure 1.5*). Accurate centring is essential to ensure that the filter does not hide some area of interest.

The second filter is of aluminium and is used to avoid over-exposure of the anterior abdomen on a lateral film (*Figure 1.6*).

CHOICE OF RADIOGRAPHIC PROJECTION

The prone-oblique film should be used for the primary basic examination because of the lower fetal dose associated with it. The chart (*Table 1.1*) assists in the choice of a suitable projection. It is not meant to be regarded as sacrosanct and, depending on the appearances found, can be modified.

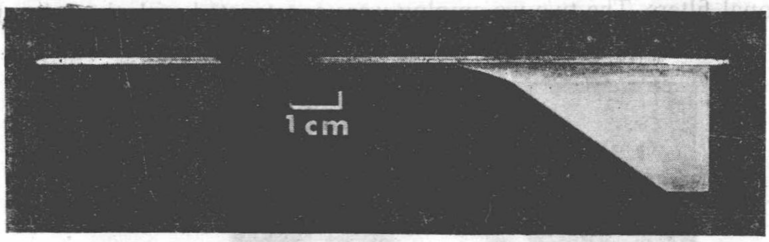

Figure 1.6. The shape of the wedge filter used for lateral views of the uterus, viewed from the side (the x-ray beam is vertical). The aluminium helps prevent over-exposure of anterior part of the uterus, and reduces fetal x-ray dose

TABLE 1.1

Indication	*Projection*
Placental siting (Soft tissue)	Antero-posterior and lateral. Occasionally, if needed, proceed to erect lateral with patient leaning backwards
Pelvimetry	Erect lateral Orthodiagraphic antero-posterior (unless placentography has provided an A.P. film)
Maturity Fetal abnormality Fetal death Plural pregnancy	Prone oblique—unless information available from above } If information not available: ? other prone oblique ? antero-posterior ? lateral view first film and decide

The choice of which oblique to take is governed by the position of the fetal back. If the back is on the left a left anterior oblique is exposed, if on the right a right anterior oblique. The side of the fetal back is best indicated by the referring obstetrician but, after a little practice, can be identified fairly accurately by palpation by the radiographer when the patient is on the table; alternatively it can be seen by a rapid ultrasonic scan if this facility is available. If no information can be obtained as to on which side the back lies then the left anterior oblique should be exposed as the back lies more often on the left than on the right.

Radiographic Notes

Before any film is exposed in pregnancy the patient must empty her bladder. A film-focus distance of 100 cm should always be used.

Prone-oblique

Film size: 35 × 40 cm (17 × 14 in).

The side on which the fetal back lies should be nearer the film. The patient lies in a lateral position and then turns herself as far towards a prone position as she can comfortably manage. For a right oblique the left knee is flexed to support her and vice versa. A pillow is used under the shoulders and a compression band is applied with care.

Centre 2 cm above the iliac crest.

Factors for average patient: 160 mAs; 60 kVp.

Supine, Antero-posterior

Film size: 35 × 40 cm (17 × 14 in).

The mother lies on her back with a pillow to support her head. A compression band is used.

Centre at a level 2 cm above the iliac crest, in the midline.

Factors for average patient: 160 mAs; 60 kVp.

Lateral Decubitus

Film size: 35 × 40 cm (17 × 14 in).

The mother lies on her side with a pillow under her head and sandbags to steady her at the front and back of the thighs; the arms should be above the head. The lumbar spine should be as extended as possible by extension of the legs. The wedge filter (*Figure 1.6*) is used. The fetal spine should be on the side nearest the film.

Centre 2 cm above the iliac crest, so as just to include the front of the uterus.

Factors for average patient: 100 mAs; 70 kVp.

Lateral Erect (for Pelvimetry)

Film size: 30 × 25 cm (12 × 10 in).

Particular care should be exercised to obtain a true lateral. A lead cut-out filter is used to reduce fetal irradiation (*see Figure 1.5*).

Centre accurately 8 cm above the middle of the greater trochanter, which is the mid-point of the pelvic inlet.

Factors for average patient: 320 mAs; 88 kVp.

Horizontal Beam Lateral Film

Film size: 35 × 40 cm (17 × 14 in).

This view is taken occasionally if there is doubt about the placental site. It is designed to position the pelvic brim horizontally. The fetus settles on the brim, being heavier than liquor. The commonest cause for failure to do this is placenta praevia. The patient lies supine on the radiography table and then is tilted some 40 degrees, feet down. A lateral film is taken with a horizontal beam and a vertical film with a stationary grid. A similar result is obtained by taking a lateral film with the patient standing, leaning backwards as far as she can.

Factors for average patient: 160 mAs; 72 kVp.

Orthodiagraphic Pelvimetry Film

Film size: 30 × 25 cm (12 × 10 in).

The patient lies supine on a horizontal table and the x-ray tube is tilted 15 degrees towards the feet. The beam is collimated to an area 4 cm wide and 12 cm long, the longer axis lying vertically along the patient. The middle of this beam is centred in the mid-line at the level of the anterior superior iliac spine. The tube is moved 5 cm to the patient's right and an exposure made; the tube is then moved 10 cm to the left and the exposure repeated. The patient and the film must not move between the exposures, so a compression band is applied lightly to keep the patient quite still.

Factors for average patient: 160 mAs; 70 kVp.

AMNIOGRAPHY AND FETOGRAPHY

Amniography

This technique was initially introduced by Menees *et al.* (1930) and used by Burke (1935) as a method of placentography. It fell into disrepute because the media then used, sodium iodide, strontium iodide and Uroselectan-B, very frequently provoked premature labour. Indeed Playfair (1941) used intra-amniotic Uroselectan-B as a method of inducing labour with a 95 per cent success rate. The employment of newer and less irritating water-soluble contrast media has allowed the reintroduction of the method. Because the sodium ion is still likely to provoke labour, the methylglucamine (meglumine) salts should be used.